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ABSTRACT

This document is the proceedings of the 10th annual meeting of the International Organization for Science and Technology Education (IOSTE). Papers include: (1) "Liberal Education, Information Assessment and Argumentation in Science-LIA" (Andreas Quale, Anders Isnes, Terje Kristensen, and Ketil Mathiassen); (2) "Placing the History and the Philosophy of Science on Teacher Education" (Antonio F. Cachapuz and Fatima Paixao); (3) "Can Feminist Critique of Science and Science Education Be of Relevance for Gender and Science Projects in Developing Countries?" (Astrid Sinnes); (4) "A World of Different Colors: Trying to Teach Solidarity and Global Consciousness in Sixth Grade" (Aurora Lacueva); (5) "Constructing Technology Education: A Cross-Case Study of Teachers Realizing Technology as a New Subject of Teaching" (Berit Bungum); (6) "The Evolution/Creation Science Controversy: Educate Rather than Debate" (Beverly Jane); (7) "Towards Learner-Centered Approach in Senior Secondary School Science Lessons" (C.D. Yandila, S.S. Komane, and S.V. Moganane); (8) "Process Skills in Botswana Primary School Science Lessons" (D. Letsholo Francistown and C.D. Yandila); (9) "Globalization, Traditional Knowledge and HIV in South Africa: Challenges for Schools and Curriculum" (Cliff Malcolm); (10) "The Role of Teacher Preparation for Informal Settings: Understanding the Educators and Teacher Perspectives" (Christiane Gioppo); (11) "Science and Scientists: A Complementary Study" (Edward L. Shaw, Jr. and Ann K. Nauman); (12) "Dinosaur Forests and Glacial Terrains: New Zealand Preservice and United States Inservice Teachers Developing a Vision of Environmental Sustainability" (Eleanor Abrams and Miles Barker); (13) "K-12 Instruction in the United States: Integrating National Standards for Science and Writing through Emerging Technologies" (Kathy I. Norman and Katherine L. Hayden); (14) "Agrochemistry: An Institutional Project of the Universidad Nacional

Autonoma de Mexico, for the Elementary and the High School Education" (Laura Berta Reyes- Sanchez); (15) "Fostering Both Creativity and Care in Science and Technology Education" (Leo Elshof); (16) "Chaos in the Science Center: A Multimedia Exhibit" (Nelson Canzian da Silva and Ernst Wolfgang Hamburger); (17) "The Teaching of Business Administration Using Business Games" (Paulo A. Marques-Filho and Marcelo S. de Paula Pessoa); (18) "Complementary Epistemologies of Science Teaching: An Integral Perspective" (Peter C. Taylor and John W. Willison); (19) "Satisfied or Dissatisfied with Their Science Teaching? What Distinguishes between Teachers Who Evaluate Their Teaching Positively from Those Who Evaluate It Negatively?" (Tom Klepaker, Siv Almendingen, and Johannes Tveita); (20) "Methods of Using Student Assessment to Improve a Conceptual Physics Course" (Peter Martin and Adam Niculescu); (21) "An Applied Methodology for a New Form of Technology Education: Electronic Commerce" (Victoria E. Erosa Martin and Pilar E. Arroyo Lopez); (22) "The Knowledge of Teachers, Mothers and Stuttering Subjects on the Stutter: Pedagogical and Educational Implications" (V.S. Galvao, D.T. Curriel, J.D. Delagracia, and A.P.G. Carvalho); (23) "Pedagogic Skills Needed by the University Professor for Successful Teaching and Learning" (Etelvina Maria Valente dos Anjos Silva, Silvia Regina Sangaletti Bellato, and Jaya Earnest); (24) "Partnership in Primary Science Project: Developing a Community of Practice to Encourage the Development of Pedagogical Content Knowledge" (Susan Rodrigues); (25) "The Role, Value, and the Actual Circumstances of Science Museums in Japan" (Midori Suzuki); (26) "Approaches Using Analogies in Interactionist Environments in Education" (Ronaldo Luix Nagem and Dulcineia de Oliveira Carvalhaes); (27) "The Testing of Skills in Dutch Central Examinations" (Joop Hendricx and Boy Kneepkens); (28) "The Science Education Enterprise in Developing Countries as a Battlefield of Different Dreamers: How to Overcome Groupthink Symptoms?" (Masakata Ogawa); and (29) "Classroom Debates on Biotechnology in Agricultural Education" (Laurence Simonneaux). (YDS)

# Rethinking Science and Technology Education To Meet the Demands of Future Generations in a Changing World. International Organization for Science and Technology Education (IOSTE) Symposium Proceedings (10th, Foz do Iguacu, Parana, Brazil, July 28-August 2, 2002, Volumes I [and] II.

Nelio Bizzo, Clarice Sumi Kawasaki, Laercio Ferracioli, Vivian Leyser da Rosa, Editors

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28th July - 2nd August 2002 Foz do Iguaçu, Brazil

# INTERNATIONAL ORGANIZATION FOR SCIENCE AND TECHNOLOGY EDUCATION (IOSTE)

## X Symposium Proceedings


editors
Nelio Bizzo, Clarice Sumi Kawasaki, Laercio Ferracioli, Vivian Leyser da Rosa




3

volume 1

# Rethinking Science and Technology Education to Meet the Demands of Future Generations in a Changing World

International Organization for
Science and Technology Education

10th Symposium Proceedings

## VOLUME I

# Rethinking Science and Technology Education to Meet the Demands of Future Generations in a Changing World

## International Organization for Science and Technology Education

## 10th Symposium Proceedings

In 1979, an informal network for exchanging information on world trends in science education was established. In 1984, this group became IOSTE, a formal organization with membership in over 50 countries which is dedicated to advancement of science and technology education around the world. IOSTE is officially recognized by UNESCO as a non-governmental organization.

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## FOREWORD:

### RETHINKING SCIENCE AND TECHNOLOGY EDUCATION TO MEET THE DEMANDS OF FUTURE GENERATIONS IN A CHANGING WORLD

**BRAZIL, 2002**

In June 1999, the IX IOSTE Symposium assembly voted that Brazil ought to be the host of the next symposium. Since then, a great deal of work has been undertaken in order to meet two major guidelines of IOSTE. On the one hand, we wanted to attain excellency by gathering a group of science educators that have been meeting in the last years. On the other hand, we wanted to have an impact on public schools as much as possible. For the first time in IOSTE symposia, we included a special program for teenagers, which was called "*IOSTEen*", broadcasted in a TV open signal by the Ministry of Education. We shared the common belief that science and technology are related to the understanding of the natural world and the changes introduced to it by deliberate human action, as well as that education plays an important role in preparing future generations to be conscious of the complexities involved in scientific enquiry and in the judgment of planned changes. This is what 500 educators had in their minds during the period from July 28 to August 2, 2002, in the beautiful town of Foz do Iguaçu in Paraná, Brazil.

All educators recognize that societies throughout the world are becoming increasingly diverse and complex. Citizens live in a technologically dominated society, where equity in social relationships, respect for the environment and sustainable development are yet to be achieved throughout the world. Science and technology education, therefore, have very significant roles to play in the socio-economic development of communities in a global environment.

In addition, we were planning a symposium while the Organization for Economic Cooperation and Development (OECD) was performing a horizontal assessment in 33 countries of the world (PISA 2000). It is acknowledged that assessment plays a key role in designing and monitoring changes in education. However, many people believe that it is time to re-appraise the role of assessment in a variety of educational situations, and this issue had to be addressed in the conference. We have noted that several papers deal with this subject, and that a morning session was entirely devoted to the theme.

Education in science and technology is an essential process, which must take the diversity in societies into consideration and relate this diversity to sustainable development. Students need to be able to evaluate evidence and draw conclusions from a scientific point of view. They must be able to critically grasp the extent to which scientific uncertainty allows predictions. As citizens, they should be able to evaluate possible technological solutions, based on their knowledge of the natural world and its complexity. Many papers are devoted to this theme, and two morning sessions were devoted entirely to the theme. In one of them, science teachers preparation was addressed, and in another, we planned to debate the tense relationship between academic and vocational perspectives in science education.

We believe that the two volumes which you have in your hands, and which represent the proceedings of IOSTE X Symposium, bring relevant contributions to the role of science and technology education, at a time in which much attention has been placed on "Education for All". We wanted to go further and offer a relevant contribution for those who are looking for a deeper understanding of the possible roles played by science and technology education in providing a relevant education for all citizens. There has been a strong history of rewarding academic excellence in science education, even at the expense of relevance for all. However, for the new century we believe there is a need to find ways to combine both. If educators are not able to do so, the so called "*post modern perspectives*" can seduce many people, creating an apparently equally legitimate alternative, driving out of the scientific field many who could possibly understand the real contribution science and technology can bring to populations in a proper way.

How is it possible to provide a strong science and technology background for those students wishing to pursue these subjects at a higher level, while at the same time provide an appropriate and rewarding science and technology experience for all students? In other words, how can we increase public awareness of science, and encourage problem-solving and decision-making activities in students rather than to portray science and technology as knowledge subjects where success is largely measured by memorizing facts?

We believe that many clues to these questions can be found in these proceedings, which include papers in five core-areas:

1-Science, Technology and Society: how can we educate citizens to live in a sustainable environment, providing basic needs for all, with a deep ethical concern.

2-Content Areas: science and technology education have connections to traditional content areas (e.g. Biology, Chemistry, Physics, and Geology), and may bring a number of different areas together. Many articles deal with contents, either taken as subjects or skills or competencies, aimed at improving pupils skills and knowledge, including many examples from science textbooks used worldwide.

3-Teaching Practice: Different teaching methods have shown a variety of usefulness in formal and non-formal education. Eliciting students' ideas and designing learning environments have been part of the strategies aimed at improving students' capacities to evaluate evidence, to distinguish theories from observations and to assess the level of certainty that can be ascribed to 'scientific' claims. Those interested in these subjects will find very interesting articles in these proceedings.

4-Assessment: re-appraising the role of assessment in a demanding and changing world is essential. There are papers in the proceedings which describe the problems which are encountered when standardized assessment procedures are applied in different sociocultural settings.

5-History and Philosophy of Science: several papers show how history and philosophy of science can play important roles in understanding students' ideas. History and philosophy of science can be used in a series of contexts when designing activities aimed at improving pupils' skills and knowledge.

Last, but not least, a great effort has been made to follow the format that IOSTE proceedings traditionally have had, but we have tried to improve on this format by adding indices of authors and of keywords. The result is, we believe, an outstanding group of articles, which bring together in almost 1000 pages the state-of-art in science and technology education in many countries.

Nelio Bizzo

Clarice S. Kawasaki

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001

# LIBERAL EDUCATION, INFORMATION ASSESSMENT AND ARGUMENTATION IN SCIENCE – LIA

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## Abstract

We report on the ongoing project LIA, addressing the training of science teachers at the universities of Oslo and Bergen, in Norway. The project is centred on the notion of a *liberal science education*. Specifically, we investigate the connection between the ability of science teachers and pupils to *assess information* with a scientific content, as e.g. disseminated by the media, and their understanding of the role of *argumentation* in justifying scientific claims. Several groups of science teacher trainees are interviewed, to get a general overview of their interpretation and comprehension of these issues. After this, they perform various *open experiments*, where both the target (what one is looking for) and the method (how to find it) are ill defined at the outset and need to be clarified through discussion first. And, finally, they are interviewed again, to see whether and how their interpretation and comprehension of the issues have changed. The data are being collected and analysed, and some preliminary results will be reported here.

## Project rationale

It is generally accepted that the ability to assess scientifically based information and claims, in a critical and constructive manner, is a crucial one to promote in science education. However, it is perhaps not so widely recognised that this ability also forms an important part of a general education: Every citizen, whether professionally trained in a science or not, will almost daily come into contact with contentious societal issues that have a strong scientific component: genetic engineering, chemical pollution, benefits and risks of nuclear power, exploitation of (renewable or non-renewable) natural resources, etc. etc.

As is well known, these are often difficult questions to resolve, with no clear-cut and universally accepted answers, even among science professionals. Nevertheless, members of the general public are regularly invited to form their own opinion on issues of this kind: to participate in the common societal discourse in the media, to vote for some particular political group or course of action, etc. So, how can they do this: make informed decisions in a meaningful (for them) and responsible way?

The answer is that they must be exposed to such issues, in their school education. The ability to assess information, especially scientifically based propositions, in a critical and constructive manner is an important part of the notion of a *liberal education*[2], and this is in fact an explicit learning goal of the Norwegian National Curriculum:

> *Education entails training in thinking – in making conjectures, examining them conceptually, drawing inferences, and reaching verdicts by reasoning, observation and experiment. Its counterpart is practice in expressing oneself concisely – in argument, disputation and demonstration. (Norwegian National Curriculum 1994, p.13)*

The scientific way of thinking and working is based on argumentation and assessment of information – a resource that seems to be under-exploited in the teaching of science in our schools. This is the background for our project: *Liberal education, Information assessment and Argumentation in science – LIA*. (In Norwegian: *Danning, Informasjonsvurdering og Argumentering i naturvitenskap*, with acronym *DIA*.) The project is directed

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[2] By a liberal education we mean: a broad and general education, enabling one to cope with a variety of societal issues without necessarily possessing expert knowledge or training.

toward pre-service teacher education, working with students (trainees) who have completed at least a bachelor degree in one or more of the school sciences (physics, chemistry, biology). It is funded by the Norwegian Ministry of Education, and the participating researchers are:

| University of Bergen | University of Oslo |
|---|---|
| Stein Dankert Kolstø[3]<br>Marit Ulvik<br>Erik Arnesen<br>Anne Sissel<br>TonningIdar Mestad | Andreas Quale<br>Anders Isnes<br>Terje Kristensen<br>Ketil Mathiassen |

The principal aim of LIA is to investigate a possible connection between learning goals traditionally associated with *argumentation in science* and the desired competency in *assessment of scientific information*. Briefly: argumentation must be based on knowledge about scientific research as a process driving the frontier of science, and it may be argued (see e.g. Kolstø, 1998) that such knowledge is relevant for analysis and assessment of many controversial scientific issues that are presented in the media (including the internet). More specifically, a competency in assessment and decision-making with respect to issues of current societal interest requires some knowledge of various types of scientific propositions – i.e. knowledge of the crucial role played by argumentation and discourse in scientific work. Hence it is pedagogically desirable to explore the association between argumentation in science and assessment of scientific information, as this project aims to do.

The Norwegian National Curriculum also emphasizes (1994, p.14) the development of a critical sense of judgement in the assessment of information:

> *Critical judgement is required in all areas of life…A sense of discernment is developed by testing expression and performance against specific standards…appraising the quality of a piece of work requires the professional insight gained from repeated experience.*

However, neither in the curriculum plans nor in the textbooks is it made clear how these laudable goals are to be realised in practice. In LIA we let the teacher trainees work on practical applications involving assessment of scientific propositions, to (hopefully) enhance their understanding of such assessment, and thus prime them for passing on this understanding to the pupils, in their future professional life as science teachers.

To this end, it is necessary that the trainees have a conscious idea of the notion of a liberal education (see footnote 2), and that they develop a positive view of the value of having such an education. A clarification of terms is in order here:

In the English language the word 'educated' has two meanings: *having a broad general knowledge of many subjects*, as in "…he is an educated person", and *having received a more specialized formal training in a particular subject*, as in "…he was educated in math and physics". (In the following: for "he", "him", etc., please read "he or she", "him or her" etc.) In the German language we would distinguish between the two by using the terms *Bildung* and *Ausbildung*, respectively. It is the first meaning of *Bildung* that is denoted here as *liberal education*. Moreover, a person possessing this kind of education will be referred to as *cultured*, instead of the more cumbersome "liberally educated"; the further significance of this term is discussed below.

**Theoretical framework**
The LIA project is based on a constructivist approach to learning: The individual learner does not meet the world unconditionally, but constructs knowledge in an active process of interaction between his preconceptions and the

[3] National Coordinator of LIA

environment (Glasersfeld, 1995). At the same time, learning is a social process, where learners construct their own mental representations of reality through dialogue (Solomon, 1987) and action (Vygotsky, 1978): it is in interaction with others that we experience the function and value of knowledge, and receive corrections to our own understanding. We try to capture the essence of this interplay (between individual and social dimensions) by letting the teacher trainees solve individual assignments, whereupon their solutions are challenged by the whole group. And, following Solomon (1987), we argue that new concepts must be introduced in such a way that they become meaningful to the learner, otherwise they will not be adopted and internalised by him.

Summing up: Knowledge gives us a set of cultural tools, developed through the interplay of individual construction and social interaction. Through the activities embodied in the LIA project, the teacher trainees will acquire their own experiences and construct their learning from those. For a successful learning process it is essential that the learners "own" the knowledge gained, in the sense of having internalised the motivation for learning this knowledge. Here, an essential motivation of the trainees will be that whatever they experience in the project activity must have transfer value to their future work as science teachers in school.

**A liberal teacher education – the notion of culturedness**

One aim of LIA is to contribute to a *liberal* education of teachers – one that provides them with a platform for action. Hellesnes (1992) discusses the notion of education, as an aspect of individual development and adjustment to a cultural environment, and proposes the following two outcomes: (i) the *adapted* person, who accepts external constraints without question and settles well into a world defined and organised by others; and (ii) the *cultured* person, who can think critically and ask fundamental questions about the world, trusting in his own rationality. In this scenario, then, the goal of a liberal education is to produce such cultured persons.

The dichotomy of adaptation and culturedness will be central to the LIA project. We see the purpose of teacher education as, not only accommodating the teacher trainees to the school system, but also enabling them to react critically to the school environment, and to develop and (if necessary) change it. A teacher should encourage critical thinking in the learners, for which reason it is necessary that he himself have this ability: to stimulate the development of the learners toward culturedness, he must himself be able to develop and change. An adapted person will have difficulties in considering alternatives – he will "...see reality as static" (Freire, 1978). A good society is dependent on people who can assess what is going on, and who do not fall easy prey to indoctrination. Hence a liberal education, in Hellesnes' sense, is a prerequisite for democracy. It encourages an understanding of reality as a process, not a result; we can influence the world, not just be governed by it.

Bakhtin (1981) distinguishes between the acts of *persuading* and *convincing*: the first has to do with rhetoric and manipulation, the second with conveying to the listener insight and understanding. He claims (and we agree) that it is the teacher's responsibility to give the learners a voice in the learning process: learning is inherently dialogic, and meaning is created through dialogue and interplay. This has not been a prominent part of traditional school education, which has seen its task more as passing on the established truths of society to the next generation. Within this paradigm a teacher-learner dialogue may easily become illusory: the learner learns to answer what he expects the teacher wants to hear..!

**Argumentation in science**

One crucial part of LIA has to do with the nature of science. We consider science to be not only a product, but also a process; and the production of scientific knowledge then incorporates important social processes pertaining to assessment and validation of propositions through critical discussions (Ziman, 2000). Cole (1992) and many others distinguish between *core science*, i.e. established scientific knowledge on which there is more or less unanimous agreement in the scientific community, and *frontier science*, which is research-driven and addresses issues where there is little or no consensus about hard conclusions.

In school, we are mainly exposed to core science, which carries a tacit message that scientific knowledge delivers "true information" about nature. On the other hand, the science we most often meet in the media is frontier science, as an ingredient of current controversial issues. In LIA we aim to mitigate this apparent contradiction, by exposing the teacher trainees to a number of such issues, and discussing how to incorporate them into science teaching in such a way that the learners get a more realistic picture of science. Thus, learners should learn not to interpret a disagreement among scientists as necessarily indicating either incompetence or lack of disinterest. This has not been paid attention to in traditional science teaching:

> *Traditionally, science teaching has paid little attention to argument and controversy. This has given the false impression of science as the unproblematic collection of facts about the world, thereby rendering disputes between scientists, whether historical or contemporary, puzzling events (Driver et al, p. 556)*

With the cited authors, we maintain that *argumentation* should be given a more central role to play in the teaching of science: it forms an important part of the scientific working method, and the ability to pose scientific questions and answer them is a necessary prerequisite for the learner to become confident and familiar with science.

## Project organization

The LIA project works with some sixty teacher trainees, around forty (divided into two groups) at the university of Oslo and the rest at the university of Bergen. It has two main investigative modules:

1. Planning and performing of open experiments, with particular focus on the argumentation presented by the trainees, in support of their chosen strategies and conclusions.
2. A study of some controversial societal issues with a scientific component: which groups of people have vested interests in these issues, what are their views, and how can we assess the scientific validity of the information found?

Module 1 is under way, and it is work on this module that will be reported here. Module 2 will be started in the first part of 2002. The whole project is expected to be concluded by the end of 2003. The general organization of LIA module 1 is as follows:

- The teacher trainees are first given a questionnaire, intended to provide an overview of some of their preconceptions about the notion of culturedness and the role played by science in this connection. A selected few of them are also interviewed, about the same topic.
- They are then asked to plan and perform an open experiment, where both the goal (what precisely is being sought) and the method (how to perform the experiment) are ill defined at the outset and need to be determined through discussion first.
- Lab reports of the experiment will be discussed among the trainees, concerning the trustworthiness of their own results, and of scientific knowledge more generally. These discussions will provide data for further analysis, addressing the main goal of LIA (in this module): to explore the understanding of science teacher trainees concerning the role of *argumentation* in justifying scientific claims.

The analysis of LIA is primarily based on three sets of data:
1. The questionnaires and interviews given to the trainees before the open experiment
2. The reports of the experiment
3. The discussions of the groups after the experiment, as documented by written summaries

These data will be processed in detail, both quantitatively and qualitatively. As a preliminary step, we have looked at: (a) the trainees' preconceptions about the notion of culturedness, and its relevance for science in general and school science in particular, and (b) their ability to plan, perform and discuss strategies and results of open experiments.

We present here some preliminary data and results as obtained from the first Oslo group, comprising around 20 teacher trainees. The percentages reported are, of course, not claimed to have any statistical significance; rather, they give a rough indication, to be followed up in subsequent investigations as the project continues.

Further work will analyse data gathered from all the Oslo trainees, and correlate them with the corresponding data gathered in Bergen. In particular, we will explore the possible impact of the open experiment (with discussion both before and after actual implementation) on their attitudes concerning argumentation in science and its importance for the assessment of scientific information.

**Preconceptions of the trainees**

Three types of questions are posed in the questionnaire:

1. about the notion of education, liberal and otherwise
2. about science as taught in school
3. about the nature of science in general

*Category 1: The notion of Education*

*What is a liberal education / a cultured person?* Almost all (90 %) recognized a difference between the two notions of education: a liberal education as defined above, and a formal training in some particular field of expertise. Most of them (75 %) identified a cultured person as one having a broad knowledge of literature and the arts, and a grasp of societal issues. Hardly any of them claimed that such a person must have studied at university or college level, or that he must take an interest in political issues.

*How would you describe an education that may rightfully be classed as "liberal"?* This topic is discussed extensively in the Norwegian National Curriculum (1994) – which is required reading for teacher trainees at this stage of their training. A majority (80 %) claimed that it must cover a wide variety of subjects, and about half stated that it must provide knowledge of philosophy and the arts, and promote qualities such as tolerance and democratic leanings. About 40 % maintained that such an education should be achievable for everybody, irrespective of intellectual abilities or preferences.

*Category 2: School science*

*Is the notion of a liberal education relevant for school science?* When asked to name, "from the top of their mind", three scientific topics that they felt to be important for a liberal education, most of the trainees declined to answer. One may surmise that at least one reason for this reticence is that they had not previously reflected in any depth on the status of their own particular school science subject in the perspective of a liberal education. This conjecture is supported by the results emerging from the question: *What should be emphasized in the teaching of school science, to promote a liberal education?*, where they were now asked to pick topics from a list of given alternatives. About half of them chose the following three:

- the pupils should achieve an understanding of how the laws of nature function
- they should receive training in assessing information systematically
- they should become curious about natural phenomena

Very few chose:

- the pupils should learn to work independently
- they should become interested in societal issues

And only about 20 % chose:

- the pupils ability to argue logically should be strengthened
- they should learn about how science has developed up to its present stage

We note that these results appear not to be in complete accord with the trainees answers concerning the more general issues raised in the category 1 questions.

One of the questions in this section was: *What do you feel should be emphasized in the teaching of science, in a liberal education perspective? (Mark three of the items listed below, in ranking order: 1 for the item you consider most important, 2 for the second most important, etc. – or mark "Do not know" if you have no opinion.)*

1. Understanding of how the laws of nature function
2. Proficiency in solving assigned problems

3. Learning how science has developed from its beginning up to the present day
4. Proficiency in logical argumentation
5. Proficiency in systematic assessment of information
6. Some insight into the nature of science
7. Some insight into connections between science, industry and society
8. Learning to work independently
9. Acquiring an interest in societal issues
10. Acquiring an interest in science
11. Becoming more curious about phenomena of natural science
12. Do not know

After the questionnaire was turned in, we let the trainees discuss this question in groups, asking each group to achieve consensus about an agreed ranking list of items. The following four were then the most frequently chosen: Nos. 1, 5 and 11 (i.e. the same that were most often marked in the individual questionnaire), and No. 7. Many stated that they had changed the positions that they had initially held on these issues, as a result of the discussions.

*Category 3: Science in general*
Most of the trainees associated science with experimental work (80 %), and regarded it as giving a theoretical description of nature (70 %). Few (15 %) considered science to be more objective than other fields of knowledge, and none claimed that it is politically neutral. More than half stated that science is part of our cultural heritage – a stance that is strongly promoted by the National Curriculum. Later, when more data have been gathered, a more detailed analysis will be carried out, exploring possible connections between the trainees' views on this issue (the nature of science) and their views on the topic of culturedness and a liberal education (in particular, the importance of argumentation in the assessment of information with a scientific component)

Next, the trainees were asked to judge, for each of a given list of current contentious propositions, to what extent it represents reliable scientific knowledge. The majority then maintained that the following do *not* represent reliable knowledge:

- Irradiation of food products can harm the consumer
- Nuclear energy causes less environmental problems than fossil energy sources
- Biodynamically cultivated vegetables are more nutritious than traditionally cultivated ones
- One glass of red wine per day is good for your health
- Gene technology will give us more healthy domestic animals

A large majority (> 90 %) regarded as reliable knowledge the proposition that a reduction of the ozone layer leads to an increased risk of skin cancer. But they were fairly evenly divided on these two propositions:

- the cause of climate problems is the increasing release of greenhouse gases
- radiation from high-voltage power lines constitutes a health hazard

In the continuation of LIA we will make a more detailed assessment of the information that is found in the media on some of these topics.

*What is the difference, in your opinion, between the science that is published in journals where researchers describe their findings and the science that is found in school and university textbooks?* Here around one third of the trainees answered that the first is always more complex and uncertain than the second. Very few claimed that journal science is more correct than textbook science.

**The open experiment**
An open experiment is one where the performers have to design a strategy for investigating a problem experimentally, and then plan and perform the experiment this strategy. The problem may be given, or identified by the performers, but the crucial point is that there is no "known correct answer". Here, the problem is gives as a practical task, which they then have to analyse: specify what is sought, decide what to measure, formulate

hypotheses about relevant variables, choose experimental set-up and make observations. And then they must use the observed data to test their hypotheses, formulate conclusions and argue the validity of their results.

It should be noted that open experiments are not often given as pupil assignments in our school science education. It is more common to let the pupils perform *closed experiments*, where both the method of implementation (what precisely is to be done at each step), and the expected result (the correct answer) are fairly well defined, and dictated by the teacher or textbook. Thus, our goals for the open experiment were that the trainees should:

- acquire experience with the planning and implementation of open experiments in general
- develop an awareness of the interplay between observational data and argumentation, as essential components in the production of scientific knowledge

The trainees were organized in groups, to perform the experiment. Their subject backgrounds were various: more had studied biology than physics; and some had studied several school science subjects, and completed a master degree in one of them, while others had only one, and no more than a bachelor degree in it.

The experiment addresses the following practical situation: *At a party there will be served hot and cold drinks. The question to be resolved is: what kind of drinking cup is best suited, for keeping the content beverage at a desirable temperature? The cups provided for consideration are made of cardboard, plastic or polystyrene, and they come both with and without a lid.*

Each group had to plan and then perform the experiment. Planning was done according to a scheme given to the groups at the beginning:

*The problem*
Identifying what is to be done:
*We will try to find out ...*

*Hypotheses*
To be formulated and argued by the group:
*We think ... may happen (will be observed), because...*

*Procedure*
Identifying relevant variables, such as: presence/absence of a lid, material of the cup, volume of content, etc. Which variables should be kept constant? Which are most influential in determining the observed result?
*We expect ... to have a large influence, because...*
*The influence of ... will probably be negligible, because...*

The group plans the experiment: how and what they will observe. The plan should be argued, with emphasis on control of variables and concrete implementation:

*Our plan is a good one, because...*
*Our results will be valid, because...*

*Performance*
Data logging equipment were used to monitor temperatures in the beverages. Some groups compared cardboard cups with and without a lid; others compared different materials (cardboard vs. plastic). For 'warm beverage' they used heated water, as 'cold beverage' water with ice was used. Starting temperatures/ranges were decided on by the group. Each group wrote a report documenting their experimental set-up, observed data, arguments and conclusions.

Some observations, regarding the actual performance of the open experiment:

- None tried to ascertain what the usual serving temperature for coffee/tea is, and how this temperature varies while it is being consumed. Thus the choices of starting temperature and range were somewhat arbitrary.

- Very few used technical terms from physics in communicating with the other group members. Concepts such as *heat loss*, *energy transfer*, etc. did not seem to form a natural part of their vocabulary, when discussing the observations.
- The practical implementations were various: some groups were very creative in their choice of materials and strategies; others just chose the simplest solution.

**Discussion of experiment and further analysis of report data**

Based on the different hypotheses and implementation strategies chosen by the groups, we devised a strategy for initiating group discussions after the experiment was concluded. Briefly, discussions were conducted on two levels:

- A primary discussion, addressing the evaluation of the results found – which of them were the most reliable, and why?
- A meta-discussion, aiming to develop the students' reflection concerning the role played by argumentation in the production of scientific knowledge.

**Analysis of Report Data**

Our analysis of report data is primarily based on:

1. The reports of the experiment
2. The discussions of the groups, as documented by written summaries

This has led us to propose the following specific categories of analysis.

We want to explore the ability of the trainees to:

1. formulate problem descriptions and hypotheses, whether experience-driven (based on own observations) or theory-driven (based on relevant materiel from established scientific knowledge)
2. plan an open experiment – to what extent they are able to:
   - identify relevant variables, and assess their influence on observed values
   - vary one variable at a time, observing the effect of this
   - identify variables unlikely to influence results
   - identify variables that cannot be held constant
   - reflect on methodical problems and uncertainties in measurements
3. describe observations, and distinguish between observation and theory
4. use scientific knowledge to interpret observations, and distinguish interpretation from observation
5. use scientific terms such as heat, heat capacity, temperature etc. in the planning of the experiment, and in the discussion of results (argumentation, assessment of validity, etc.)
6. present the report in a clear and convincing way.

**Some observations**

We have made a preliminary analysis of the reports and discussions, relative to the categories listed above:

*Hypotheses and problem description*

These are essentially characterized by formulations originating in "everyday life", and rarely based on scientific theory and concepts. Here are phrases such as: *keeping the warmth (or cold), conserving the temperature*. They frequently confuse the concepts of *temperature* and *heat* – we often see imprecise use of terminology, such as: *exchange of temperature, spreading cold.*

*Identifying and assessing variables, choice of procedure*

They can identify the most important variables, but mostly without giving any scientific grounds for their choice. None reflect over why the temperature changes "in the opposite direction" when the observations start (the sensors are then at a higher/lower temperature than the liquid beverage), but just note this as "peculiar". Some reflect on the placement of sensors, and on stirring the liquid, but without any scientific argumentation: thus the effect of stirring on heat loss is not considered. Many discuss the shape and material of the cup, but make no mention of relevant concepts such as *heat capacity*, *evaporation heat*, and *heat loss through conduction or convection.*

*Observations, interpretations and comments*
Measured values are given as temperature differences (not as changes of temperature with time), and sometimes even as *percentage change* of temperature. The crossing of two temperature graphs (temperature variations in two different cups) is not commented on; instead we see imprecise statements such as *temperature exchanges are faster when temperature differences are larger.*

Comments/criticisms are often vague and inexact. Very few address imprecise use of concepts and argumentation in support of hypotheses. Even blatantly incorrect statements, e.g. confusing heat and temperature, are not commented on.

## Conclusion

Science teachers who wish to use open experiments need to pay attention to their own language precision and correct use of scientific terminology. The simple experiment reported here provides ample opportunity to address important aspects of hypothesizing and argumentation in science. Our analyses will be discussed with the trainees, to (hopefully) help them develop a more conscious attitude toward the use of open experiments in their future teaching.

## References

Bakhtin, M. M. (1981). *The Dialogic Imagination*. Austin: University of Texas Press.

Driver, R., Newton, P. & Osborne, J. (1999). 'The place of argumentation in the pedagogy of school science'. *International Journal of Science Education, 21*(5), 553-576.

Freire, P. (1978). *Education of the oppressed* (in Danish: *De undertryktes pædagogik*). Copenhagen: Ejlers Forlag.

Glasersfeld, E.v. (1995). *Radical Constructivism: A Way of Knowing and Learning*. London: The Falmer Press.

Hellesnes, J. (1992). 'Tilpassingsideologien, sosialisering og dei materielle ordningane' (in Norwegian). In E. L. Dale (ed.), *Pedagogisk Filosofi* (pp. 28-51). Oslo: Ad Notam Gyldendal.

Kolstø, S. D. (2001). 'Scientific literacy for citizenship: tools for dealing with the science dimension of controversial socioscientific issues'. *Science Education, 85,* 291-310.

Norwegian National Curriculum (1994). *Core curriculum for primary, secondary and adult education in Norway.* Oslo: Ministry of Church, Education and Research.

Solomon, J. (1987). 'Social influences on the construction of pupils' understanding of science'. *Studies in Science Education, 14*, 63-82.

Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Cambridge: Harvard University Press.

Ziman, J. (2000). *Real Science*. Cambridge University Press.

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# PLACING THE HISTORY AND THE PHILOSOPHY OF SCIENCE ON TEACHER EDUCATION

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**Abstract**

Recent research indicates that teachers conceive and orient his/her teaching depending (among others things) on his/her conceptions about both the nature of science and the construction of the scientific knowledge. This is an important educational issue because the image of science that is generally held by students consider science simply as a rhetoric of conclusions. Science teaching strategies designed in line with the principles of the "new philosophy of science", e.g. emphasising the context of discovery of scientific ideas (and not simply the context of justification of those ideas), methodological pluralism and the human and social side of science (STS relationships), are usually ignored. Part of the problem lies in inadequated teacher education strategies. Thus the aim of this study was to design, to develop and to evaluate an innovative teacher education program exploring the History and the Philosophy of Science (HPS) in order to improve the teaching and learning of mass conservation in chemical reactions, a key curricular theme in Portuguese secondary teaching and also a relevant historical and cultural topic of study. The main hypothesis was that it is possible to develop in –service teacher education strategies based on the HPS to promote adequated epistemological perspectives of science teachers.

The research design followed was organised in three interrelated steps: a naturalistic phase (over 40 hours of teaching of two secondary teachers were videorecorded and analysed); a second phase concerning the teacher education program itself exploring action-research strategies and involving the design of new teaching plans and the construction of new didactic materials.; the third phase in which the new teaching strategies were then implemented by the two teachers.

Evidences of the evolution of the epistemological perspectives underlying teachers' practices from the first to the third phase are presented together with examples of the use of the HPS in the three methodological categories of analysis: scientific methodology, dynamics of the construction of scientific knowledge and the human and social face of science. The results of a triangular evaluation of the program (external observer, students and teachers self-evaluation) is also presented. We can conclude that the teacher education program developed exploring HPS was able to improve the teaching of the chosen topic, in particular making the students more aware of images of science congruent with the principles of the "new philosophy of science".

## Introduction

Educational innovation can only really succeed if it also involves professional development and teacher empowerment. This implies a new way to look at teacher education. We now have some new general orientations to guide teacher education (Schon 1987; Zeichner 1993).What is still missing are systemic research approaches to teacher education in order to improve teachers' personal and professional growth. Teachers need to reflect more and better on their own practices and this (hopefully) will have a positive influence on their classroom strategies. It means that we need educational research strategies that will help classroom teachers to promote effective and conscious changes in their teaching.

The more consensual position indicates that each teacher conceives and orients his/her teaching depending on his/her conceptions of the nature of science and scientific knowledge, his/her professional experience, on his/her interpretation of curriculum, on the way he/she conceives education in particular the more general goals of science education.

As Gallagher (1991) said, "secondary teachers' knowledge about the nature of science is important because they play a key role in forming the image of science that is held by the general public", and he asks "what do teachers understand about the nature of science, and how does this knowledge influence their teaching?"

Many research studies point to a strong link between teachers' conceptions and their practices (Pomeroy 1993; Lederman 1986), others consider some influences and a selected collection of situational variables (Brichouse & Bodner 1992; Lederman 1992).

Among teachers' images of science, some prevail over others, namely positivists', empiricists' and inductivists' perspectives (Aguirre 1990; Hodson 1985, 1993; Praia & Cachapuz 1994, 1998) and science is viewed exclusively as a definitive well-established body of knowledge. The understanding of scientific principles and relationships received far less attention than terminology; teachers devoted no time to the discussion of matters related to the nature of science, such as how the knowledge included in the curriculum was formulated or the process by which scientists validate knowledge, teachers emphasised the objectivity of scientific knowledge and they based the objective aspect on scientists' use of the scientific method; teachers frequently fail to point out obvious connections between classwork and the world outside the school (Gallagher 1991).

Gallagher (1991) and Matthews (1990) attribute responsibility for this to the fact that teachers have had no formal education in the history, philosophy and sociology of science.

Despite some well known dissimilarities between contemporary epistemologies about scientific construction and its structure, scientific philosophers, particularly Khun, Lakatos, Toulmin ...converge on a coherent image of science with important implications for science education (Cleminson 1990, Duschl & Guitomer 1991, Hodson 1985, 1996, Gil-Pérez 1996, Duschl 1995...). These arguments known as New Philosophy of Science (NPS) may be summed up in the following way: 1- Scientific knowledge cannot suggest an absolute truth, it has temporary status and errors must be an object of reflection; 2- Scientific discoveries have context and structure and the history of science helps us to understand those aspects; 3- Scientists are part of the very world they investigate and they must constantly submit their results to the certification of a scientific community; 4- There is no unique and singular method of producing scientific knowledge but a context-dependent methodological pluralism; 5- Observation does not exist apart from a theory that orientates and gives meaning to it. Scientific theories interpret and explain the world tentatively; and 6- Science is not objective (in the positivist sense), impersonal and problem-free, but it is closely related to society and technology.

We know that the history and philosophy of science has for many years been absent both from science curricula and, in particular, from science teacher education (Matthews 1990, Acevedo Díaz 1996, Pomeroy 1993...). During the 80's and early 90's the consideration of the inclusion of philosophical aspects in science teaching education began to increase and relate the philosophy of science to science teaching and learning.

From another point of view, as we mentioned earlier, educational research has not achieved relevant changes in classroom practices. Teaching practice is mainly guided by pedagogical preoccupations and the images of science and scientific knowledge in the classroom do not match with the NPS principles. These ideas led us to the problem of what kind of innovative strategies of teacher education should be considered in order to promote effective changes in teachers' usual classroom practices. Thus a major challenge for us is how to design and to develop effective science teacher education so that teachers may understand the importance of the inclusion of the philosophy of science in their science teaching.

There are two main aspects related to the NPS worth of attention. They are the consideration of the social construction of science and scientific knowledge and the associated technological development (STS perspectives (Matthews 1994)) and the importance of the inclusion of the history of science in science teaching. In practical terms we need to improve conditions which will enable teachers to analyse their teaching after a guided reflection on a previously selected theme of the curriculum. A possible strategy is to involve teachers in cooperative action research studies designed in order to conceive and explore concrete curricular strategies based on the history and philosophy of science (Monk & Osborne 1997) and also to analyse and discuss the way they may implement them in the classroom.

**Mass conservation in chemical reactions: an epistemologically relevant theme**

As referred to by Paixão (1999) "mass conservation in chemical reactions" was selected as a relevant theme because it has usually been viewed from a poor perspective and because of this, it has been a point of crystallisation of an exclusivist form of academic knowledge; students only resolve "exercises" (non problematic questions) of equation balancing and stoichiometric aspects, and even when they do them, it does not follow that they understand what they have done.

Classroom practices and textbooks have a particular incidence of an empiricist point of view (as far as this theme is concerned) which implies the absence of current perspectives on the contemporary principles of the New Philosophy of Science. For example, Experimental Work (EW) developed in classrooms (practical work) is very far from those principles. Most of the time the practical work proposed on the theme of mass conservation follow a confirmatory epistemological perspective involving the 'classical' chemical reaction of precipitation of the lead iodide by reaction between potassium iodide and lead nitrate. On the other hand, we must consider the academic interest of the theme: it is the pre-requisite for all and subsequent understanding of chemistry and it has a central position in the curriculum of basic studies. In fact, the understanding of the mass conservation principle, and also the understanding and knowledge of the general theory of chemical reactions, is indispensable for the understanding of the properties and the transformation of substances. There are many research studies that point out the existence of students alternative conceptions about this theme (Hesse & Anderson 1992, Yarroch 1985, Ben-Zvi et al. 1987...)

From the epistemological point of view, the study of the controversies that followed the interpretation of one of the most common chemical reactions, i.e. combustion, and the establishment of the general theory of chemical reactions, the mass conservation principle (later an empirical law), which guided Lavoisier in the establishment of his theory, cannot be underestimated. It is also a historically and culturally strong theme due to the correspondence of a period in the history of mankind and in the history of science with many special important social, economical, political and scientific implications. After the commemoration of the 200 years since Lavoisier's death, the available literature about that period of chemical history increases quantitatively and qualitatively (Bensaude Vincent & Stengers 1996). The theme is also important in a social and technologically up-to-date and foreseen future context – thermal power stations; incineration; recycling...

Teachers cannot ignore all those questions about the way scientific knowledge grows, and they must give students an image of that difficult and contextualized construction.

There are, in fact, many epistemological elements that contribute to a more consistent image of science, like scientific controversy, scientific community and societies, technologies associated with science, publications, communications and scientific correspondence... acceptance or non acceptance of a new theory... social, economical and political implications which, as was the case in a period such as the French Revolution, influenced the status of chemistry as a modern science. That is a cultural view of science very different from the instrumental image transmitted by teachers in science classrooms.

**Hypothesis and aims**

The main hypothesis that guided the study was that it is possible to develop in-service teacher education strategies in order to promote teachers' professional and personal growth, using the History and Philosophy of Science (HPS) framework in the teaching of science curriculum themes. This, in turn, results in a substantial empowerment in professional fulfilment and in the suitable images of science transmitted to the students. The assumption is that students' learning increases in the same desirable direction.

The aim of the study was to develop a Teacher Education Program (TEP) in order to improve both the epistemological perspectives of teachers and their teaching strategies of the theme "mass conservation in chemical reactions" (low secondary school) using the HPS framework.

**Methodology and procedures**

This research is included in a case study methodology in the perspective indicated by Yin (1987, 14): "The case study allows an investigation to retain the holistic and meaningful characteristics of real-life events" and "are the preferred strategy when "how" and "why" questions are being posed". The results from the research are concrete aspects related to each presented case and they can be used to confront them with others in similar contexts and to stimulate continuing research in the same direction. This is more a question of transferability than a question of generalisation.

The study was developed in three main related phases.

The general purpose of the first phase of the research was to elucidate the teachers´epistemological perspectives as revealed by their practices. The question that guided the 1st phase was to investigate the congruence (if any) between the theoretical framework and the nature of classroom practices of teachers. Beyond this general purpose, the effective value of that first phase in the whole study, was to elucidate the main difficulties which teachers faced in their practices, to give us some orientations for the elaboration of alternative teaching strategies and to obtain videorecorded materials to be explored in the individual teacher education phase (2 th phase). These videorecorded materials gave the opportunity for participant teachers to become aware of the need to develop the epistemological dimension of the understanding of science teaching and learning and to allow them to assess the evolution of their practice. Thus an awareness of the progress made concerning the images of science and scientific knowledge held before and after the participation in subsequent phases of the study. With these objectives in mind the study was conducted according to a naturalistic approach. Four in-service Physics and Chemistry teachers, all of whom were female, participated in the study during the first phase. The participants were permanent members of the staff of four different Portuguese (low) secondary schools. The academic background and the professional experience of the participants were diversified. We videorecorded over 40 hours of actual teaching, on the selected theme. The written protocols were then analysed to identify teacher´s epistemological conceptions (oral discourse and teaching activities implemented). It was simultaneously a descriptive and a critical interpretative process of data analysis, guided by a theoretical framework instrument (Figure 1). This was the instrument of analysis of classroom practices.

| Epistemological Categories | Analysis Dimensions | Teaching Practice Indicators(examples) |
|---|---|---|
| I - Scientific Methodology | A - Methodological pluralism | Explicit references to some episodes of the HS and/or current aspects of scientific investigation with relevance to different scientists' working methods.<br>Discussion of students' ways of working with clarification of the means of selecting experimental procedures and their adequacy and/or limitation (not recipes). |
| | B - Theory / Observation / Experiment relations | Theoretical considerations before observation and experiments.<br>Initial problematic questions and predictions.<br>Critical report of the experimental work guided by problematic questions and including critical assessment of the results |
| II - The dynamics of Scientific knowledge construction | C - Scientific discovery Context and structure | Activities exploring historical controversies in the establishment of a given scientific theory (i.e. texts and related questions) |
| | D - Error /Truth Dynamics | Intentional evaluation and exploration of students' errors.<br>Identification of misconceptions.<br>Discussion of discrepant experimental work results. |

| | | |
|---|---|---|
| III - The human and social side of science | E - Images of scientists and of the scientific community | Explicit references to the human side of scientists. Opportunities for the students to express their own ideas and confront them with their colleagues' ideas and/or with the current scientific version. |
| | F - STS interrelations | To begin with a social or a technological problem. To promote debates about science related questions, showing the relation between science and technology, ethical or environmental questions, with the opportunity for students to express their own ideas. |

**Figure1:** Instrument of analysis of teaching practices

During the second phase the alternative planning began, guided by the following question: What kind of changes in the teaching strategies are desirable and possible? We started the Teacher Education Program (TEP) simultaneously with the preparation of new historical materials involving texts, related practical work sheets and STS questions. The TEP began with the design of the teaching strategies and materials with the required epistemological discussion. The third phase was the continuing development of the TEP that now includes the teaching of the proposed theme according to the new perspectives and finally the assessment by the participants (teachers and students) involved in the program using half-structured interviews. Only two of the initial four teachers involved wanted to participate in the 2 th and 3rd phases. The analysis of the teaching practices during the third phase was parallel to the process done in the first phase, using the analysis instrument (Fig.1). After this analysis the researchers conducted the interview step involving the critical confrontation of each teacher with selected episodes of their teaching (as revealed by videorecorded materials).

**The Teacher Education Program**

Given the nature of the study (collaborative action research (Elliot 1994)) the design and the implementation of the Teacher Education Program (TEP) were closely articulated.

The Teacher Education Programme (Figure 2) involved seminars, discussions and critical reflections with the collaborative organisation of the teaching strategies and the preparation of the new materials.

| Meeting | Date | Place | Time | Aims and activities |
|---|---|---|---|---|
| Seminar | 23 April 1997 | University of Aveiro | 8 hours | To present and discuss the interest of SH and EW as relevant dimensions to innovative science teaching strategies (Prof. J. Praia - University of Oporto)<br>To critically explore a teaching proposal using the theme: "mass conservation in chemical reactions" at low secondary school levels (M.F. Paixão)<br>To select participants for the subsequent phases of the study (criteria: volunteers; interested in their own education and enthusiasts; having the 8th degree in 1997/98; and who allow the videorecording of their classroom teaching).<br>An assessment of the seminar was made by the participants (11 participants.) |

| | | | | |
|---|---|---|---|---|
| 1st Individual meeting | Oct/Nov 1997 | Secondary school of each participant teacher | 3/4 hours | Formal contact with the head of the school<br>To inform about the specific aims of the program.<br>To make each one aware of the need to involve teachers in their own education with the intention of developing their own teaching practices and the subsequent empowerment of students' images of science(Action-research perspective).<br>To discuss the importance of epistemologically based science teaching, in which the HS and EW are fundamental elements.<br>To present the selected theme and its educational interest as a whole.<br>To give out some documents about Philosophy of Science and Science Education as well as a document organised by researchers concerning the historical and scientific aspects of the selected theme (homework). |
| 2nd individual meeting | Nov 1997 | Secondary school of each participant teacher /teacher training college C.Branco | 3/4 hours | To critically analyse and discuss the documents given out in the last meeting.<br>To discuss the general aspects of science teaching planning.<br>To discuss the scientific concepts involved and the students' common misconceptions.<br>To analyse the official curriculum.<br>To discuss the epistemological value of the theme. |
| 3rd individual meeting | Nov 1997 | // | 3/4 hours | To analyse and discuss the teaching carried out during the 1st phase (videorecorded and analysed by the researchers)<br>To begin the planning of teaching strategies |
| 4th Individual meeting | Nov/Dec1 997 | // | 3/4 hours | To prepare materials: to translate texts from the original papers of Lavoisier; to prepare experimental work sheets and STS related questions.<br>To discuss the adequacy of some materials for the development of the proposed strategies<br>To prevent some problematic aspects.<br>To certify that the teacher feels prepared to do the teaching of the theme in the desirable perspective |
| 5th Individual meeting | Dec/Jan 1997/8 | // | 3/4 hours | During the teaching of the theme:<br>To analyse selected videorecorded classroom episodes with the teacher.<br>To reflect on the basis of initial goals and framework.<br>To make eventual adjustments in the initial teaching planning and/or didactic materials<br>To prepare a questionnaire and a half structured interview to give to the students at the end of the teaching |

| | | | | |
|---|---|---|---|---|
| 6th individual meeting | Feb/Marc 1998 (at the end of the sequence and after the analysis of the written protocols) | Secondary school of each participant teacher | 3/4 hours | After teaching the theme:<br>An analysis and assessment of the course (half structured interviews with each teacher):<br>The importance and interest of the TEP.<br>An analysis of the teaching strategy developed<br>The interest and/or difficulties in the strategy implementation<br>To confront the teacher with students' answers to the questionnaire and interviews.<br>Global conclusion:<br>To confront the teachers' analyses with the researchers' opinions and students' opinions (triangle effect) |
| TOTAL:7 meetings | April 97/ March 98 | | 32 hours | |

**Figure 2:** Teacher Education Program (TEP)

This plan was developed during half an academic year, before the 3rd phase began. In the 3 rd phase, the innovative phase, the specific aim was to reconstruct the teaching practices.

This phase was developed in a research perspective of collaborative action-research, with each participant teachers and the researchers working together systematically, namely: videorecording of all the teaching practices, with systematic feed-back on the evolution of the work, a scientific and epistemological preparation of the theme, a collaborative structuring of laboratory materials, common decisions and finally an assessment of the evolution of the program.

**Results**

The results are reported according to four separate aspects: The first aspect focuses on the epistemological perspectives of the teachers in the first phase, the second concernes the teachers' opinions about the TEP, the third focuses on the new epistemological aspects of the teachers' practices after and during the participation in the TEP and the final aspect highlights the relation between teachers, researchers and students' opinions.

During the first phase, the theme of mass conservation was teached basically following the same main lines by all the (4) teachers, in geographically distant schools and with different academic backgrounds. They used the same central experiment, the confrontation of mass before and after the reaction between lead nitrate and potassium iodide, and after this they induced the mass conservation law. They used this problematic-free chemical reaction between lead nitrate and potassium iodide, without reference to the existence of gaseous substances and the mass conservation in those cases. There was no discussion of and no reference to Lavoisier's time, life or work, no references to the scientific controversy that accompanied the establishment of the theory of oxygen, no references to the political, social or technological context of the building of scientific knowledge... No mention was made of particular scientific facts, terms or experiments... The image of science as a neutral body of knowledge translating a naive image of realism was prevalent. Specific epistemological aspects related to the theme were totally absent. In short, pedagogical and scientific concerns prevailed and an instrumental view of science and of the construction of scientific konwledge was passed to the students.

However, the teaching practices developed by each of the two participant teachers during the 2th and the 3rd phases reflected some suitable changes of epistemological relevance. In fact, more value was given to a more rationalist image of the role of the experiment and also to the critical role of theory and its articulation with observation. Prediction activities were introduced. Also the error was considered to play an important role in students´learning. The HS conducted the strategy and the dependence on scientific knowledge of the whole context and the related STS questions about the theme were highlighted. The naive realistic perspective about the world gave place to a more critical perspective.

The two teachers recognised the changes ocurred in their usual teaching of the topic. They were also aware of the influence of the TEP in changing their science images and their understanding of the teaching and the value of an adequate epistemological perspective of science teaching.

The teachers' confrontation with their initial own teaching is a fundamental step in order to make them aware of the kind of improvements needed. That implies an individual approach to the "intervention phase".

The teachers' opinions may be categorised in three main related aspects: the personal and professional meaning of the involvement in the developed program; the thrust of the program in their classroom practices and the analysis of their own classroom teaching as well as the access to the analysis made by the researchers.

As teacher A said: *"I really want to change... and... I will at least... change the... way... I teach this theme..."*

*"The documents were interesting, it was a very good proposal... but what I considered the best during the training was effectively the dialogue between us... I felt the necessity to say and do more in the classroom... students did ask those predicted questions... I could foresee those questions... and... it was interesting."*

Having access to the analysis made by researchers was considered a very important aspect: *"You referred to many aspects... I felt these things and... in a concrete way! So, I'm going... to make my teaching practice different... based on the analysis made... I'm going... to improve, no doubt about it!"*

Teacher B evaluated her participation in the TEP: *"It was very useful... all teachers should have access to some videorecorded teaching practices and reflect on them... I think they should."* And about changing her epistemological perspective *"...the experimental method... We used to say that sequence of... of phases... and now I have began to wonder also about this sequence, the meaning of what I used to say."*

The study was developed with the assumption that to improve teaching, based on an up-to-date epistemological perspective, the students' understanding about the scientific content and their images of science will increase in the same direction as well as the interest and participation in the classroom activities. The students' opinions suggest two main concerns: their understanding of the curricular theme was good and the interest in the way it was developed in the classroom was greatly appreciated. The first aspect was assessed by each teacher and also in the final interviews conducted by researchers (two different questions related to mass conservation in different situations, open and closed system). As one of teacher A's students said: *"It was a very different way of learning... It was not just arriving in the classroom and simply to speak about the subject was".... "it was not easy for him to arrive at that theory"*. Teacher B's students perceived the difficulty in changing a theory: *"It was difficult... and it took a long time for it to be accepted"*. Concerning the interest of the theme and the way it was done in the classroom this same student said: *"We were interested in what was going on in the classroom... some times this does not happen"*. Another student added: *"We also talked about these aspects outside the school, during breaks or after the chemistry class and... in fact... we talked and... we discussed those problems"*.

This arguments converge with that of the researchers, in a triangular form of internal assessment of the study, towards the acknowledgement of the interest of this new approach to teach mass conservation.

**Conclusions and educational implications for science teacher education**

This approach represents a significant improvement of teacher education research because it involves researchers and collaborative teachers with the same goals involved together with the central objective of effectively changing science teaching practices. Significant efforts have been made to make participant teachers aware of the effective significance of the consideration of the epistemological perspectives in teaching practices with a view to developing students' desired understanding of science and scientific knowledge (images of science).

At present we can delineate a central framework for in-service teacher education: The history and philosophy of science contribute in a sustainable way to teacher education. Effectively, when teachers are involved in an action-research program designed with reference to a suitable selected central theme of the curricular programme their classroom practice improves in a desirable, epistemologically consistent way.

In practical terms, it is necessary to start with the selection of an interesting theme with epistemological relevance and to prepare its teaching with interested and capable teachers. The comparison with more traditional teaching (self-observation) reveals a good teacher education strategy which increases personal and professional fulfilment. The approach outlined here may be developed in other epistemologically interesting curricular areas.

There are some critical aspects, as pointed out earlier, related to difficulty in conducting these lengthy studies. This is probably why the teachers' adherence to these processes of education is still very weak.

## References

Acevedo Díaz, J.A. La tecnologia en las relaciones CTS. Una aproximación al tema. *Enseñanza de las Ciencias*, 14, 1, 35-44, 1996.

Aguirre, J.A. Student-teachers' conceptions of science, teaching and learning: a case study in preservice science education. *International Journal of Science Education*, 12, 4, 381-390, 1990.

Ben-Zvi, R.; Eylon, B. & Silberstein, J. Students' visualisation of a chemical reaction. *Education in Chemistry*, 24, 117-120, 1987.

Bensaude-Vincent, B. & Stengers, I. *História da Química*. Lisboa: Instituto Piaget, 1996.

Brickhouse, N.W. & Bodner, G.M. The beginning science teachers: narratives of convictions and constraints. *Journal of Research in Science Teaching*, 29, 5, 471-485, 1992.

Cleminson, A. Establishing an epistemological base for science teaching in the light of contemporary notions of the nature of science and how children learn science. *Journal of Research in Science Teaching*, 27, 5, 429-445, 1990.

Duschl, R.A. & Guitomer, D.H. Epistemological perspectives on conceptual change: implications for educational practice. *Journal of Research in Science Teaching*, 28, 9, 839-858, 1991.

Elliot, J. *La investigación-ación en educación*. Madrid: Morata, 1994.

Gallagher, J. Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. *Science Education*, 75, 1, 121-133, 1991.

Gil-Pérez, D. New trends in science education. *International Journal of Science Education*, 18, 8, 889-901, 1996.

Hesse, J.J. & Anderson, C.W. Students' conceptions of chemical change. *Journal of Research in Science Teaching*, 29, 3, 277-299, 1992.

Hodson, D. Philosophy of science, science and science education. *Studies in Science Education*, 12, 25-57, 1985.

Hodson, D. Philosophic science of secondary school science teachers, curriculum experiences and children' understanding of science: some preliminary findings. *Interchange*, 24, 1/2, 41-52, 1993.

Hodson, D. Practical work in school science: exploring some directions for change. *International Journal of Science Education*, 18, 7, 755-760, 1996.

Lederman, N.G. Relating teaching behaviour and classroom climate to change in students' conceptions of nature of science. Science Education, 70, 1, 3-19, 1986.

Lederman, N.G. Students' and teachers' conceptions of the nature of science: a review of the research. *Journal of Research in Science Teaching*, 29, 4, 331-359, 1992.

Matthews, M.R. History, philosophy and science teaching. What can be done in an undergraduate course? *Studies in Philosophy and Education*, 10, 1, 93-97, 1990.

Matthews, M.R. Discontent with constructivism. *Studies in Science Education*, 23, 165-172, 1994.

Monk, M. & Osborne, J. Placing the history and philosophy of science on the curriculum: a model for the development of pedagogy. *Science Education*, 81, 4, 405-423, 1997.

Paixão, M.F. *Da construção do conheciemnto didáctico na formação de professores de ciências. Conservação da massa nas reacções químicas: Estudo de índole epistemológica*. Dissertação de Doutoramento, não publicada. Aveiro: Universidade de Aveiro, 1999.

Pomeroy, D. Implications of teachers' beliefs about the nature of science: comparison of the beliefs of scientists, secondary science teachers, and elementary teachers. *Science Education*, 77, 3, 261-278, 1993.

Praia, J. & Cachapuz, A. Un análisis de las concepciones acerca de la naturaleza del conocimiento científico de los profesores portugueses de la enseñanza secundária. *Enseñanza de las Ciencias*, 12, 3, 350-354, 1994.

Praia, J. & Cachapuz, A. Concepções epistemológicas dos professores portugueses sobre o trabalho experimental. *Revista Portuguesa de Educação*, 11, 1, 71-85, 1998.

Schon, D. *Educating the reflective practitioner*. San Francisco: Jossey Bass, 1987.

Yarroch, W.L. *Student understanding of chemical equation balancing*. Journal of Research in Science Teaching. 22, 5, 449-459, 1985.

Yin, R.K. Case study research. Design and methods. Beverly Hills: SAGE Publications, 1987.

Zeichner, K. *A formação reflexiva de professores: Ideias e práticas*. Lisboa: Educa, 1993.

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003

# CAN FEMINIST CRITIQUE OF SCIENCE AND SCIENCE EDUCATION BE OF RELEVANCE FOR GENDER AND SCIENCE PROJECTS IN DEVELOPING COUNTRIES?

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*Representation of the world, like the world itself, is the work of men;they describe it from their point of view, which they confuse with the absolute truth.*
Simone De Beauvoir

**Abstract**

In most parts of the world boys outnumber the girls in science education. Both in the developed and in the developing world girls tend to choose other subjects than science (especially physics) when given a choice. The last 10 years developing and lending institutions have focused an increasing amount of money towards support and lending to girls education. There seems to be a consensus among aid organisations and donors that supporting development of science education for girls will increase and accelerate development. How science education should be carried out in order to reach this end is seldom discussed by the donors and development agencies. Science education in most developing countries is still very influenced by the former colonial power. It is very theoretical and instrumental and of very little relevance to the pupils lives. Thus it can be questioned whether this science education is suited to reach the aims of the donors and moneylenders supporting it.

Extensive theory building has been conducted concerning the effect of science education for girls in developing countries. This paper question whether the feminist critique of science can be relevant to the discussion of how science education should be carried out in order to be attractive to girls.
In this paper I present briefly how some donors and moneylenders in the west legitimise the support to gender and education projects in developing countries through their policy documents. I present different types of feminist critique of science as it has developed over the last 30 to 40 years. I then show the possible impact of the different critique on science education for girls. On this basis I question whether any of this critique can be relevant in terms of improving science education for girls in developing countries and meet the expectations of the donors that is expressed in their policy documents.

## Introduction

The last 10 years developing and lending institutions have focused an increasing amount of money towards support and lending to girls education. The background for this support seems to be a consensus among aid organisations and donors that supporting education for girls will promote a positive development for society as well as for the families. Even though science education is seldom mentioned explicitly in the policy documents of these organisations it is obvious that some of the gains they expect to achieve by this support have to be learned in science class. Donors and development agencies, however, seldom discuss in detail educational issues such as the content of the curriculum and pedagogical presentation needed to achieve these aims.

Science education in most post-colonial developing countries has proven to be theoretical and of very little relevance to the pupils lives. Thus it can be questioned whether this theoretical science education is suitable to equip the pupils with scientific knowledge that can be of use to promote development.

In academic journals and literature, a wide array of different forms of critique against science and technology has emerged over the last decade, as well as about the role and form of education to promote development. The critique of science stresses its cultural as well as its gender bias. The feminist critique of science criticise science for being masculine and dominated by men and men's needs. This masculinity is said to be reflected in science education and can thus be an explanation to the gender differences we se in science education.

The background for this critique is the special status science has acquired as being able to conduct rational and objective knowledge. The notion of science as rational and objective has to a great extent survived in spite of being challenged by historians, philosophers, literary critics and feminists.

The view of science as neutral and objective has to great extent been transmitted to education systems, and has influenced how science has been and is taught in schools in many parts of the world. People working with science in the educational sector often have limited knowledge of the critique of science and therefore take science for granted. As scientific inquiry is seen as a neutral and unproblematic activity, and the science curriculum is often simply a "shrinkage" of scientific knowledge. The role of the scientist in creation of scientific knowledge is seldom questioned, and science appears in educational literature as neutral and unproblematic facts and descriptions of the world.

The notion of scientific knowledge as objective and decontextualised has also justified an uncritical export of scientific curricula from the West, with only a limited degree of local adaptation, to colonised countries that lack the same scientific traditions. Several critics of education and it's role in developing aid have claimed the export of European education systems to developing countries are conscious policies put in place to keep people in developing countries down.

By exporting education systems, expertise, books etc the "aid " has been criticised for contributing to a continued dependency on the West when it comes to education and intellectual development. Several academics have shown that most Sub-Saharan African countries have their education policies determined by bilateral and multilateral donors and moneylenders. From a democratic and critical perspective it seems hard to justify why the donors should have such major influence on education in developing countries. I will however not address these issues in this paper.

**Why do developed countries support education for girls in developing countries?**

In the following I will give a brief summary of how some organisations that support girls' education in developing countries legitimise this support through their policy documents. Working with this paper my focus has been to look for policies dealing with girls and science education. As very few organisations have such explicit policies the focus has somewhat been moved towards a general search for arguments stating the importance of education for girls and trying to trace any possible implications for science education.

The World Bank is today the largest single source of external finance for education in developing countries accounting for about a quarter of all external support (World Bank 1995). The World Bank supported its first education project in 1963. In the mid 90's it started focusing explicitly on education of girls. The argumentation for giving priorities to girls' education has ever since the World Bank started supporting education of girls been to reduce poverty by lowering fertility rates, improving child health and raising women's income from the labour marked. Education is seen as an investment in human capital that lifts individuals out of poverty by increasing their returns to the labour marked (World Bank 1995). The World Bank's chief economist, Lawrence Summers in 1993 argued for the support of education for girls in the following way:

> *An educated mother faces higher opportunity cost of time spent caring for the children. She has greater value outside the house and thus has entirely different set of choices she would have without education. She is married at later age and is better able to influence family decisions. She has fewer healthier children and can insist on the development of all of them, ensuring her daughters are given a fair chance. And the education of her daughters makes it much more likely that the next generation of girls as well as boys, will be healthy and educated as well. The vicious cycle is thus transformed in to a virtuous circle. (Quoted in Heward 1999).*

The World Bank does not have any policies stating explicitly the importance of educating girls in science. One would nevertheless expect these policies to have great implications for science education. Learning how to improve child health, use contraceptives right, keep healthy and reduce infant mortality rates should according to these policies be expected to have a central part of science education.

UNESCO has, in contrast to the World Bank's focus on education for girls as a sound economic investment, been committed to education as a human right hitherto denied to girls and women. In UNESCO's medium term strategy for 2002 to 2007, promoting education as a fundamental right in accordance with the "Universal Declaration of Human Rights" is "Strategic objective 1".

> *Advancing the right to education as enshrined in the Universal Declaration of Human Rights is central to UNESCO's mission. Free, compulsory and universal primary education for all is among the most clearly defined of these rights; with governments have a duty and a responsibility to make a reality (UNESCO 2001, p 16).*

UNESCO is also, in contrast to the World Bank, explicit in their policies regarding science education as an important tool for reaching their developmental goals. In 1996 UNESCO published the "World Science Report" where one chapter was devoted to girls and science education. In connection to the World Conference on Women in Beijing in 1995, UNESCO published a book called "The scientific education of girls. Education beyond reproach?" presenting different sides to the importance of educating girls in science. Also in the organisation's newly published strategy document (UNESCO 2001) science education as a tool for achieving development is highlighted. The need to strengthen international scientific and intellectual cooperation, the fight against the spreading of HIV and AIDS and the need to bridge the digital divide between developing and developed countries are goals legitimising the importance of educating girls in science (UNESCO 2001). But most important in all the UNESCO policies seems to be the view of education as a human right and the fight towards equity.

The Norwegian Agency for Development Cooperation (NORAD) does not have any direct policies concerning girls and science education (NORAD 1995). What they do have are policies concerning girls and the importance of gender equity when it comes to education.

> *It is fair to say that there has been an emphasis on reaching women and girls as a target group through Norwegian bilateral assistance to the education sector (NORAD 1995).*

The policy document further states that:

> *Assistance to promote the education of girls and women is a priority area for NORAD. In particular measures that stimulate girls' retainment in school and their completion of primary education, along with literacy programmes, adult vocational training of women will be supported (NORAD 1995).*
>
> *NORAD legitimises the support to education by stating some general benefits of education. Education, according to NORAD, improves the lives of people, provides a foundation for continued learning, strengthens the child's cultural identity and is a cornerstone for democratic development. Education also benefits nations, is a foundation for higher research (primary and secondary), is a prerequisite for technological development, economic growth and lower reproduction rates (NORAD 1995).*

Feminist critics of science have accused science for being masculine and androcentric [1]and therefore less interesting and relevant for girls. Masculine bias might seem as a minor limiting factor preventing girls from choosing science in Africa as the girls are faced with such a huge number of other obstacles. Nevertheless it might not do any harm to take a closer look at the feminist critique of science and science education to se whether it might can offer some ideas about why girls all over the world seems to be outnumbered by the boys in science education. I will now briefly present the feminist critique of science as it has developed throughout the

[1] Androcentricm: Preoccupation with men and the activities of men to the exclusion of women in human affairs (Webster's comprehensive dictionary if the English language, 1998)

last 30 to 40 years. I will thereafter reflect on the possible impact of the different "waves" of feminism on the thinking about science education for girls.

**First wave feminism: feminist empiricism**

The first feminist criticism of science was influenced by the women's and civil rights movements in the 1960s and 1970s (Barton 1998).

This type of feminist critique of science has later been labelled liberal critique of science, as it does not criticise science in it self for being masculine but the research and employment praxis within the sciences.

The main concern of the feminist empiricists was to achieve equality and equal opportunities for the sexes and create a research practice that dealt equally with women's problems. The feminist empiricists did not believe that scientific inquiry per se would be changed by recruiting more women, but that the focus of scientific research would change when an equal number of men and women engaged in research. In other words, feminist empiricists believed that including more women in science would change what is being researched at, while the nature of scientific inquiry would remain the same (Longino 1990 p. 9).

Sandra Harding (1991) writes in the book "Whose science? Whose knowledge?" that this type of critique was mainly a critique of what she calls "bad science". She argued that men focus their research on issues that they care about, and therefore it is interesting and relevant only for half of the world's population and, therefore should be considered "bad science". The feminist empiricists also reacted upon the fact that results of research conducted on men, particularly on medical issues, were generalised to apply also to women.

**Second wave feminism: standpoint theory**

The next phase of feminist critique of science was in the 1980s and 90s. This critique of science argued that science is not neutral but constructed and therefore influenced by the scientists and the surroundings they live in.

This critique went further than the feminist empiricist since it criticised the epistemological and methodological foundations of science (Longino 1990). These feminist critics argued that scientific inquiry was still influenced by the positivist tradition that was the ideal in the 17th century when modern science was developed. They argued that the assumptions had persisted of the essential nature of science, namely that scientific facts are grounded in theory largely free of personal, social and cultural values.

Evelyn Fox Keller argued that the values, goals and assumptions of the researchers influence the outcomes of the research. Since most or all scientists were male, values held by most males were not distinguishable as biasing: They became synonymous with the "objective" view of the world.

Sandra Harding developed through her 'standpoint theory', a way for researchers to become conscious of their role as researcher. She used Marxist theories to explain the effect of oppression on women. She argued that society put constraints on the production of knowledge. The knowledge and culture of a class society therefore reflects the interests of its ruling class. In the twentieth century scientific knowledge particularly in western countries would be determined by capitalism and reflect the interest of the dominating class. A more objective and transformative knowledge can only be found through the perspective of an oppressed class (Longino 1990, p 12).

Because women are oppressed she claimed that they are epistemological privileged compared to men since they are forced to see the world from two perspectives. They must see the world from the male perspective in order to survive in a masculine world but they will also see the world from their feminine perspective because they are women. This double vision allows them to see more than men. In their capacity of being oppressed, women therefore are epistemologically privileged compared to men who are in a position of being oppressors. Because of this women will conduct better scientific research[2].

[2] For a more detailed description of Harding's justification of standpoint theory compared to feminist empiricism, see the article "Rethinking Standpoint epistemology: What is "Strong Objectivity" (In Harding 1993).

*"The oppressed are indeed damaged by their social experience, but what is a disadvantage in terms of their oppression can become an advantage in terms of science" (Harding 1990)*

**Third wave feminism: theory of situated knowledge**

Both feminist empiricists and standpoint feminists highlight the differences between genders. Girls and boys, men and women are considered to be different from each other and will therefore contribute to science in different ways. The post-modern critique of science criticises this feminist critique of science for treating all women alike.

The post-modern feminists argued that the differences within a group of people of the same sex can be just as big as the sex differences.

One feminist philosopher of science typically representative of the post-modern feminist critique of science is Dona Haraway. She criticises the standpoint theory, arguing that no position is more privileged than others. Haraway argued against the view that oppressed people conduct better scientific knowledge. Describing the world is, according to Haraway, always a matter of interpretation (Haraway 1991, p 195). Neither men nor women are in the position of describing the world on any other behalf than their own. Haraway argues that researchers claiming to be able to conduct universal and objective knowledge conduct what she labels the "God-trick", the view from nowhere. By this she means that they try to exclude their own position, and thereby biased basis for research, to be able to conduct neutral observations.

Haraway's alternative to Harding's "standpoint theory" is the theory of "situated knowledge". According to the theory of situated knowledge, no positions is more privileged than others when it comes to viewing the world. Nobody, no matter whether being oppressed or oppressor, man or woman, can see the world more clearly than others. We can only see the world from our personal perspective. In that way all knowledge is situated. (Haraway 1991, p 188).

According to post-modern theories and Haraway, the standpoint of the researcher as a subject and all other subjects differ from each other. The knowledge that can be achieved about the world is therefore of an individual character and implies no universal truths.

**Impact of feminist empiricism on science education**

According to the liberal feminist critique there is nothing wrong with science. Men and women can both conduct objective scientific knowledge. But more women are needed in science to determine what is being researched at.

The feminist empiricists were therefore concerned with recruiting more female scientists to secure equality in research topics. Their main issue when it came to education was therefore to recruit more girls into science. Since this "wave" of feminism did not regard science in itself to be masculine and androcentric, the focus at this time was not to question the neutrality and objectivity of science, but to find ways to make it more attractive to female students. The feminist empiricists did thereby not want to change science as a discipline but change the way science was being presented to make it more interesting for girls (Barton 1998).

To recruit more women into the sciences, feminist empiricists regarded it as necessary that all obstacles be removed that prevent girls from choosing science in school (Barton 1998 p 3). A good way of doing this is to demystify and demasculinize the image of science by exposing girls to role models and career information, to sensitise teachers on the importance of including girls, gender analyses of textbooks and so on.

Implications for science education:

- Remove obstacles preventing girls from choosing science.
- No problem to continue teaching scientific facts as long as this is done in a way that is equally interesting to boys as to girls.

**The impact of standpoint theory on science education**

According to standpoint theory / second wave feminism women / girls see the world more clearly then men because they have to see it both from men and women's perspective. This enables them to conduct better science than men.

The main difference between the feminist theoreticians that applied to a standpoint theory and the philosophers of science that had argued against the neutrality of science earlier, was that the feminists highlighted the impact of the researchers *gender* on the outcome of the research. The standpoint theoreticians' critique of science brings new perspectives to the thinking in science education because it argues against the positivist myth that there is an objective, solitary way of doing science that results in independent, unbiased knowledge (Barton 1998, p 10). Standpoint feminists concerned about the androcentric bias in science and technology agreed with the feminist empiricists about the importance of recruiting more girls to science. They did not, however, regard this a sufficient change in the presentation of science in school. Science itself needed to be questioned. Since science, according to the standpoint feminists, is influenced by the scientists creating it, science itself needs to be reconstructed in order to be accessible to girls.

Standpoint feminists explored new approaches to science education that reflected the social, historical and political context in which science had been constructed (Barton 1998). Science education influenced by a standpoint feminist critique of science should aim to put science in a social context to show pupils that science is shaped by the standpoint of the scientists, their background, and their gender. Since standpoint theoreticians believed that women were epistemologically privileged compared to men a science created by women would be of higher quality than a science created by men It would therefore be crucial to include in the science curriculum information about science that had been developed by female scientists.

The implications of this critique to science education would therefore be:

- Show examples of what Hading call "bad science" in science class.
- Focus on showing science that is conducted by women and minorities.
- Encourage girls in particular to be scientists.

**Impact of situated knowledge and post modern critique on science education**

The post-modern critique of science claim that the background of the scientist influences both what one chooses to study and how this is studied.

The view that science is created within a context that is highly influenced by the experiences of the people creating it is in sharp contrast with the picture of science presented in most science textbooks. The post-modern critique of science as Haraway presents it would thus have dramatic consequences for science education if taken literally. A relativist view like this would break totally with the ideals for science and scientific inquiry. This ultimately could lead to a science education where western science were explained to be no more scientific than all kinds if indigenous knowledge and astrology because all knowledge is seen to be personal.

It is difficult to se how an extreme relativist position like this could benefit science education and make it more relevant for girls. Still I believe that this position can offer interesting perspectives to science education.

I think it is possible to interpret the post-modern feminist critique of science in two different ways. The impact on science education of these two interpretations can be explained in terms of different types of constructivism. Constructivism is the epistemology that has been dominating the science education discourse the last 20 years (Sjøberg 1998, p 295). Very simplified the view of learning within this epistemology is that all knowledge has to be constructed by the learner. There are within constructivism extreme positions. Radical constructivism claims that not only our knowledge about the world is constructed but that the world itself is socially constructed. Our knowledge about the world is therefore strictly personal as no objective knowledge is possible. This view of learning would perhaps be the dominating epistemology if the post-modern feminist critique of science should be taken literally.

A less radical view of how knowledge is constructed is labelled "personal constructivism". According to this view of learning all knowledge needs to be constructed by the person who are learning. This view of learning, in contrast to radical constructivism, opens for shared knowledge about the world. This view of learning is influenced by the theories of Piaget who also claimed that the learner could only construct new knowledge by building the new knowledge on already existing knowledge structures. It is thus crucial for the teacher to understand what the student already know, and be aware of that all pupils have different knowledge. The way I see it the impact of post-modern feminist critique on science education can also be interpreted in terms of a personal constructivist view of learning. By highlighting the difference between all people, not only between girls and boys, the signal to teachers would be to not assume that all boys and girls think in the same way just because they have the same sex. Haraway highlights the importance of being explicit in what shapes your observations and reflect upon your own situatedness when knowledge is constructed. The way I read her she does not reject the existence of an outside world.

Barton (1998) argues that acknowledging the influencing factors of the science being created would make it easier for pupils to construct science from their own questions and experiences, even when those experiences challenge social norms. According to Barton a science education building on the post-modern feminist critique of science would be an activist science education that highlights the background of the pupils and aims to teach science relevant to the (female) pupils. A prerequisite for this would of course be that scientific knowledge would not be regarded as personal although it has been personally constructed.

A radical interpretation of post-modern feminist critique of science is that all knowledge is personally constructed and therefore personal. Thus all knowledge is equally scientific ore rather: equally non-scientific. The implications of this for science education could be to:

- Teach all kinds of knowledge systems equally in science class.
- Include in science indigenous knowledge and present it as equally right as western science.

A liberal interpretation of post-modern feminist critique of science is that all knowledge about the world needs to be constructed personally. It is though possible to construct knowledge about the outside world. Implications of this critique on science education could be to:

- Be aware of the pupils' prior knowledge and arrange for the pupils to construct new knowledge on the basis of what they know from before.
- Do not take for granted common experiences or knowledge although the pupils have same sex.
- Make science relevant for girls by building on their own personal problems. Show the influence of the researcher on the research and use this to visualise the possibility of the pupils to use their science knowledge to explore what they find important.

## Conclusion

I believe that feminist critique of science can be of relevance for gender and science education projects in developing countries as well as for everybody else working with girls and science. The implications to science education of much of this critique is the way I see it the awareness of how both science research and learning is influenced by the background of the person who conduct scientific research or construct knowledge about the natural world. I think that the feminist critique is well suited to visualise the close connection between how we see science and how we construct our images of science education. I believe that awareness of this connection can be of help in planning interventions in science education in Africa. If one for instance apply to the liberal post-modern critique of science this would have other implications to science education for girls than if one applied to the feminist empiricists critique.

I also believe that the feminist critique can be relevant for gender and education projects in terms of visualising the importance of teaching girls science to donors and money lenders. This could hopefully have positive implications for the economic support to such projects.

According to this critique it should be crucial for donors and money lenders to be aware of the effect different types of science education might have on girls. Achieving the aims of the donors and other stakeholders does not require only money but also detailed discussions of educational issues such as the content of the curriculum and the pedagogical presentation.

**References**

BARTON, A.C (1998). *Feminist Science Education,* Teachers College Press, New York.

HARAWAY, D. (1991). *Simians, Cyborgs and Women*, London.

HARDING, S. (1990): Feminism, Science and the Anti-Enlightenment Critiques, in Nicholson. L (red). *Feminism / Postmodernism,* Routledge, New York and London.

HARDING, S. (1991). *Whose Science? Whose Knowledge?,* Open University Press, Buckingham.

HARDING, S. (1993). Feminism, Science and the Anti-Enlightenment Critiques, in Nicholson. L (red): *Feminism / Postmodernism,* Routledge, New York and London.

HEWARD, C and BUNWAREE, S (1999). *Gender Education and Development. Beyond Access to Empowerment*, Zed Books, London.

LONGINO, H. (1990). *Science as social knowledge,* Princeton University Press, New Jersey.

NORAD (1995). *Basic Principles. Norads support to the education sector with focus on primary, secondary and Basic Adult Education*, Norad, Norway

SJØBERG, S. (1998). *Naturfag som allmenndannelse. En kritisk Fagdidaktikk*, Ad Notam, Gyldendal.

UNESCO (2001). Medium-Term Strategy 2002-2007, UNESCO, France

World Bank (1995). *Priorities and Strategies for Education.* A World Bank Review, The World Bank, Washington DC.

**Key words:** science education, development, girls, feminist critique.

004

# A WORLD OF DIFFERENT COLORS": TRYING TO TEACH SOLIDARITY AND GLOBAL CONSCIOUSNESS IN SIXTH GRADE

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*(Data collected during a stay at Universidad de Barcelona, Spain)*

## Abstract

This is a case study of a teacher enacting project-based learning with his sixth grade students. The teacher Jaume Baras (not his real name) states that he uses projects as a way to break the barriers among subject-areas, give students a leading role, and develop creativity, initiative, collaborative work, solidarity and knowledge tied to action. During the project studied, I observed almost all the classes, interviewed the teacher at the beginning and end, interviewed six children at the end, collected didactic material and copies of children's work. Also, the teacher agreed to keep a diary, using a form I gave him.

Mr. Baras wanted children to get ampler perspectives and invited them to study health in six regions of the world. The project lasted five months, meeting once a week, plus some extra classes towards the end. There were three phases during the work. In the first phase each team chose a region and did library research about it, using a comprehensive concept of health they had constructed in class. The teams presented their results to their classmates, utilizing strategies like posters, dramatizations, a "TV news report", etcetera. In the second phase, Mr. Baras asked them to go beyond data and try to present a message. In the third phase Mr. Baras found a collection of books about "children of the world": in each book a child presented his or her own country. He decided to center each team work in a single country instead of in a whole region. Each team chose a country among the ones in the collection. In this phase, work went more smoothly because the books were easy to read and the information was more focalized. The class presented their project (named by them "A world of different colors") in an inter-schools event. Besides, the children talked about it in a regional radio station.

Baras thinks the project helped children "to get a new vision of the world". And that the students also advanced in group work and independent search for information. To my question "What have you learned in this project?", children interviewed said: "Things about other countries we didn't know, we thought everybody lived like us", "Not all people live equally well... You have to respect others, no matter how different they are from you". Other learnings: to read and write better, to have a deeper concept of health. From my perspective, it would have been better if the project had focus in specific countries from the beginning. Also, it could have been enriched with more empirical research. The general idea was powerful and formative.

## Introduction

Globalization: a complex term which encompasses promises and threats and which receives very different interpretations, according to different interests and perspectives. Is it unavoidable a globalization marked by the dominance of a powerful few? Will "First World" poles of well-being turn into (or are they already) fortresses besieged by millions of disenfranchised who strive for a better life? Will the terrible shadow of terrorism cover the 21th. century? Or will it perhaps be possible, thanks to the efforts and struggles of diverse peoples and social groups throughout the world, to use present technologies and capabilities (and to develop new ones) in the attainment of a more inter-related, more prosperous planet, with opportunities for all?

These questions challenge educators: the school cannot stay away from so severe and pressing problems. In this paper, I present a teacher's attempts to face some aspects of this challenge through a classroom project, where his students investigated health conditions around the world.

**Aims and Methodology: An educative case-study**

This research can be considered an *educative case-study* (Stenhouse, 1991) since its general purpose is to contribute to the improvement of educational practice and in this way of the condition of children and the professionalism of teachers. This kind of work aims at the development of educative theory and/or the refinement of prudence, through systematic and reflective documentation of experience. In this investigation, I focused on project-based learning (Manning, Manning & Long, 1994; Marx et al., 1997) and on the issue of "global consciousness".

I observed the classroom project from beginning to end, and kept field notes. I also video-recorded three classroom periods and audio-recorded one, collected samples of pupils' work and all the didactic material given by the teacher, took photographs and sketched a plan of the classroom. Besides, I interviewed the teacher both at the beginning and at the end of the project, and interviewed three pairs of students at the end. The teacher kindly kept a weekly diary, using a form I supplied. Months later, he also read and made critical comments about the first draft of the research report.

In the interpretation of data, my intention has been to consider the most interesting facets of the case without losing its unicity. There are three kinds of text in the report: *particular descriptions, general descriptions,* and *assertions* or *orientative commentaries* (Erickson, 1998). The descriptions have taken a *narrative character*, with the advantages of straightforwardness and subtlety (Stenhouse, 1991). Straightforwardness because of the readers' familiarity with narrative conventions, and also because the narrative forms forbid the author to impose her or his own logic against the resistance of the story. Subtlety because of the capacity of narrative to communicate ambiguity, selecting information that invites the reader to speculate with alternative interpretations.

The strategies followed in order to increase the trustworthiness of the research (Guba, 1981) included: lengthy work in the same place and persistent observation, triangulation, collection and use of referential material, participants' verification and structural corroboration.

**Background information on the case**

The school where the observations took place is a private, non-confessional institution, with a partial subsidy from the regional government of Catalonia (Spain). It is located in a small town very near Barcelona.

At the time of the observations (1998-1999), the teacher, Mr. Jaume Baras, had seven years of experience in formal education plus another five years in non-formal education. He had a three-year university degree in Magisterio (Teaching), and was studying for a five-year degree in Psychopedagogy. Mr. Baras had seven pedagogical publications, as author or co-author.

The class was a sixth grade, integrated by 26 students, 12 girls and 14 boys, all 11 or 12-years old. Most of these students were middle-class, third generation of castilian-speaking emigrants to Catalonia from other regions of Spain. In very few cases the parents had higher-level education.

The project lasted five months, with 90 minutes class periods once a week. The classes were in catalan, with occasional use of castilian by some of the children. The names of teacher and pupils have been changed to guarantee confidentiality.

**Origen and great objectives of the project observed**

In this classroom, they develop a long project from October to March, which they then present at an Inter-Schools event in town. The theme of the project has to be in the area of Health and Environment, because that is the focus of the event. Besides, there are shorter, more limited, projects throughout the year. In parallel, Mr. Baras follows the textbook in a more traditional way, since this is a requirement in the school.

Projects are proposed by Mr. Baras, from what he thinks can generate a sustained and relevant work. However, the teacher considers it necessary to "transfer" the control of the project to the students during the first sessions.

This year, teacher Jaume wanted to approach health making comparisons among regions of the world. Jaume thought that studying the world the children could become familiar with other cultures, and in this way they could not only have a broader knowledge of health matters but, in the future, when they heard about Morocco or Subsaharian Africa they could say: "Yes, I remember a recipe from Morocco" or they could relate an african country with a music or a landscape, instead of the sterotype that they are the ones who come to take our jobs from us, or other negative images.

Another great objective of project work, according to Mr. Baras, is that pupils learn to reflect and to take a stand about what could be done in real life problematic situations (the "what would you do", he says).

In general, through projects Mr. Baras wants to develop creativity, initiative, collaborative work, solidarity and knowledge tied to action. He considers it important that children, faced with a relevant issue, be able to look for information in different sources, analyze it and write a report. Metacognition is also a relevant aim for Mr. Baras. Besides, through projects he wants to break the barriers among the different school disciplines. And another important aspect, according to the teacher, is that with projects school work gains significance for the students, since they are protagonists and the contents are more related to real life issues.

**Phases in the development of the project**

This project was long and convoluted, developing through three distinct phases. After an initial theme proposal by the teacher and planning done in students' teams, the First Phase of the work started, centered on library research by each team about health conditions in a particular region of the world (Europe, South America, North America...). The results of this work were presented and appraised in general classroom meetings.

**Table No. 1.** A sequence of the work done during the project

| |
|---|
| Readings and discussions on key concepts |
| ↓ |
| The teacher proposes the theme of the project |
| ↓ |
| Planning |
| ↓ |
| First Phase of Project Development |
| (each team works on "Health and Environment" at a particular continent) |
| Library research |
| Visit of expert |
| ↓ |
| Presentation of team work to the rest of the class |
| ↓ |
| Appraisal |
| ↓ |
| New Project Phase |
| (aborted) |
| ↓ |
| Message |
| (Second Phase of Project Development) |
| (Definition of the message they want to communicate) |
| Readings |
| Songs |
| Team work |
| General discussions |
| Common proposal |
| Each team a country |
| (Third Phase of Project Development) |

Team work
Library research
Reports
General discussions
↓
Communication
Radio program
Rehearsals
Event
Appraisal
↓
Final evaluation
Observation of video, comments
General discussion: "What have we learned"

Then, it was decided to reorganize teams and topics, which implied a new phase of reelaboration and completing of information collected. But this phase never took place. Instead, the teacher proposed a change: a Second Phase focused on the definition of a "message" from all the information compiled, and on the designing of the ways to communicate this message to the public.

The project continued through a Third Phase, where each team, practically rejecting what was done during the First Phase, undertook the study of a particular country, thanks to a new collection of children's books.

All the effort ended with the participation in a radio program and the presentation in the Inter-School Event. Finally, there was an assessment of the work done and a closing session of evaluation based on the observation and critical commentary of a video about recent immigration to Spain.

The limits of this paper allow only a very summarized report of the whole process.

**The beginning: theme proposal and planning**
Mr. Baras began the work on the project distributing a hand-out, written by him, with faked interviews where four invented children (two boys and two girls) gave their own definitions of "health" and "environment". Definitions ran from the simpler, more limited and individualistic to the more complex, elaborated and of solidarity character. The pupils studied the hand-out and made two tables at the blackboard classifying the definitions offered.

In following periods, they discussed about the factors that influence health and their variations throughout the world. The teacher raised the possibility of the project and the pupils accepted it and organized in teams, each team choosing a different continent for their study.

The teams planned their work, according to three questions posed by Mr. Baras: what are we going to do, how are we going to do it and who will do what. Each team explained to the rest of the class how they were organizing their work.

**Table No. 2.** Distribution of classroom periods during the project

<table>
<tr><th colspan="2">Kind of activity</th><th colspan="2">Number of periods</th></tr>
<tr><td colspan="2">Beginning: theme proposal and planning</td><td colspan="2">4</td></tr>
<tr><td rowspan="2">First Phase of Development</td><td>Library research<br>Visit of expert</td><td>6</td><td rowspan="2">7</td></tr>
<tr><td>Team's presentations<br>to the class</td><td>1</td></tr>
<tr><td colspan="2">Midway reorientation</td><td colspan="2">2</td></tr>
<tr><td colspan="2">Second Phase of Development:<br>The message and its communication</td><td colspan="2">3</td></tr>
<tr><td rowspan="3">Third Phase of Development:<br>Each team a country</td><td>Focalized search</td><td>3</td><td rowspan="3">5</td></tr>
<tr><td>Radio program</td><td>1</td></tr>
<tr><td>Rehearsal</td><td>1</td></tr>
<tr><td rowspan="3">Culmination</td><td>Event</td><td>1</td><td rowspan="3">3</td></tr>
<tr><td>Appraisal</td><td>1</td></tr>
<tr><td>Evaluation</td><td>1</td></tr>
<tr><td colspan="2">Activities outside project</td><td colspan="2">1</td></tr>
<tr><td colspan="2">TOTAL</td><td colspan="2">25</td></tr>
</table>

**First Phase of Development: Information search and classroom presentation**

Children were familiar with the dynamic of projects, as understood by their teacher, so they set to work without hesitation, and during five periods, they brought to class, read and copied information from different sources: books, brochures, maps, CD-Roms, Internet...

The South America team interviewed me, I suspect at their teacher's request. And, following a suggestion by Mr. Baras, a student, Tatiana, explained to the class her experience as "godmother" to a peruvian girl, giving money through a NGO.

In spite of the achievements, work during this phase was difficult, because of the magnitude of the teacher's proposal and the scarcity of suitable sources of information: those available were interesting and attractive but, often, of very high reading level. Well advanced this phase, Mr. Baras suggested to focus the search on the Catalonian Encyclopedia, which simplify things.

An enriching experience was the visit of a member of a NGO, invited by teacher Jaume. Her organization, of catalan origin, works in Nepal, building schools for poor children. Jaume's students, in teams, prepared questions for their guest. The visitor gave us a short talk about Nepal and showed us a video of the work of her organization there. Several times she told us that those children "do not have anything". At the same time, she informed us that in Nepal there are also very rich people, whose children go in Mercedes Benz cars to luxurious schools, which may even have tennis courts. This information shocked the students, who asked among themselves why was it then necesssary to give help from Spain, and how come these rich people didn't help their own poor fellow countrymen.

At the end of this phase, each team prepared and then made a presentation to the rest of the class about their library research. The presentations took from five to twenty minutes, with an average of fifteen minutes. After each one, there were questions and an assessment, for another twelve to fifteen minutes.

Several teams made posters with maps, graphics and texts, but these were usually very small to be seen from the desks in the presentation. The North America team just read the information they had compiled, issue by issue: drugs, economy, health, diet... The rest of the groups tried to make more attractive presentations. For example, the Asia team invented a "TV news program", reading "news" (really general information took from books), interviewing "a lady who had been in Asia", giving a weather report on the continent, and even adding an advertisement break, during which they asked the audience to be "godparents" to Third World children.

> *Interview to Montse, "who has been in Asia". (...)*
> *-How are living conditions in Asia?*
> *-The rich very rich and the poor very poor.*
> *-What do they eat in Asia?*
> *-Mostly rice, lentils and legumes.*
> *-How are the health conditions of the people?*
> *-It depends if you are rich or poor.*
> (From the field notes of the observer).

The effort made was commendable, but there was need of a more careful development of good ideas, more rehearsal and a better command of information on the part of each student.

**Midway reorientation**

Mr. Baras organized an extra session to make an assessment of the work done until that point and to plan next phases. I was surprised when he proposed two alternatives: to continue as before, improving each team's work, or else to make a change of approach, establishing new teams, and working not by regions of the world but by issues (diet, medical attention...). A pupil proposed a third alternative, actually a combination of the two previous ones: to continue like before, but to organize also occasional meetings by issue with representatives of each team.

Children voted for the second option, which they would take on in January, after the Christmas holiday.

But at the end of the vacations, Mr. Baras told me he had been thinking: they needed a change of direction in the project, they could not go on as they had decided, because it was more of the same. Mr. Baras said that they had overlooked creativity. And added that he intended to discuss this problem with the students.

He actually did in their first January class: the project has gone into too much information, he said. And remarked that there were two paths: either to explain information directly, or to start from an idea, a message that you want to convey, and use the information accordingly. He added that music could help focus the idea, and invited the children to listen to two songs he had brought. Both songs stressed the need for peace, tolerance and brotherhood in the world.

After listening to the songs, Mr. Baras asked the students to think about two questions:

> - Do you think that these two songs have something to do with our project? Explain what and why.
> - Can you imagine some way of including these songs into our project?

After a while, the teacher wrote the students' answers in the blackboard, a column for each question:

| | |
|---|---|
| War | Accompaniment |
| World situation | Background music |

| | |
|---|---|
| Peace, friendship | To compare |
| Wealth, poverty | TV news, pauses |
| Equity | |
| Freedom | |
| Rights of children | |
| Racism | |

Mr. Baras added: "Can we take all these ideas we have mentioned and get a message out of them?".

At the beginning children were silent, but soon they began to participate: Why can't they all be equal, rich and poor?; in this way we have realized how the world is, there are more poor people everyday; we realized there are differences among countries...

A girl, naively, broke the line and said: "Racism is not bad. I am a racist, but if someone introduces a black child to me, I shake hands with him".

"Then you are not a racist", replied Mr. Baras.

And the girl: "Yes, I am, because I don't want him in my country".

Other children started to discuss if their classmate was a racist or not, and about it is not your fault if you have to leave your country because there is a war... But the teacher postponed to "another day" this discussion and asked: "Do you agree that we have a message?".

"Yes!", said the children almost in unison.

Mr. Baras insisted: "What should we do: keep on explaining or look for the message?".

At first, some pupils answered "keep on explaining", but after a while, almost all participants favored the message.

Mr. Baras proposed to specify resources and ideas at the next session.

Second Phase of Project Development: a message and a proposal

But message specification was not inmediate. Mr. Baras thought it useful first to read and discuss two texts, in subsequent sessions: the Universal Declaration of Human Rights and a news clipping on the experience of a group of young people from their town in an encounter of "Meninos da Rua" (street children) in Brasil. The teacher even suggested students to ask this group of young people to come to the classroom, which the students did, but the youth group had problems of schedule.

During the next days children, in teams, wrote their proposals for "a message", and presented them to the rest of the class. Teacher Jaume wrote the main ideas at the blackboard:

*Environment*
*Human rights: school, health, life, work...*
*No prostitution, no drugs*
*All have rights*

---

*Inequalities*
*The world is not perfect*

---

*Songs can help us in our learning*

*We are privileged*

*Equity*

*Health*
*AIDS*

*Racism*
*Drugs*
*Health, Equity* *Implications*
*Work*
*Future*
*Diet*

Mr. Baras asked the children what could they do to sell their ideas. The students made suggestions: to explain them at the event, to join forces, to make posters... A child suggested to go to the municipal magazine and put an add. Mr. Baras corrected: "Make an statement". "And we will all appear on the magazine!", said the child, generating enthusiasm in the class. Others proposed to go to the regional television station, but the teacher explained that the TV people receive a lot of requests and would not listen to them, then the children opted for the radio. Besides, Mr. Baras suggested and was accepted to visit the town major.

**Third Phase of Project Development: each team, a country**
In a new turn of the work, Mr. Baras showed up in class with a pile of books. He said they could be useful for the project. Each title dealt with a particular country, presented by a boy or a girl from that place: "*Minu. I am from India*", "*Dana. I am fron USA*", "*Fátima. I am from El Salvador*". The books were written for children, their language was simple and enjoyable, and they had good illustrations.

As there were six titles, and each country belonged to a different continent, the teacher proposed that each team worked with one of these countries for the presentation at the event. At first, no one wanted to be representative of small and poor countries like Gambia or El Salvador or of the by then troubled Serbia, but little by little the children formed the new teams.

Work continued in following sessions: children read their new books with interest and extracted the information they deemed relevant. They also added notions from encyclopedias and encyclopedic dictionaries. The title of the presentation was decided by the whole class, selecting it among more that twenty proposals: "A world of different colors".

Thanks to Mr. Baras efforts, they presented their project in a children's program of a regional radio station. Their participation there was simply a shorter version of what they were going to say at the inter-schools event. Probably, it would have been more appropriate a conversation about the project, how they had worked on it and what they had accomplished, but that was the way the teacher planned it, perhaps because the aim was to transmit their message.

A day before the event they did a general rehearsal and appraissed it.

**Culmination: Final Presentation, Appraisal and Evaluation**
After five months of work, the children and Mr. Baras (all quite nervous) went to the Inter-Schools Event. When the curtains of the auditorium opened, two presenters could be seen: a girl and a boy of the group, elegantly dressed. They announced the "physicians" who, with their spotless white coats, read the broad concept of health they had constructed in class. Then, appeared in order the representatives of the different countries, all more or less accurately disguised.

Children read their speeches, some did it better than others but, as the texts were short and highlighted important issues, it was not tedious to listen to them.

*Since the seventies, this region* (Gambia) *suffers the consequences of the advance of the desert, like many other regions of the Sahel. The progressive rain decrease has had very negative effects, mainly in agriculture, cattle raising, and in the availability of drinking water.*

*In this same decade and in conjunction with the ecological and economic deterioration, the young people from Gambia started emigrating towards Europe.*

To write these texts, children relied too much on the books read during the Third Phase. However, the writing did involve an effort: the books were much longer, students had to select and summarize.

At the end of their presentation, the representatives of the six countries, the presenters and the physicians gathered on stage holding hands, and sang one of the songs their teacher had brought to the class months before: "El món seria" ("The world would be"), accompanied on the piano by the cousin of one of the students. It was a little touching to see and hear them: "El món seria mes huma / si tots fossim germans..." ("The world would be more human / if we all were brothers and sisters..."). In total, twenty minutes. The audience applauded them. To finnish, they distributed a hand-out.

This leaflet was well designed and had a pertinent content, showing a careful work on the children's part. The first page indicated the title of the project: "A world of different colors", the school and class and the name of the event. Each one of the following five faces of the hand-out presented a particular issue: Health, Rights of Children, The world (Data about the six countries researched at the Third Phase), "El món seria" (Lyrics of the song), Think that... (The message: "Health is a kind of chain with many links, and which makes everything run...We have to think about the world, think about other people... We all have the right to live...").

The same afternoon of the event, Mr. Baras and the children made an appraisal of their presentation. In general, they shared positive considerations of accomplishment, comradeship and pride.

**Final Evaluation**

Mr. Baras decided to add a special evaluation activity, which consisted in watching a video about immigration towards Spain and then answering in writing the following question: "If you were asked to write an article for the school magazine about immigration, what would you say?" Mr. Baras reminded the students to say positive and negative things and, above all, consider the "what would you do".

Very few of the children's answers summarized properly the issues presented in the video, they only repeated some of the statements heard. As for their opinion, fourteen children opted for a position of "All have right to a good life", and therefore everybody should be allow to move freely from one country to another. Only three students expressed clearly that immigrants should not come to Spain, because they take jobs from the spaniards and besides some of them are delinquents. A student stated that he is not racist, but he thought immigrants could "get their feet wet" and fix their own country. Eight children had a mixed position: they were sorry that illegal immigrants were not allowed in Spain and so missed the chance for a better life, but remarked that one has to worry also about jobs and housing for the spaniards.

About the "what would you do", most students opted for solutions out of their reach, proposed with no consideration for real life situations or constraints: "I would make for everyone to have housing and jobs", "If I were a person in power, I would change the laws, the world would be free", "If I were famous or rich, I would give means to the poor, so they did not have to emigrate". For many students, it was difficult to think about what would they do as common adult citizens or what could they do now as children. Maybe the very way of posing the assignment favored the escape to magical solutions. Even so, some students made proposals that coincide with ambitious but very reasonable ideas suggested by experts in the field: "If I had power, I would improve societies like Morocco, because they leave since they do not have jobs or means of life at home".

The second half of this same class was used for a self-evaluation, considering eighteen aspects: eight proposed by the teacher and ten put forward by different students. Children assessment of their learning during the project was positive.

## Conclusions

### From the point of view of the teacher

Teacher Jaume Baras has, on the whole, a positive appreciation of the project. He remarks that group dynamics worked very well, and the children took charge of the project and drove it to a good end, with enthusiasm and motivation, making he enthusiastic too. He considers that children learned a lot and are conscious of it. Also, that they performed their work with few interpersonal conflicts, and developed good debates in the general sessions. Participation in the event went well. Mr. Baras also values that the group as well as himself reacted properly to difficult moments, like the impasse before Christmas, when it seemed that the project had reached a deadlock.

Mr. Baras started this project concerned about the themes of solidarity, globalization and multiculturality, and he returns to them in his final consideration of the work done:

> *According to what I understand is a good person, and what I understand is the challenge of young people of the two thousand and something, which are going to be them (...) well, I think that this will have been useful. Because, at least, they will have received a volume of information in a direction different from usual. And that has had some usefulness already. To unbalance you a little and make you think...isn't it?*
> (From the final interview to the teacher).

With respect to what "did not work" in the project, Mr. Baras points out that the first phase was too dense, because they did not find adequate sources of information, adapted to the children's age. He questions himself about if he should have foreseen this or if it is part of the education of children to face this kind of obstacle sometimes. Besides, this first phase, said teacher Jaume, revolved too much around library research and got into a stalemate in December, which was difficult to overcome.

### From the point of view of the students

Thanks to the numerous (maybe too numerous) appraisal sessions done during the project, it is possible to say that the vast majority of the students expressed a very positive appreciation of the project, as a worthwhile activity, useful for their future. They stated that they learned new notions, improved their group work abilities, had a good time and advanced in their self-management. Although in a lesser measure, children also considered that they had adquired a new vision of the world and of the relations among people and that they had advanced in their responsibility. It is good to add that these are answers to questions posed by the teacher or by themselves, and which guided the appraisal sessions.

But these considerations were corroborated in the more open interviews which I had with three pairs of students. What is more, here the great aim of Mr. Baras "to contribute to reach a new world vision" moves to the first plane, as all the children mention it in one way or another. For example, Berta remarked that what she liked most in the project was to learn more about the world, to know that others live differently. On his turn, Manuel said that the most interesting thing was to do the in-depth research of some countries, "because we did not know about them and now we do". To the question: "What have you learned during the project?", Tatiana commented: "(T)hat everybody has to be... has to be equal. No matter how different they can be, they have to be treated equally, because they are human beings".

On his turn, Riqui V. stated that what he liked most was to work in group, although it was also the most difficult, because of the need to reach agreements. Berta shared his opinion since "(In a group) each one thinks that what he or she says is the best, but of course you have to think of the others too". When asking Tatiana: "What has been the most difficult for you, during the project?", she answered: "To reach agreements". And then added: "And to know what we were going to do, to have everything clear".

Children indicated that other things they learned were to read and write better, and to have a deeper concept of health.

The issue of the first phase of the project, with its difficult search for information in complex and dense books, was mentioned by several children during the interviews and in classroom appraisals. Magda, for example, said at the interview: "When we started we were not doing very well, because the teams... we had a lot of information and it was very hard for us".

**From the point of view of the observer**

Mr. Baras proposed a great theme: relevant and with considerable impact in these children's present and future life. It is valid that some classroom projects arise from the reflection of the teacher, and not only from students' initiatives.

However, children never really took the work in their own hands, as the teacher expected and presumed. Maybe they needed at the beginning more of what we could call "exploratory" or "unleashing" activities (Lacueva, 2000). And a more careful preparation of the work environment so that they could choose more and could propose more.

On other hand, it took too much time to give the project the right direction. During the first weeks, the teacher's proposal was too difficult for a sixth grade, both in terms of the topics to consider as in terms of the books and other resources available.

Besides, the production of the "message" was too guided by the teacher: authentic debate was lacking.

It is fundamental not to center projects just on library research, but to combine this with empirical research of some kind. In this way, students can really act as direct investigators of reality. In a project like "A world of different colors", for example, it would be possible to make more interviews to immigrants, experts and spaniards who have lived abroad, to study videos of health and environmental problems in different parts of the world, to analyze statistics (something that this class started to do), to observe critically foreign television programs or films, to attend cultural events and fairs of foreign communities in town and reflect on them, to visit ethnological museums and artistic exhibitions from other parts of the world, among other initiatives that could contribute to study first-hand the topic under investigation. Without the empirical component, project-based learning loses investigative character and is limited to a respectable but more modest activity of search and organization of documentary information.

## References

EISNER, E. W. (1990). *The enlightened eye. Qualitative inquiry and the enhancement of educational practice.* Upper Saddle River, NJ: Prentice Hall.

ERICKSON, F. (1998). Qualitative Research Methods for Science Education. In Fraser, B. J. & Tobin, K. G., eds., *International Handbook of Science Education* (pp. 1155-1173). Dordrecht / Boston / London: Kluwer.

GUBA, E. G. (1981). Criteria for assessing the trustworthiness of naturalistic inquiries. *ERIC/ECTJ Annual.* 29(2): 75-91.

LACUEVA, A. (2000). *Ciencia y tecnología en la escuela.* Madrid / Caracas: Popular / Laboratorio Educativo.

MANNING, M., MANNING, G. & LONG, R. (1994). *Theme Immersion: Inquiry-Based Curriculum in Elementary and Middle Schools.* Portsmouth, NH: Heinemann. (Hay traducción al español: *Inmersión temática. El currículo basado en la indagación para los primeros años y años intermedios de la escuela elemental.* Barcelona: Gedisa. 2000).

MARX, R. W., BLUMENFELD, P. C., KRAJCIK, J. S. & SOLOWAY, E. (1997). Enacting Project-Based Science. *The Elementary School Journal.* 97(4): 341-358.

STENHOUSE, L. (1991). Métodos de estudio de casos. In Husén, T. & Postlethwaite, T. N., eds. *Enciclopedia Internacional de la Educación. Volumen 7*, (3911-3916). Madrid: M.E.C. / Vicens Vives. (Orig.: *International Encyclopedia of Education. Research and Studies*. Pergamon. Oxford, 1987).

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005

# CONSTRUCTING TECHNOLOGY EDUCATION. A CROSS-CASE STUDY OF TEACHERS REALISING TECHNOLOGY AS A NEW SUBJECT OF TEACHING

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**Abstract**

This paper presents an on-going PhD project on technology teaching in Norway. In contrast to the situation in many of our neighbouring countries, Norwegian schools do not have technology as a compulsory subject for all pupils, and our traditions for technology teaching in existing subjects are weak. However, a curriculum development project currently run by the Norwegian Society of Engineers (NITO) gives an opportunity to study the realisation of technology as a new educational subject in Norwegian schools. This project, called TiS (Technology in Schools) is highly influenced by the subject 'Design & Technology' taught as a compulsory subject in England and Wales. However, the aims of the TiS project link technology teaching to science to a much higher degree. Further, a range of other factors are likely to influence the 'transfer' of curricular content across national borders.

In attempting educational reforms, appreciation of the influential role of the teachers is essential. In the presented research project, teachers are viewed as active curriculum constructors, and it explores how teachers perceive and realise technology teaching within the TiS project in Norwegian schools. It also attempts to identify important influences from factors such as the TiS project policy, the course the teachers attended and from the teachers themselves.

The research is carried out as a cross-case study involving classroom observations and semi-structured interviews. Results show that the project policy has minor influence on the teachers' realisation of technology as a subject. Their teaching is highly influenced by activities undertaken on a teacher-training course, but activities are strongly shaped under influence of the teachers' professional frames. The teachers' realisation of technology teaching is to a varying degree associated with science teaching. This variation does not appear to be determined by the variation in teachers' own educational background in science. Rather, their underlying educational philosophy is found as more fundamental to their realisation of technology as a field of teaching. This is illustrated by the presentation of two case studies.

## Background

During recent years, there has been an increasing attention internationally towards the importance of technology as a part of general education, and the concept of 'technological literacy' has emerged. As technology is an all-pervading phenomenon in human culture, society and history, there are diverse interpretations of the nature of technology, its basis of knowledge and role in society. The many aspects and differing comprehensions of technology itself leave the concept of technology education open to many possible interpretations. Correspondingly, a range of approaches to technology in general education is exposed in different countries, conveying different content and objectives and with different underpinning rationales. Technology teaching in compulsory schools may be influenced by the tradition of vocational training in post-compulsory education, mainly understood as specialised training for a specific technical occupation. Technology may also be represented within science teaching, where it can serve diverse purposes. It may here have a basically motivational function, it may appear as a tool for learning scientific subject content or the purpose may be to promote pupils' comprehension of the relevance of science in contemporary technology. Some approaches address cultural and societal aspects of technology, its importance in human history and culture and its transformatory power in society. Yet again, other approaches maintain that technology constitutes a unique tradition of human endeavour, justifying technology as a distinct subject of teaching in general education. Technology as such a distinct subject has during the last decades been introduced as part of compulsory education in several countries, such as England and Sweden.

**A technology project in Norwegian schools**

In contrast to the situation in some of our neighbouring countries – like those mentioned above – technology is not taught as a distinct subject for all pupils in Norway, and our traditions of technology teaching in existing subjects are weak. Further, a declining recruitment to higher education and careers in technology and related fields is a matter of widespread concern. With the aim of changing this situation and putting technology on the educational agenda in Norway, the Norwegian Society of Engineers (NITO) has since 1997 been running a project called 'Technology in Schools' ('Teknologi i Skolen', henceforth abbreviated to TiS) in 19 Norwegian schools (age 10 – 16). As a trade union of engineers, NITO may be assumed to see technology teaching in schools as a way of promoting interest in technology and engineer education among pupils, with the purpose of enhancing recruitment. However, the TiS project gathered its inspiration from rather different sources than what can be designated as 'engineering technology'. The project is highly influenced by ideas and practice in the subject 'Design and Technology' run as a compulsory subject in schools in England and Wales, and aspires to introduce elements of this subject in Norwegian schools. It may hence be seen as an attempt to transfer curricular ideas of 'Design & Technology' across national borders. However, the aims set for the project are rather different from those associated with this subject in England and Wales, and signal a much closer relationship to science. The specified aims for the project include to promote better understanding of the relation between technology and science, to support science and mathematics (as school subjects), to place technology and development of technology in a historical and societal context, to develop practical and aesthetic skills by designing a product and contribute to the inclusion of technology as a part of liberal education.

Participation in the project includes an initial course of two weeks training for teachers at a college in England, a largely practical course where the teachers worked on projects in fields like electronics, constructions and mechanisms, moulding with plastics and computer-aided designing. No formal curriculum is associated with the project, but the teaching must be carried out within the broader framework of the Norwegian curriculum guidelines for compulsory education. Responsibility for realising the aims and content of the project after the course lay with the individual schools and teachers, though NITO provided some material resources and organised yearly seminars. This weak framing has given the schools and teachers a great sense of ownership to the project.

**Teachers as active curriculum constructors**

In attempting educational reforms, appreciation of the influential role of the teachers is essential. Teachers' work does not imply a 'delivery' of a predefined curricular content from the ideal or formal level to the pupils. The curricular content has to be contextualised and put in concrete terms by the teacher. In doing so, the teachers also influence – or even alter - the educational aims and objectives associated with the content (Hargreavas & Evans 1997). Hence, teachers should be regarded as *active curriculum constructors* rather than technicians of implementation. The comprehension of their role as curriculum constructors becomes especially important when implementing educational reforms, and in the formation of a new subject which lacks identity – as in the case of technology in Norwegian schools.

Despite the rising acknowledgement of the importance of technology in general education, research on how teachers interpret the content, aims and objectives of technology as an educational subject are still very limited. Some studies essentially address fields of disjunction between curriculum policy and teachers' practice (e. g. Mittell & Penny 1997). Others have investigated how teachers respond to a task of giving a definition of what technology as such is, statements on the relationship between technology and science, or the role of technology in society (Rennie 1987, Zoller & Donn 1991, Jarvis & Rennie 1996)

However, it is reasonable that teachers draw upon additional and more complex considerations than theoretical definitions and conceptualisations of the nature of technology as such in planning and realising their technology teaching. A more useful framework in comprehending the complexity of teachers work is offered by Barnes (1992). Based on the work of Schön and others, he developed the concept of *teachers' professional frames*. 'Frames' refer to clustered sets of standard expectations, or preconceptions, through which all adults organise their knowledge of the world and their behaviour in it. Unlike 'knowledge', frames are value-laden and dynamic, and develop in relation to and in interaction with frames of colleagues, pupils, the overall school culture and values inherent in society more generally. Barnes suggests five domains that contain repertoires of teachers' professional frames: preconceptions about the nature of what they are teaching, preconceptions about learning and how it takes place, preconceptions about students that place limits upon what is thought to be useful or possible, beliefs about priorities and constraints inherent in the professional and institutional context and finally the nature of his or her overall commitment to teaching. Constructive collaboration requires shared or mutual "compatible" frames. Compared with curriculum developers or administrators, teachers may have frames that represent responses to different concerns and priorities, and consequently teachers may be unable to make use of advice if they can only interpret it in terms of an inappropriate frame (ibid. p. 17).

In establishing a subject that lacks identity and the tacit assumptions embedded in traditions, the comprehension of teachers as active curriculum constructors and the influence of their professional frames on the process of establishing a new subject of teaching becomes especially important.

**The research project and research methods**

The presented research project explores how teachers in the TiS project perceive and realise technology as a new subject[1] of teaching with regard to organisation, aims and content. It also attempts to identify the influences on their realisation of the project from factors such as the project policy, the course related to 'Design Technology' that the teachers attended, and the individual teachers' educational background and professional frames.

The research is carried out as an exploratory cross-case study using semi-structured interviews and classroom observations. 12 teachers from 8 schools participating in the TiS project constituted the sample of the study.

Teachers were interviewed at various stages in their realisation of technology as a subject, before starting with technology teaching, throughout their technology teaching and after having concluded periods of technology teaching. Interviews covered a range of topics; teachers' experience of the course they attended, how technology is realised as a field of teaching at their school, perspectives on aims and content of technology education in general as well as related to their own teaching, views upon the nature of technology and relation to other subjects, and how they look upon the role and future of technology in Norwegian schools.

Data were analysed in light of perspectives on technology education found in the research literature. However, as readymade 'typologies' in this field were not found to be fully appropriate for interpreting the teachers' views and actions, analysis of data in terms of broader thematic codes was approached. Emerging categories and perspectives were subsequently compared across cases in the search for similarities and differences.

**Findings and discussion**

This section presents some findings on how teachers perceived and realised technology as a subject of teaching. Possible influences from the TiS project policy, the course they attended and the teachers' educational background and professional frames are also considered, partly as a presentation of two case studies.

Technology teaching associated with the TiS project is organised in a range of different ways in the participating schools. Some offers technology as elective units, some incorporate it for all pupils as a specific part of the subject Arts and Craft or as occasional activities in science. Some run technology teaching as cross-curricular pupil projects in a specific period of the school year. All these organisational approaches are consistent with the framework for compulsory education set up by the Norwegian curriculum guidelines for compulsory education.

The teachers' lessons in technology were mainly carried out with pupils' making of artefacts as a structuring element. Examples of activities undertaken were constructing towers and bridges from rolled paper, moulding

[1] Technology teaching associated with the project is not necessarily run as a distinct 'subject' on the school's timetable, as it may be integrated in existing subjects or run as cross-curricular teaching. The notion 'subject' will still be used in a rather loose way in this paper.

with plastics, designing and making boxes from paper, making buggies and products involving simple electronics. Some activities did, however, deviate from the concept of making artefacts. Those included working with Legodacta for construction tasks and investigation of how everyday technological equipment work.

The strong relation to science that the aims of the TiS project communicated was, with a few exceptions, not absorbed in the teachers' perceptions and realisations of technology as a subject. On the other hand, the more implicit policy of the project was more recognised by the teachers. This agenda implies promotion of pupils' interest in and uptake of studies in science, mathematics and technology. However, the aim of generating interest was often interpreted as enhancing motivation for school in general. In some cases, this was essential to such a degree that it tended to define the content of the lessons.

Consequently, the teachers' perceptions and realisation of technology teaching were not found to directly reflect the aims of the project they were attending. Nor did they correspond much with the subject 'Design & Technology' with its process approach and focus on designing artefacts and the communication of design proposals by drawing. The main influence rather appeared to come from the teachers themselves, manifested through the activities they experienced during the course they attended as part of the TiS project. These activities were to a high degree transferred into the teachers' own teaching. However, the transfer mainly applied to the activities as such, not so much with regard to pedagogy, content focus and aims. The teachers realised their technology teaching by attaching their own aims and pedagogy to the activities, a process that influenced how content was structured, focused and communicated to the pupils.

Technology is a many-sided subject, and interfaces with several other subjects, such as science, crafts and social science. It may appear a plausible assumption that teachers will tend to lean on their prior knowledge and interest in related fields, and hence that their conceptualisation and construction of technology as an educational topic will be biased towards the subjects represented in their own education and in ordinary teaching. A few earlier studies give some indications that teachers' background influence how they conceptualise technology and technology teaching in interviews and questionnaires (see e. g. Jones 1997). The influence on their teaching in praxis is, however, a different and more important matter. The results of this study of Norwegian teachers realising technology as a subject suggest that there are totally different mechanisms at work when teachers construct their teaching in practice than a bias towards subject identity.

The following presentation of two case studies will focus on the two teachers' relation to science as a subject, and how they do - or do not – incorporate science in their perceptions and realisation of technology teaching.

**Constructing technology teaching: two cases**

Gina and Ann are both young, female teachers with a few years of teaching experience. They live in the same city in Norway and have attended the same courses and seminars related to the TiS project. Both teachers taught technology teaching within their schools allocation of weekly lessons for elective units for the pupils. Their educational background and subject identity are, however, very different and will be described below.

<u>Gina</u> has studied science, mathematics and computer science at a university, and holds a Master degree in physics. She mainly teaches science and mathematics at her lower secondary school. Her background and subject identity is reflected when Gina in an interview gives her motives for joining the TiS project. She thought the project and the course would suit her as a physicist, and she expected it to be about mechanics, electronics and maybe computers. She did, however, find the course she attended to be less 'technical' and more about design than she expected. When reflecting upon the aims of technology teaching after having attended the course, she states that it should give pupils insight into how things function, and how products are manufactured. She also points to the school as being too theoretical, and that technology as a subject may give pupils a chance to use what they have learned in other subjects, and especially in science. She sees technology teaching as a "golden opportunity to *use* science knowledge for something". She may hence be seen as being searching for a tool to reinforce the relevance of science education, and as considering technology a promising candidate to serve this purpose.

Gina's teaching is characterised by a relaxed atmosphere and high degree of freedom for the pupils. A range of activities was presented to them, such as the designing and making of boxes from paper, three-dimensional drawing by use of a grid system, constructing towers from rolled sheets of paper and moulding with plastics. Further, a series of lessons was used for taking apart old computers and printers, with the initial idea of creating new artefacts from their components. The artefacts resulting of this teaching project were, however, sparse, but the pupils apparently enjoyed the investigation of the inside of the electronic devices.

During her lessons, Gina hardly made any references to science, and her emphasis on the 'golden opportunity to *use* science knowledge for something' seems to have slipped away both in her teaching and in how she reflects upon it afterwards. She now emphasises that technology should be something *different* than the usual school subjects, and in particular science. For Gina, this difference implies the absence of a pre-defined curriculum and textbooks, activities that are more practical, a stronger attention on the pupils' interests and initiatives and -above all - no grading.

The lack of science content or its 'use' in Gina's technology teaching may appear as being at odds with her stated motive of reinforcing the relevance of science education. However, the two positions Gina seems to be taking may both be interpreted as expressions of Gina's fight against a phenomenon that can be denoted as 'the grammar of schooling' (Tylack & Tobin 1994). This is understood as the regular structures and rules that organise the work of instruction including the "splintering" of knowledge into "subjects" (p. 454). Technology teaching, with its lack of traditions and a pre-defined 'grammar' can hence serve as a free space where Gina and her pupils can escape from 'the grammar of schooling'. This interpretation is warranted by the fact that Gina rejects the idea of establishing technology as an 'official' subject in Norwegian schools. She worries that the subject then will include theory and textbooks and presumably also formal assessment and grading. Thereby, technology will become similar to the traditional school subjects - and hence adopt the same 'grammar of schooling'.

Another aspect of how Gina consider her technology as 'different' is that it does not imply any attempt to 'deliver' an amount of predefined knowledge to the pupils. Such a position does not, however, mean that the 'teaching' suffers from a lack of educational content and intentions. One important intention of her lessons is the *building of experiences*. She addresses the phenomena that pupils do not obtain they used to in earlier times:

> Gina:
> *Even if technology wasn't a subject in school earlier, there were many who made things at home and inkered and operated and investigated things and obtained the experiences in other ways. But maybe they don't do that anymore, the youngsters, they sit on their backside and watch TV and look into a pc screen and maybe do not tamper with very much. So, maybe we need to include it in schools so that they can get some practical experiences.*

As pupils lack these experiences, Gina points to the building of practical experiences as a rising responsibility of formal education. This concern, as well as her fight against the 'grammar of schooling' can be seen as expressions of Gina's professional frames as a teacher, and appear as more influential on her realisation of technology as a subject of teaching than her educational background and subject identity are.

Ann has a different background than Gina. She holds a general teacher certificate from a college, where she specialised in Music and Arts and Craft. She expresses her motivation for and experiences with the TiS course in rather different ways to Gina, stressing the aesthetic aspects of the subject. The technical part made her a bit anxious – as she said – "I have never been one who tinkers with things and... technology and stuff". Ann also signals an alienation from science, describing it as "a strange planet that is very big, and that I haven't really been into!". More specifically, she describes her personal view of physics this way:

> Ann:
> *Physics has been some kind of a non-subject to me. I know very little of what it is all about in a way, as I feel it, because I have never been very much interested in physics! I never did any courses on it in secondary school or anything.*

The "strange world she had never been into" was, however, not absent from Ann's realisation of technology teaching as an elective unit for her pupils. The main projects the pupils were undertaking were the making of a buggy that can run by inflating and then releasing a balloon, and a 'flashing postcard' with two light-emitting diodes attached to a battery. Ann's teaching was characterised by being highly teacher-led, with low degrees of freedom for the pupils. Ann emphasised the quality of the pupils' products strongly, and she taught them proper use of tools and techniques to achieve the required quality. In this concern, she also introduced and discussed mathematical concepts and principles such as being at right angles or parallel, and the relation between those. Scientific concepts such as friction, energy and air resistance were also highlighted. When introducing the flashing postcard project, Ann did an introductory session on electricity, addressing the concepts current and voltage and the principle of a closed circuit, even if this was not strictly necessary for the pupils in order to complete the circuits as they had ready-made templates to work from.

The relatively high emphasis on concepts and principles from science in Ann's technology teaching may be somewhat surprising, taking her background and also her own statements made in interviews into account. However, when Ann reflects on her technology teaching, the picture is again altered. She does not address practical skills or proper use of equipment as a learning outcome of her teaching. Rather, her focus goes in an affective direction, emphasising that pupils should be proud of themselves and their products. The teaching of practical skills functions as a means to this end. This is also found to apply to theoretical knowledge from science and mathematics. In the sequence below, Ann maintains that she did not have a sense of teaching physics as part of her technology teaching:

> Ann
> *When I talk about buggies and light and so, then it is only related to the things I am doing and not to the background which is physics. So I do not think that I am teaching physics, I don't. I kind of don't do that, because I am kind of not able to do that! At least I believe so. I am more thinking that I have some specific things I wish to do, and then I have to cope with what it is all about and…*
>
> BB
> *To reach that goal?*
>
> Ann
> *Yes. So, if it is physics or if is something else, that doesn't really bother me much!*

What is essential for Ann is not to teach science or to convey its relevance in technology. It is rather to give the pupils the opportunity to be proud of themselves, and a prerequisite for this pride is product quality – which in her view requires knowledge and skills.

As exposed above, Gina and Ann perceived and realised technology as a subject of teaching in rather different ways. The way they conceptualised technology, before attending the course as well as after, can be understood in light of their educational background and subject identity. However, when realising the subject in the classroom, their roles became opposite: Ann taught technology with a visible and essential element of science, while Gina, the physicist, taught technology almost without any reference to science. This shows that the teachers' educational background and subject identity may not be decisive for how they interpret and realise a new subject such as technology. On the contrary, the results may be interpreted as both teachers seeing technology teaching as field where they can realise – not only technology education – but also some more fundamental educational beliefs. To Gina, this means pupils' autonomy, the building of experiences and an escape from 'the grammar of schooling', while to Ann it means working towards high quality products in order to promote pupils self esteem and pride.

Interpreted within Barnes' (1992) framework of teachers' professional frames, the results may be seen as illustrating how teachers perceive the content, aims and objectives of a new subject in terms of their professional frames, and how their frames influence their realisation of technology as a subject of teaching. Their professional frames, together with constraints due to material resources and institutional settings, determine which aspects of new educational ideas they adopt and build into their praxis. The 'nature of what they are teaching' (Barnes 1992) is not necessarily conceptualised as beliefs about technology as such and what pupils need to learn about it. On the contrary, the 'nature of what they are teaching' is highly interpreted in terms of what the associated activities may offer to their pupils. This may indicate that beliefs related to educational values constitute an essential component of teachers professional' frames, and that the influence of these beliefs on other components is substantial.

## Conclusion

This paper has conveyed some aspects of how teachers in a Norwegian project on technology teaching perceive and realise technology as a new subject of teaching. The official policy of the TiS project, understood as its stated aims, was found to have limited influence on this process. However, the underlying aim of generating interest and motivation for technology and related subjects was found to have more resonance with the teachers' perceptions, and this aim was also expanded to cover motivation towards school more generally.

The course the teachers attended as participants in the TiS project was, on the contrary, found to have a strong influence on their teaching. This influence was mainly in terms of the activities they experienced and then transferred to their own teaching. The high degree of 'transfer' of the activities from the course the teachers attended may be related to the fact that many teachers judged their principal need for support as technology teachers to be new ideas for classroom activities. This confirms what has been earlier found to be of highest consideration for teachers in planning their work, that is, factors associated with the teaching context more than considerations about for example aims and purposes (Clark & Yinger 1987). This is not to imply that teachers do not consider aims of their work as important, or that they are narrowly occupied with refilling their 'activity account' consisting of a repertoire of activities with which to keep the pupils occupied. On the contrary, it shows that teaching and its planning are in their nature highly contextualised activities, and that teaching can be directly derived from educational principles and aims no more than technology can be derived from scientific concepts and theories alone.

Further, the two case studies briefly reported here suggest that teachers' educational background and subject identity may influence the ways they conceptualise technology education, but that these are subordinated to other concerns when it comes to realising technology teaching in praxis. In the process of realising technology as a new subject of teaching, beliefs about pupils and education in general appear as more important facets of teachers' professional frames.

The specific project in which this research is carried out facilitates autonomy for the teachers and a lack of formal constraints that may be rare in other contexts and in many countries' educational systems. The findings in this research may nevertheless apply in wider perspectives. It contributes to the understanding of teachers as active agents in the process of constructing a curriculum. This understanding, though still incomplete, is of major importance when attempting to implement educational reforms. The findings also add new aspects, the ones seen by the teachers, to the continuing debate over content, aims and objectives of technology as part of general education.

## References

BARNES, D. (1992): The Significance of Teachers' Frames for Teaching. In: Russell, T. & Munby, H. (eds): Teachers and Teaching: From Classrooms to Reflection. London: The Falmer Press.

CLARK & YINGER (1987). Teacher Planning. In: Calderhead, J.: Exploring Teachers' Thinking. London: Cassell.

HARGREAVES, A. & EVANS, R. (ED.) (1997). Beyond educational reform : bringing teachers back in. Buckingham: Open University Press.

JARVIS, T., RENNIE, L. J. (1996). Perceptions about Technology Held by Primary Teachers in England. Research in Science and Technology Education, 14 (1): 43-54.

JONES, A. (1997). Recent Research in Learning Technological Concepts and Processes. International Journal of Technology and Design Education, 7: 83-96.

MITTELL, I. & PENNY, A. (1997). Teacher Perceptions of Design and Technology: A Study of Disjunction between Policy and Practice. International Journal of Technology and Design Education, 7: 279-293.

RENNIE, L. J. (1987). Teachers' and Pupils' Perceptions of Technology and the implications for Curriculum. Research in Science and Technological Education, 5 (2): 121-133.

TYLACK & TOBIN (1994). The grammar of schooling: Why Has it Been so Hard to Change? American Educational Research Journal 31 (3): 453-479.

ZOLLER, U. & DONN, S. (1991). Students' versus their teachers' beliefs and positions on science/technology/society-oriented issues. International Journal of Science Education, 13 (1): 25-36.

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# THE EVOLUTION/CREATION SCIENCE CONTROVERSY: EDUCATE RATHER THAN DEBATE

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**Abstract**

This paper is linked to the theme History and Philosophy of Science. The evolution and creation science controversy is now in the general public's arena and poses a challenge for school science. I begin the paper by briefly describing the current situation concerning this issue in Australia and the United States of America. In the subject Biology, debating controversial issues is a popular strategy with teachers. However, Roger Bybee questions this approach. He contends that when teaching about evolution teachers should educate students about the nature of science and develop their science inquiry abilities, rather than debating the issue.

In this paper I support this view, based on the argument that the creationism and evolution dispute is not really about Biology or faith, but is about Biblical interpretation. A summary of the major differences between Theistic Evolution and Creationism is described. Teaching about Charles Darwin in the historical context of the 19th century is suggested as one way to assist students to develop an understanding of science as being socially constructed.

Henri Bergson argued that the process of natural selection could not adequately explain the evolution of complex organs such as the vertebrate eye. He believed that there is another channelling force at work called the 'vital impulse'. In Bergson's Creative Evolution he argues for lived time – the uniqueness of time in the lived experience – which is duration, not the mechanistic clock time. Accordingly, I challenge the view of science currently being taught in schools. The dilemma is that while a mechanistic view of science continues to dominate Western thinking, the science taught in classrooms will be inadequate.

## Introduction

Thinking back, I now realise that for 13 years, as a young Biology teacher in secondary schools in Victoria and overseas in Malaysia, I taught the process of evolution as if it was the accepted view. In those days, in my classes creationism was not discussed. To my recollection, there was only one occasion where a student handed in an assignment that focused on ideas from Creationism[1] As it happened that Year 12 student failed the assignment - not because she opposed the process of evolution - but because she heavily plagiarised work from a well-known article. Since then my views on the nature of science have changed. I now use constructivist teaching strategies to elicit and engage students' prior ideas and beliefs, and realise how resistant these are to change.

**What is the current situation in Australia?**
You only have to read the newspapers to be aware that the evolution and creation science[2] controversy is in the public arena. Earlier this year I read Garry Linnell's well-constructed story, "God's classroom" (The Age Good Weekend, 24/2/2001).

[1] Opponents to the biologists are the Creationists or fundamentalist Christians. They believe the Book of Genesis in the Bible is the only source of information about the origin of life, including humans. Creationists view the fossil evidence for evolution as unacceptable, believing that species cannot change (Webster, 2000).

[2] The term "creation science" is used by creationists interchangeably with the term creationism, presumably to give it more credibility.

Linnell was horrified at the extent to which creationism was being taught in science classrooms in Australia. Linnell questions whether creationism has a place in the science classroom at all. He claims that in many Christian schools creationism is being taught alongside the theory of evolution - not in the subject area of religious education - but in science. A literature search revealed that the situation is even more pronounced in the USA.

**The debate is alive and well in the United States of America**

Ian Pilmer (2001) argues strongly that Creation Science is not about science or religion but is political, and stems from a Protestant Christian Fundamentalist group in the USA.[3] Staver experienced the effects of the evolution-creation controversy while on the committee responsible for writing the science standards. "A year into the developmental process, Kansas State Board of Education (KSBE) members and the writing committee remain engaged in a dialogue about a single issue, the presence or absence of evolution theory in the state science standards" Staver (2001). This disagreement arises because half the KSBE members have an understanding of the nature of science that is consistent with their fundamentalist religious views. These members believe in a literal reading of Scripture and therefore oppose the inclusion of evolution theory in the school curriculum.

The quandary for science educators is whether to include evolution and/or creation science in school curricula. Brent Dalrymple (2000), Professor in the College of Oceanic and Atmospheric Sciences, Oregon State University, questioned whether the scientific version of the history of the Earth and Universe or the creationist's view should be taught in public schools. He argues that science education evidence and conclusions of real science, not pseudoscience, should be taught. He asserts that creationism is not science and therefore should not be included in the science curriculum.

**The continuing controversy between Creationism and Evolution**

Before discussing further this far-reaching sociocultural controversy, it is helpful to clarify the meaning of the term creationism. *Creationism* refers to the viewpoint that the literal Biblical account of creation is the correct explanation for the origin of the Earth and its living forms, and that evolutionary theories are false. Fulljames (1996) argues that Creationism must be carefully distinguished from the belief in God as creator because many Christians claim that belief in God as creator is consistent with an evolutionary theory of origins.

The basic elements of Creationism are:

- The age of Creation – the earth is approx 6,000 – 12,000 years old.
- The Time of Creation - six days with the seventh the Sabbath day God rested.
- The mode of Creation – with God's 'special' creative acts.

According to Murray and Buffaloe (1983, p. 464) "the vast mainstream of Theistic interpretation has long ago assimilated the concept of evolution into its faith-perspective, along with modern astronomy, the atomic theory, and other scientific findings." Creationism disputes the age of the Earth, claiming that it is very young, only 6,000 to 12,000 years old. Young-Earth Creationists contend that their beliefs about the origin and history of the natural world - that they call "scientific creationism" - are just as scientific as those of real science.

[3] Modern creationism had its origins in the speculations of Christian Science founder Mary Baker Eddy and her disciple George McCready Price (Berry, 1999).

**Figure 1** A summary of the major differences between Theistic Evolution and Creationism (Murray & Buffaloe, 1983, p. 468).

| Issue | Theistic Evolution | Creationism |
|---|---|---|
| 1. Existence of God | God is the sole creator of the universe – purposefully brought it into existence. | 1. (Same) |
| 2. The Place of Man | 2. Man bears the "image of God" – Is called into special relationship with his creator. | 2. (Same) |
| 3. Age of the World | 3. 4.5 - 4.7 billion years. | 3. Not more than 10,000 years. |
| 4. Mode of Creation | 4. God initiated the principles of nature and allowed them to take a gradual, unfolding course, which is continuing. | 4. God directly created all things in seven days or periods, following the sequence in Genesis I. |
| 5. Origin of Man | 5. Man's biological nature emerged from more primitive origins, until he became capable of bearing a spiritual nature. | 5. Man was instantaneously created by God's direct act, physically and spiritually. |
| 6. Biblical Interpretation | 6. Genesis accounts of creation are pre-scientific literature of parable and saga, not in competition with modern science. | 6. Genesis accounts are to be interpreted as literal, scientific descriptions. |

Dalrymple considers "scientific creationism an oxymoron, as it is religion pure and simple, a fact clearly recognised by federal court rulings in both Arkansas and Louisiana ... that struck down as unconstitutional the 'equal time for creationism' laws of those states" (2000, p. 45). He contends that the Creationists have no valid data or calculations to support their claims, but rely on their interpretation of the six-day creation and global flood 4000 years ago. In contrast, there is a vast amount of scientific evidence, such as radiometric dating of rocks and star dates, that tell us the Earth and Solar System are approximately 4.54 billion years old.

**Biblical Interpretation**
Murray and Buffaloe (1983) see the major thrust of Creationists is a questioning of the validity of evidence (supplied by various areas in science) for evolution. This questioning comes from a theological bias that is based on a literal interpretation of the Genesis account of creation.

Antony Campbell (1997) from the Jesuit Theological College in Melbourne argues against claims that creationism takes the Bible literally on the grounds that there are numerous portrayals of creation in the Bible with the most familiar being in Genesis 1 and 2.

Scripture the big three images of the creator God are:

- *the mighty fighter* (Psalm 74 (vv 13-14, 16-17) and 89 (vv 9-12), Job 7:12, 9:13-14, 26:6-11, 12-14; 38-41), Isaiah 51:9-11);
- *the co-operative artist* (God of Genesis 2 – 2:7, 19); and
- *the majestic proclaimer* (Genesis 1 – 1:3, 1: 11, 24-25).

Creationists would not agree with the picture of creation by combat with the God of Israel and the forces of chaos. Campbell considers literalism to be a red herring in creation issues. "Creationism is not supported by the biblical text. The biblical text itself is the best evidence for that" (Campbell, 1997, p. 31). The central issue then is about Biblical interpretation, making the two viewpoints irreconcilable. The Institute for the Study of Christianity in an Age of Science and Technology (Vic) holds the following view on scientific accounts of origins:

> The principal reason that biological evolution, together with theories of cosmic origins of the universe and geological origins of the earth, are held to be incompatible with Scripture is defective hermeneutical method in the approach to Scripture. Meanings are read into the literary form of Scripture, which are beyond the apparent intent of the passages concerned. (ISCAST, discussion paper, http://www.iscast.org.au/papers)

The 'days' in Genesis 1 can be interpreted as 24-hour periods. However, exegetically days could be representations of long periods of time. "God resting" on day seven could indicate rhythm in God's pattern for Creation.

**How does the nature of science differ from creationism?**
It is generally accepted that science is socially constructed. Ben Selinger, emeritus professor of chemistry at ANU, contends that " science offers us a reliable, testable and repeatable process for making decisions, using the best available information as a basis" (2001, p.115). Repeatable evidence, gained through observation, measurement, experimentation, calculation and deduction, is what underpins science. Such evidence is transparent to an international scientific community and is out there available for all to evaluate. When new evidence is discovered, explanations change and these may disprove the scientific theory, giving rise to a new theory. In this way a scientific theory is the best explanation at a given time that accounts for the evidence available On the other hand 'Creation science' requires an untestable supernatural being, and hence is not science. "Creationism first starts with an untestable conclusion and then trawls for evidence" (Pilmer, 2001, p. 36).

**Approaches to teaching evolution**
Science educators take a variety of approaches to addressing the classroom implications of the conflict between creationism and evolution. "Some take on a crusading spirit and try to expurgate all mention of religious notions from the science classroom in the name of the higher principle of naturalistic explanation" (Jackson et al., 1995, p. 588). Others encourage teachers to use the controversial issue by explicitly raising and then critically examining 'creation science' arguments in class to provide an interesting counter example to a scientific theory.

A third group push for allowing alternative views to emerge in less structured peer discussions. This context arouses less anxiety about the theory of evolution as an example of scientific knowledge.

**Teaching the nature of science rather than debating the controversial issue**
Teaching about science will require the teaching of theories such as biological evolution. However, Roger Bybee believes that evolution is not taught well in schools. He suggests that science teachers should not debate creationists. Instead they should assist students to better understand and appreciate science as a way of explaining the natural world. He recommends the teaching of the relationships between the scientific processes and the structure and development of a theory like evolution. Teachers could encourage students to reflect on the nature of current scientific knowledge, and how the scientists come to know what they do about nature. This view flies in the face of many science textbooks that describe science as a body of knowledge rather than 'one way of knowing'. Bybee also argues that often science is taught as a systematic method or as a process involving skills such as observing, hypothesising and inferring. Both perspectives leave students uncertain about the human endeavour called science. It would be more helpful to teach about the nature of science and incorporate inquiry in school science curricula.

In agreement with this view, within the context of Northern Ireland, is the research by Francis and Greer who identified the conditions that allowed students to develop positive attitudes towards both Science and Christianity.

> These conditions include an understanding of the nature of science, which questions the claim of scientism[4] and an understanding of the Christian faith, which questions the literal authority of the genesis creation narratives. Both positions being highly consistent with the accepted trends

4 Scientism is the view that scientific theories can attain absolute truth and that only science is of value in explaining phenomena.

within the philosophy of science and within the critical traditions of Christian theology should be presented as intellectually viable options within the curriculum of science education and religious education. (Francis & Greer, 2001, p. 50)

**Why teach about Darwin as the reluctant revolutionary?**

For 20 years Charles Darwin kept his controversial idea about the natural order, collecting a vast amount of evidence before going public with his idea. He did this because he knew that his views relating to human evolution could be damaging to the understanding of the nature of human kind. Teaching about Darwin in the historical context of the 19th century means that students will better understand that science is a human endeavour, which is socially constructed. As a young man Darwin sailed the world; a naturalist on a small Royal Navy ship HMS *Beagle*. He collected insects, wrote natural history books, fathered ten children, and was an invalid for 40 of his 73 years. Darwin's view of evolution by the process of natural selection can be engaging for students when stories are told about Darwin's life. For example "as a boy, he once found two beetles under some bark and grabbed one in each hand. Then he spied a third. Not wanting to miss it, he put the beetle in his right hand into his mouth and picked up the newcomer. The beetle in his mouth then stung the collector, forcing him to spit it out" (Thwaites, 2001).

Teachers could choose to combine stories of his life with the story of the conflict Darwin's ideas stirred up at the 'Oxford Meeting' of the British Association in 1860. Bishop Samual Wilberforce and T. H. Huxley represented the differing sides of the conflict.

"The bishop made a bad start for the creationist camp by using more rhetoric than reason (Richardson, 1999, p. 18). Hal Hellman's (1998) account in his chapter 'Darwin's Bulldog versus Soapy Sam' is a lively description of the evolution war going on at that time. Wilberforce opposed evolution because it legitimised the notion of change in the Divine order. Darwin's reaction to his attackers was anguish, and his deeply religious wife became distressed when the religious establishment went against her husband. Although Darwin made no mention of a Creator in the first edition of the *Origin of Species* in the second edition soon after, he made the change to "having been initially breathed by the Creator into a few forms or into one" (Hellman, 1998). Many religious people can accept the ideas of evolution and natural selection, but also keep the belief that God is there, most probably at the beginning. God created the universe out of chaos. Although R. A. Fisher initiated the neo-Darwinian synthesis in the 1920s through his work on the effects of gene substitution and the evolution of dominance, it was not generally accepted until the late 1940s.

**Bergson's Creative Evolution**

Evolution, the emergence of higher species including human beings, was said to be the by-product of physical processes in nature over geologic millennia. However, "this explanation was not adequate for Henri Bergson because it did not provide a satisfactory explanation of evolution itself, and did not account for human consciousness and the lived experience. Some other force - not merely mechanical - must have been at work" (Boorstin, 1998, p. 246). In his book *Creative Evolution* (1911; French edition, L'Evolution Creatrice, 1907) Bergson outlined his own vitalist view. Bergson received the Nobel Prize for literature in 1928. Bergson argued that the process of natural selection operating on random variations could not explain the evolution of a complex organ like the eye of vertebrates. There must be another channelling force at work, that he called 'vital impulse'. Bergson's idea of lived time – the uniqueness of time in the lived experience - was duration, not the mechanistic clock time. He used the metaphor of the cinema – a succession of changed images seen in rapid succession – to explain both the making of 'the mechanistic illusion' and the need for the idea of duration. For Bergson life could only be known by bathing in the full stream of experience. "Consciousness corresponds exactly to the living being's power of choice; it is coextensive with the fringe of possible action that surrounds the real action; consciousness is synonymous with invention and with freedom" (Bergson, cited in Boorstin, p, 250).

In the *Liberation of Life* ecology and evolution are considered to belong together, and evolution is described as a continuous process. "The actual process of evolution cannot be understood apart from the purposive behaviour of the animals that are evolving" (Birch & Cobb, Jr, 1981, p. 64).

## Conclusion

In this paper I have argued against debating the controversial issue of evolution versus creationism in science classrooms on the grounds that the two views are irreconcilable. Rather, teachers should educate students about the nature of science and develop their science inquiry abilities. The dilemma is that while a mechanistic view of science continues to dominate Western thinking, the science taught in schools will be inadequate.

## References

Birch, C. & Cobb, Jr, J. B. (1981). *The liberation of life*. London: Cambridge.

Boorstin, D. J. (1998) *The Seekers*. New York: Random House inc.

Campbell, A. F. (1997). Creationism! Utterly unbiblical. *Eureka Street, 7*(4) 30-34.

Dalrymple, G. B. (2000). Evidence for evolution. *The Science Teacher*, October, 44-47.

Francis, L. J. & Greer, J. E. (20001). Shaping Adolescents' Attitudes towards Science and Religion in Northern Ireland: the role of scientism, creationism and denominational schools. *Research in Science & Technological Education 18*(1), 39-53.

Fulljames, P. (1996). Science, creation and Christianity: A further look, in L.J. Francis, W.K. Kay & W. S. Campbell (Eds). *Research in Religious Education*, pp. 257-266 (Leominster, Gracewing).

Hellman, H. (1998). *Great Feuds in Science Ten of the liveliest disputes ever*. Toronto: John Wiley.

Institute for the Study of Christianity in an Age of Science and Technology (ISCAST) (Vic) *Statement on Creation with reference to Evolution*. Discussion paper (version 2.3) http://www.iscast.org.au/papers

Jackson, D. F., Doster, E. C., Meadows, L. & Wood, T. (1995). Hearts and minds in the Science Classroom: The Education of a Confirmed Evolutionist. *Journal of Research in Science Teaching 32*(6) 585-611.

Linnell, G. (2001). God's classroom. *Good Weekend The Age magazine*, February 24, pp. 18-23.

Murray, N. P. & Buffaloe, N. D. (1983). Creationism and Evolution: The Real Issues. In Zetterberg, J. P. (ed.), *Evolution versus Creationism: the Public Education Controversy*. Encanto, Phoenix: Oryx Press, pp. 454-476.

Pilmer, I. (2001). Creation Science Neither Science nor Religion. *Australasian Science 22* (1) 36-37.

Richardson, A. (1999). Evolutionary Science: A Christian perspective. *God, Genes & the Environment Integrating Biology and Theology*, COSAC99 Collected papers Second Australian Conference on Science and Christianity Lilydale July: Institute for the Study of Science and Christianity in an Age of Science and Technology. pp. 17-21.

Selinger, B. (2001). The truth is out there. *Newton* March-April. Pp. 112-115.

Staver, J. R. (2001). When Public Understanding of Science Thwarts Standards-Based Science education. httpc://unr.edu/homepage/crowther/ejse/staver.html

Twaites, T. (2001). Darwin the reluctant the revolutionary. *Newton* March-April. Pp. 106-109.

**Keywords:** evolution, creationism, teaching the nature of science, biblical interpretation, Charles Darwin.

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# TOWARDS LEARNER-CENTRED APPROACH IN SENIOR SECONDARY SCHOOL SCIENCE LESSONS

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## Abstract

Whenever a new syllabus is introduced in an educational system, it introduces a number of new features, such as aims, goals and objectives, content, teaching method and teaching orientation and, assessment strategies. It also has resource implications. This was the case with the introduction of Botswana General Certificate Secondary Education (BGCSE) science syllabi in 1997. The purpose of this study was to find out the extent to which the learner-centred approach in BGCSE syllabi was being implemented in the senior secondary school science lessons.
From a population of 27 senior secondary schools in Botswana, the study was carried out in 18 schools. In each school a sample of 3 science classes was selected. With prior arrangements with each teacher, a 40-80 minutes lesson was video-recorded and later analysed. The results of the study showed that most science teachers do not implement the recommended teaching orientation, teaching methods and assessment procedures.

## Introduction

The orientation of the traditional teaching that characterised the old Cambridge Overseas School Certificate (COSC) science syllabus in colonial and post-colonial Africa was mainly teacher-centred. Its major emphasis was to provide learners with assumed body of knowledge deemed necessary pre-requisite for tertiary education and technical fields. For this reason, it was assumed that the most effective way of passing on the knowledge to learners was by lecture method in which teachers played the central role of the learning /teaching process. In a way the teaching approach was said to be teacher-centred. So a typical science lesson was dominated by a teacher-talk accompanied by a few selected demonstrations and interrupted by questions from students. The students were passive participants and intermittently would be permitted to carry out confirmatory experiments. Towards the end of senior secondary education, students were given opportunity to carryout practical exercises as they prepared for the final practical examinations. This was a mockery of the whole issue of practical work in science subjects. Teachers drilled students in carrying out practical work in preparing them for taking examinations. One wonders whether students ever benefited from such practical work, as they would soon forget the process skills after taking the examinations. This lack of mastery of process skills was reflected in students' failure to handle simple equipment in first year science courses at university and college levels of education. Most first year students failed to handle sophisticated microscopes; electron balances and to prepare molar solutions.

In the Old COSC, secondary school students did not acquire the process skills of observation, interpretation, investigation, measurement, hypothesis, raising questions-considered necessary component of science. Nor were they involved in planning their own experiments and testing hypotheses. They were deprived of the creativity, inquiry, problem solving and several other scientific skills that characterise scientific enterprise. It was assumed that such skills would be acquired at tertiary level of education, a serious mistake because not many school leavers take science professions or careers, yet they need the same skills for survival in life.

In Botswana as in most independent African countries, the desire to change the colonial school syllabi was expressed soon after obtaining independence in 1966 (Republic of Botswana, 1977, 1993, 1994). The change in the syllabi was comprehensive including the philosophy, rationale, programme features, programme aims and objectives, programme content and structure, teaching methods and orientation and assessment. The change was made in stages, the Pure Science (Biology, Chemistry, Physics) was introduced in 1997 and Single Science and Double Science in 2000 (Yandila, 1999). Each of these three types of syllabi insists on learner-centred teaching approach as stipulated in the Curriculum Blueprint (1997).

The new syllabi involve emphasising science process skills, problem solving skills, and the acquisition of hands-on experience that should increase the performance of all groups of different student abilities. The syllabi also stipulate that teachers should use a learner-centred approach of teaching by using a variety of methods including demonstration, practical work, field trips etc. In order to facilitate a learner-centred approach there should be pre-planning of activities and adequate working space. The syllabi also stipulate that teaching methods should expose learners to practical applications of science in everyday life. Local environment should be used to provide context to the syllabus. Teachers should present science in an interesting and challenging way that should popularise it and encourage learner to opt to pursue science and science-related careers (Senior Secondary School Science Syllabus, 1997 p.iii).

The new syllabi also insist that students should be actively involved in learner-centered practical work that emphasizes the process skills of using and organizing techniques, apparatus and materials, observing, measuring and recording, handling experimental observations and data and planning investigations. These skills transcend every topic in each syllabus and are to be assessed throughout the course and examined in the final practical examinations. It is therefore, assumed that students will need these skills wherever they go-science fields, technology, industry or as common citizens.

**Definition of Learner-centred Approach**

Scholars have defined learner-centeredness in a number of ways. For example, McCombs and Whisler (1997), define it as a perspective that couples a focus on individual learners with a focus on learning. Focusing on individual learners implies looking at their heredity, experiences, perspectives, backgrounds, talents, interest, capacity and needs. Over the years, education psychologists and educators have acknowledged the individuality of every learner, their learning styles and multiple intelligence (Piaget, 1956; Slavin, 1994; Vygotsky, 1978, 1987; Visser, 1993; Armstrong, 1994). They have argued that the most meaningful learning takes place in children if the learning environment encourages self-motivated and self-driven learning. To McCombs & Whisler (1997), learning is associated with the best available knowledge about learning and how it occurs and about teaching practices that are most effective in promoting the highest levels of motivation, learning and achievement.

**Purpose of the Study**

Now that the learner-centered approach has been introduced in Botswana schools, some question are; To what extent is this learner-centered approach being followed by science teachers in classes? Do teachers experience problems when they implement this new approach? Do students accept the learner-centered approach? And do they learn more effectively through this approach? Do teachers teach the prescribed processes of science through learner-centered approach? The purpose of this study was to find out the extent to which the learner-centered approach was being implemented using the four major process skills in the senior secondary school science lessons. Answers to the following questions were sought from the study:

1. To what extent are science teachers teaching the new science syllabi as stipulated in the Curriculum Blueprint and syllabi themselves?
2. What type of lesson orientation is taking place in the class?
3. What evidence of adequate pre-planning for learner-centered approach activities is shown in the class?
4. What kind of evidence that mixed-ability teaching is taking place in the lesson?
5. What forms of differentiated teaching/learning approaches are science teachers employing in the lessons?
6. Do teachers use a variety of teaching methods in the course the lesson?
7. Is there evidence of increased participation of all groups of learners in the lesson?
8. Do teachers make effort to inculcate the following recommended processes skills in students:
    - planning investigations?
    - using and organizing apparatus and materials,
    - Collecting data
    - handling experimental observations and data
9. Do the teachers carry out demonstrations before allowing students to carry out their own group or individual practical work?
10. Do teachers effectively use a variety of teaching aids in their lessons?

**Significance of the Study**
It is hoped that the results of this study will be helpful in a number of ways:

1. To provide useful information for the preparation of pre-service teachers for teaching practice exercise.
2. To serve as a basis for comprehensive investigation to redress problems in the implementing the new science syllabi.
3. To provide empirical basis for guiding the revision of the new science syllabi.
4. The videotapes themselves would be a rich source of exemplary lessons to be used in pre- service and in-service science teacher education.

**Research Design**
This was a case study looking for actual implementation of the new syllabus in a particular science class. It is a non-participant observation using a video camera to collect data. Several researchers have developed different instruments to record classroom observations including Flander (1970), Simon and Boyer (1975), Cohen (1976), Galton (1978), Wragg and Kerry (1978) etc. As Bell (1999) concedes, "...inspite of all the tried-and-tested methods that have been employed by the experienced researchers over the years, there never seems to be an example that is unique right for the particular task. Inevitably, you will find you have to adapt or devise a completely new approach, and all new systems need careful piloting and refining in the light of experience.... You will probably need to invent your own system of shorthand symbols and these will have to be memorized. You will need to decide how often to record what is happening (all the time? every three seconds? every five minutes? Every twenty minutes?) and with whom (all the group? Individuals?" (P.164). In this study, video recording took place during the entire 40-80 minute lesson duration. Trained researchers handled it.

**Literature Review**
A number of studies have been undertaken to determine if classroom teaching and learning activities is a correct reflection of the syllabus prescription. These include the work by Rantabe (1992) in primary school science, Tabulawa (1996) in Junior Secondary School Social Studies, Ramorogo (1994) in Junior Secondary School Science and Prophet and Rowell (1993) in Junior Secondary School Integrated Science.

To the best knowledge of the investigators, only four studies have been reported in the literature since the new science syllabi were introduced in the senior secondary schools. Yandila (1999) and Rammung (2000) carried the first two. Yandila investigated the implementation hiccups of the new biology syllabus in selected senior secondary schools in Botswana. The study employed a questionnaire. Respondents were asked to suggest reasons why they were unable to successfully employ the recommended teaching methods in biology. Forty-seven dully-completed questionnaires were returned and analyzed. Teachers cited several reasons for not employing the recommended teaching methods and some common reasons were:

- Teaching large classes
- Having large teaching loads
- Lack of adequately trained laboratory assistants.
- Lack of exemplary teaching materials
- Inappropriate text books
- Absence of relevant teaching and learning aids.
- Lack of understanding of the breath and extent of the new topics such as biotechnology.
- Lack of incentives and reward for teaching the new biology syllabus statement.
- Feel grieved for being inadequately consulted during the design and development of the new biology syllabus.
- Fears and misunderstanding expressed by students on the implications for sitting for core alone or core plus extension for final examination in form 5.
- Inadequately prepared to teach the new Biology syllabus.
- Inadequately prepared to carryout continuous assessment.
- Not provided with sufficient orientation in appropriate teaching methods.

The major disadvantage of these results was that only biology teachers in the Gaborone schools were contacted. It was expanded in the next study carried out by Rammung (2000) whose purpose was to find out the coursework assessment practices in the new senior secondary school Pure Science-Biology syllabus. It sought answers to questions such as: (i) Have teachers been keeping the records of students' performance? (ii) Do the coursework marks predict the examination grades of students at the end of secondary education? (iii) Why hasn't the coursework assessment been introduced in schools as stipulated in the new syllabus? The study comprised three schools from villages around Gaborone and those selected were past and present Pure Biology students and current Pure Biology teachers. The results showed that the new assessment method had not been introduced as yet but efforts were being made to do so. Teachers gave different reasons for not teaching the biology syllabus according to its recommended methods, but the common reasons were identical to those established by Yandila (1999), presented earlier.

Yandila (2001) carried out a study to find out the extent to which senior secondary school teachers were employing the recommended teaching methods and approaches in teaching Pure, Double and Single Sciences. The study involved classroom observation using a checklist whose content was based on the prescribed teaching methods and approaches. The Class Observation Checklist consisted of a fixed number of competencies listed in the new science syllabi. It was developed by drawing information from various sources, including the instruments used for assessing student teachers at the University of Botswana, in colleges of education in Botswana and literature such as Walters (1993), Duminy, et al (1992). Twenty-seven competencies were identified and placed into three major categories of Administrative, General Professional and Teaching. Administrative competencies related to planning and managing of teaching materials and consisted of six sub-categories. General professional competencies related to the teacher's appearance, attitudes towards students, school authorities and response to students' complaints about his or her treatment of them. It consisted of three sub-categories. Teaching competencies consisted of 17 sub-categories covering a wide range of classroom activities that the teacher and students might undertake.

The results of this study suggested that most science teachers were not following the recommended teaching methods and teaching approaches and the majority of the lessons did not encourage a learner-centered approach as emphasized in the Curriculum Blueprint (1997). Teachers dominated in class activities with little student participation, except in question and answer discourse and during demonstration. Mixed ability teaching, which encourages students with different academic abilities, was evident in some lessons. However, its absence in 46% of all lessons was consistent with the findings in primary school and junior secondary school lessons reported by Tabulawa (1995), Madome (1998), and Letsholo (1996).

Most teachers did not bring lesson plans, lesson notes, or a scheme of work though they were required to do so. A variety of teaching methods including, but not limited to, inquiry, demonstration, or practical work, were not being used on a regular basis and students were not exposed to practical applications of science in everyday life.

In another study, Mogapi and Yandila (2001) sought to find out if: (i) senior secondary school science teachers agreed with the suggested reasons why they did not follow the recommended teaching methods, (ii) science departments were adequately equipped with computers for use by science teachers for computation, record-keeping and word process, (iii) science teachers were computer literate, and (iv) science teachers considered the proposed assessment guidelines for science practical work adequate, suitable and acceptable. A questionnaire was sent to 81 senior secondary school science teachers in Botswana. The results showed that senior secondary school science teachers agreed with the reasons why they did not follow the recommended teaching methods. The reasons were:

- Teaching large classes.
- Having large teaching loads.
- Inadequately prepared to carryout continuous assessment.
- Lack of adequately trained laboratory assistants.
- Feel grieved for being inadequately consulted during the design and development of the new biology syllabus.

The results also showed that:
- most science departments were not adequately equipped with computers for use by science teachers for computation, record-keeping and word process,
- most science teachers were computer literate, and expressed desire to take up special computer courses.
- science teachers considered the proposed assessment guidelines for science practical work to be inadequate

In light of all the results presented above, it was necessary to investigate how the new science syllabi were being taught in the classrooms. This required recording of the classroom observation by means of a video camera so that they can be analysed thoroughly. Except in few instances, the cameral is able to capture everything happening in a lesson.

**Population and Sample**

The population of the study includes all 27 government and government- sponsored senior secondary schools in Botswana. It is hoped that a more comprehensive report will be made after data from all the 27 schools have been analyzed. The population consists of rural, peri-urban and urban schools; boarding day schools scattered across the country. The study was initiated in 2001 and is expected to be completed at the end of 2002. However, this paper is based on data that have been analyzed from 18 senior secondary schools.

In each school, three classes were selected on the basis that Forms 4 and 5 students were taking a Pure, Single or Double Science, in 80 minute lesson being conducted in the laboratory by a confirmed science teacher in any of the three sciences subjects. General request for permission to carry out the study was sent to all the 27 schools. Once granted, heads of science departments were contacted to identify teachers. A random sample of teachers was selected and the teachers concerned contacted. Then the teachers were briefed about the study. They in turn informed their classes that they would be video-recorded. Arrangements for recording were made in terms of place and time of recording and required teaching aids and materials.

The sample consisted of 54 science teachers of whom 39 were male and 15 female. Teaching experience ranged from 2 to 20 years. Each of the 54 classes consisted of 40 students (50% male and 50% female), with an average of 19 years ranging from 15-21 years. Most were form 4 classes. All the lessons were recorded in subject-specific laboratories.

**Instrumentation**

The classroom activities may be observed using either checklist, writing while listening, audio recording or video recording-forms of the case study. All these methods possess some benefits and as well as costs; the teacher's expression (eagerness, aggressiveness) as well as the student expression would be missed out in audio recording.

A video cameral was chosen for this study because of its versatility and accuracy in capturing almost all classroom activities. It would reveal the advantages of audio recording for later analysis and also adds a record of body language and other useful indicators. It also gives a wealth of material that can later be used to construct a video film that helps to effectively disseminate the results of the study. The researchers recorded the lessons after receiving professional training in using the video camera. Training involved focusing on every possible activity as well as the operation of the video tape recorder, its installation and manurverbilty in the class. Tape recording was ruled out because it only records the activities that are focused on, rather than all the activities that take place in the classroom during a lesson. Writing on paper in the classroom was also ruled out because the researchers would not be able to note all the activities that take place in an 80-minute lesson.

The video camera was turned on at the beginning of the lesson and turned off at the end without interfering with the normal activities of the lesson. The researchers did not talk or comment on what the students were doing during the lesson. Teachers were briefed on what was going to take place before the recording started and were assured that they would receive a copy of recorded videocassette at the end of the study.

**Results of the Study**

The recorded lessons were analyzed involving several processes. Firstly, each videotape was transcribed verbally in terms of what was said by the teacher students. Every activity that was undertaken by both the teacher and students was transcribed. After the transcription, the lessons were then analyzed descriptively in order to provide answers to the research questions. The lessons fell into three major categories: (i) Demonstration, (ii) Laboratory, and (iii) Theoretical Presentation. Details and examples of each will be given in a final project report. Here below is a summary of each and overall results.

*(i) Demonstration*

In a demonstration lesson, the teacher introduced the topic and invited the class to come forward and observe phenomena that he /she performed in their presence. In most cases, the teacher explained to the class each step of the procedure he/she was following, giving reasons and stating precautions. After the demonstration, students were asked what they observed happen. This led to a series of questions and answer session. In few cases, one or two students were asked to repeat the demonstration. This was followed by theoretical discussion of the underlying principles. In few cases, the students were asked to write up the demonstration as if they had carried out. Notes were given and the lesson concluded with the giving of homework. In this case, demonstration was an end in itself. This was commonly done in Double and Single science Lessons.

In two lessons, demonstration preceded practical work. In this case, demonstration helped students to carry out their own experiments.

*(ii) Laboratory*

In a laboratory lesson the teacher gave a brief introduction and instructions on what the students were to carry out in their investigations. In most cases, the instructions were given as handouts. In some cases, they were written on the chalkboard. In few cases they were dictated. Students were asked to work in-groups of 3-8, depending on the size of the class and availability of equipment. Members of the groups were asked to collect equipment and materials from the teacher's counter. While groups were performing the experiments, the teacher walked around assisting them in their work. In most cases two or three members of the group performed the procedures while others observed or recorded results. At the end of the practical work, one member of each group reported the results and made conclusions of their experiments in front of the class. This usually provoked some discussion, particularly if the results were inconclusive. At the end of the practical work, the teacher or students summarized the lesson. In most cases, home work was given.

This type of lesson was common in Pure Science lessons. This is because students are required to take practical examinations at the end of form 5. Despite this, the lessons fell far too short in inculcating the four major process skills of using and organising techniques, apparatus and materials, observing, measuring and recording, handling experimental observations and data and planning Investigations. Students followed the experimental procedures given by their teachers.

*(iii) Theoretical Presentation*

The most common lesson was purely theoretical in which the teacher simply lectured to the students who took notes. Question and answer session and some discussion were encouraged. This type of lesson was dry and boring. The use of visual aids was minimal. A lot of notes were either dictated to students or written on the chalkboard for them to copy.

The results showed the following trends in the 54 lessons:

1. Most of the science teachers did not employ the prescribed learner-centered approach in the senior secondary schools science lessons. Only three experienced and expatriate teachers were employing it.
2. Most of the school laboratories were not fully equipped in terms of equipment, furniture, specimen, apparatus, chemicals, etc.
3. Most of the school laboratories were either in disrepair or under construction, as a result, some lessons were held in inappropriate rooms.
4. Schools did not have qualified technicians or at least laboratory assistants to manage the laboratories or assist teachers in class. This is because the schools have not been permitted to high such calibre of people.

5. The science teachers showed little evidence of adequately doing pre-planning for learner-centered approach activities. They did not show any evidence of having a lesson plan in class, except for lesson notes.
6. There was evidence of mixed-ability and differentiated learning approaches in which students took either core or core plus extension content in Pure Sciences of Biology, Chemistry and Physics, Double Science and Single Science. In very few cases students were allowed to work independently or in small groups.
7. Most of the science teachers did not use a variety of highly recommended teaching methods such as inquiry, demonstration, practical work, project work, case study, field trips, discussions, computer guided learning.
8. In most lessons, there was little evidence of increased participation in class of all groups of learners.
9. In some instances, students were being exposed to practical application of science in everyday life, through using the local environment and context.
10. Most of the teachers were not making effort to inculcate the recommended processes skills of using and organizing apparatus and materials, collecting data, handling experimental observations and data, and planning for investigation. Those who did, were very successful in achieving their objectives.
11. Most of the teachers carried out demonstrations as an end in themselves or in preparing the students to carry out their own group or individual practical work.
12. Most of the teachers effectively used a variety of teaching aids in their lessons. These were both commercially and teacher-made aids.
13. The skill of asking questions and giving well-thought out answers was not being developed in students. Most of the questions asked by teachers and students were of low order level.
14. Most of the teachers did not provide a conducive environment for asking and answering questions during the lesson.
15. Since BGCSE syllabi has more content than its predecessor did COSC, science teachers tended to rush through the new syllabi, which must be completed in two years.
16. Despite the insistence of the BGCSE syllabi that hands-on type of learning be implemented, most science teachers did not practice it.
17. Most of the science teachers were not implementing the recommended assessment procedures for course work.

**Recommendations**

1. The in-service unit of the Ministry of Education, should equip science teachers in order to employ the prescribed learner-centered approach; involving laying emphasis on the science process skills, problem-solving skills and the acquisition of hands-on experience; teacher-centered or a mixture of the two approaches is not being practiced in the senior secondary schools.
2. The University of Botswana should prepare student teachers in order to employ the prescribed learner-centered approach; involving laying emphasis on the science process skills, problem-solving skills and the acquisition of hands-on experience; teacher-centered or a mixture of the two approaches is not being practiced in the senior secondary schools.
3. The Ministry of Education should revamp science laboratories in terms of their structures, furniture, materials and chemicals and human resources so that teaching and learning can take place more effectively.
4. The recorded lessons in this study should be used in both pre- and in-service teacher training programmes so that they can learn from the strengths and weaknesses of other teachers.

## Bibliography

Ade-Ajayi, J.F. Goma, L. K.H., Johnston, G. A. (1995). The African Experience with Higher Education. The Association of African Universities. James Currey. London.

Armstrong, T. (1994). Multiple Intelligence in the classroom. Alexandria, Virginia

Barbara L. McCombs and Jo Sue Whisler. (1997). The Learner-Centered Classroom and School: Strategies for Increasing Student Motivation and Achievement. Jossey-Bass Publishers. San Francisco

Bell, J. (1999). Doing Your Research: A guide for first-time researchers in education and social science (3rd ed.). Open University, Buckingham.

Cohen, L. (1976). Educational Research in Classrooms and Schools: A Manual of Materials and Methods. London: Harper & Row.

Coombe, T. (1991). Consultation on Higher Education in Africa: A Report to the Ford Foundation and the Rokefeller Foundation. Institute of Education, University of London.

Duminy, P. A., MacLarty, A. H., & Maasdorp, N. (1992), Teaching Practice. Longman Teacher Training Series. Maskew Miller Longman.

Flander, N.A. (1970). Analysing Teaching Behaviour. Cambridge, MA: Addison-Wesley.

Galton, M. (1978). British Mirrors. Leicester: University of Leicester School of Education.

Letsholo, D. (1995). An Analysis of Process Skills in Science Lessons in Botswana Primary Schools. Unpublished Masters Project. University of Botswana.

Louis Cohen and Lawrence Manion. (1994). Research Methods in Education. Fourth Edition. Routledge. London and New York.

Madome, S. (1998). Primary Teachers' College Graduates Utilisation of Teaching Methods in Botswana Classrooms. Unpublished Masters Thesis. University of Botswana.

McCombs, B.L and Whisler, (1977). The learner-Centered Classroom and School. (5th ed.). Jossey- Bass, San Francisco.

Maluke, K. ; Modise, T. & Yandila, C. D. (2001). A Paper presented at the Biannual National Conference on Teacher Education, held at Tonota College of Education in August, 2001.

Mogapi, M. & Yandila, C. D. (2001). Assessment on the New Senior Secondary School Syllabuses. A Paper presented at the Biannual National Conference on Teacher Education, held at Tonota College of Education in August, 2001.

Nyerere, J.K. (1968). "The Role of Universities in Development". In Nyerere, J. K. Freedom and Socialism. Dar es Salaam. Oxford University Press.

Ogunniyi and Ramorogo. (1994).Relative effects of a micro-teaching programme on pre- service Science teachers classroom behaviour. Southern African Journal of Mathematics and Science Education. Volume1, Number2

Piaget, J. (1952). The Origin of Intelligence in Children. New York: International University.

Pitso, K. M. (2001). Comparison of the Old and New Biology Syllabi. Unpublished B. Ed (Science) Project. University of Botswana.

Prophet R.B. (1994). Language, learning and Conceptual Development in Secondary School Science in Botswana. Southern African Journal of Mathematics and Science Educatiion. Volume1, Number2

Prophet, R. B. and Rowell, P. M. (1993). Coping and control: science teaching strategies in Botswana. Quantitave Studies in Education. Volume6, Number3

Rammung, L. (2000). Course-work Assessment in the New Senior Secondary School. Unpublished B.ED. (Science) Project. University of Botswana.

Rantabe, D. (1992). Teacher Behaviour in the Classroom: An Analysis of Primary School Science Teaching in Botswana.Unpublished M.Ed Thesis. University of Botswana.

Regan, W. B. & Sheperd, G. D. (1971). Modern Elementary Curriculum (4th edition), New York, Holt, Rinehart and Winston, Inc.

Republic of Botswana, (1976). National Commission on Education. Gaborone: Government Printer.

Republic of Botswana, (1991). National Development Plans Numbers 1-8. . Gaborone: Government Printer.

Republic of Botswana, (1993). National Commission on Education. Gaborone: Government Printer.

Republic of Botswana, (1994). Government Paper No. 2. The Revised National Policy on Education. Government Printers. Gaborone.

Republic of Botswana, (1994). Revised Policy on Education. Gaborone: Government Printer.

Republic of Botswana, (1997). Curriculum Blueprint. Curriculum Development & Evaluation

Republic of Botswana, (1997). Senior Secondary School Biology Syllabus. Government Printer. Gaborone

Republic of Botswana, (2000). Senior Secondary School Syllabus: Double Science Award. Gaborone. Government Printer.

Republic of Botswana, (2000). Senior Secondary School Syllabus: Single Science Award. Gaborone. Government Printer.

Republic of Botswana. (1997). Curriculum Blueprint. Government Printer.

Republic of Botswana. (1997) National Development Plan, 1997/98 – 2002/3. Government Printer.

Republic of Botswana. (1997). Education for Kagisano: Report on the national commission on Education. Government Printer.

Republic of Botswana: (1997). Senior secondary school Biology Syllabus. Government Printer.

Shulman, L. S. (1986). Those who understand: A Conception of Teacher Knowledge. Educational Researcher, 15 (2), 4-14

Simon, A. and Boyer, E. (1975). The Reflective Practitioner. New York: Basic Books.

Tabulawa, R. (1998). Teachers' Perspective in Classroom Practice in Botswana: Implications for Pedagogical change. In Yandila, C. D., Mensah, J., Kakanda, A. M., Moanakwena, P., O'Mara, F. R. (Eds.). Improving Education Quality for Effective Learning: The Teacher's Dilemma. Ministry of Education, Gaborone. Pp110-114.

Visser, J. (1993). Differentiation: Making it Work: Ideas for Staff Development. NASEN: Tamworth.

Walters, R. A. (1993). Micro-teaching and Teaching Practice: A Guide for Students Teachers. Longman Teacher Training Series. Maskew Miller Longman (Pty) Ltd.

Wragg, E. C. and Kerry, T. L. (1978). Classroom Interaction Research. Rediguide 14. University of Nottingham School of Education.

Yandila, C. D. (1995). Teaching Science in Botswana. Printing & Publishing: Gaborone

Yandila, C.D. (1999). Implementation Hiccups of Senior Secondary_Syllabus in Botswana. Paper presented at the eighth Symposium of International Organisation for Science Technology Education held in Durban, 1999.

# 008 PROCESS SKILLS IN BOTSWANA PRIMARY SCHOOL SCIENCE LESSONS

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**Abstract**

The purpose of this study was to investigate whether primary school teachers in Botswana use process skills in their teaching of science and whether pupils were able to demonstrate the acquisition of certain process skills as they tackled various tasks. A classroom observation instrument was developed to assess aspects of process skills of science observable in science lessons. Twenty-seven teachers participated in the study and were from Gaborone, Ramotswa, Lobatse and Molepolole.

*The results of the study showed that pupils in the lower classes used skills for learning science better than the pupils in the upper classes learn. The results also showed that teachers adopted the traditional chalk and talk method. The study also showed the lack of texts in the upper classes that emphasised process skills. The lack of the references might exacerbate the problem of teaching by the lecture method. There were no guidelines on activities that pupils can do.*

## Introduction

The emphasis placed on various goals of science education has changed throughout the history of science teaching. There is time when teaching of content of science was emphasised. At other times, teaching of the development of scientific attitudes was emphasised (Johnson, 1962; Rowe, 1976; Taiwo, 1981; Yandila, 1995). During the past three decades, science educators have expressed concern that science teachers and curriculum developers tend to emphasise one of these components to the detriment of others. This has resulted in a distortion of the actual nature of the scientific enterprise (Robinson, 1965; Robinson, 1969; Carey and Stauss, 1970).

In the early 1960s there was a proliferation of new science programmes. This was a manifestation of a shift in emphasis of teaching from content to process skills. Scientists themselves questioned whether previous school science courses were truly representative of science (Hurd, 1969). This was the turning point from the content-led curriculum to a process-led curriculum for science teaching.

The science education movements in the West and their activities have had a significant impact on science teaching worldwide especially with curriculum development. Whether it is the current theme of "Science for all" or general science, integrated science, modular science, they all have their original roots in the West (Ogunniyi, 1993).

Several studies in the West have indicated that science teachers who are proficient in process skills use strategies that give children's opportunities to learn those skills (Tamir and Lunetta, 1979; Wellington, 1987; Harlen, 1985, 1990). Other studies have shown that knowledge of science processes is positively related to student's achievement (Roth and Raychoudhury, 1993).

Africa, Botswana in particular, has not been all together inactive. The emphasis on the teaching and learning science process skills in primary schools and teacher training colleges began in 1990. In 1989 the science panel developed a curriculum for the Teacher Training Colleges (P.T.T.C). Qualified teachers from these colleges were to impart process skills to their primary school students. The eight selected skills are observing, interpreting, hypothesising, raising questions, investigating, measuring, communicating (Harlen and Russell, 1990). One wonders whether these process skills were effectively been implemented in Botswana? This question forms the central concern of this study.

Science has been defined differently by different scholars. Some define it as a search for explanations of events in nature Gagne (1965), Schwab (1962). Others define it for its facts, ideas, laws and theories Ogunniyi, (1986). Others still define it in terms of content, processes and ethics (Yandila, 1995). Science can also be defined as processes that relate scientific activities. Such activities include observation, classification, measurement, prediction, hypothesising, **etc.** The processes of science are procedures which scientists employ in the formulation, verification of generalisations in nature (Yandila, 1995). Process skills are scientific activities that facilitate the meaningful understanding of ideas. Peacock (1986), pointed out that these skills help to stimulate the development of a curious and questioning attitude so that children can begin to understand fully their environment.

Most studies on the teaching of science have been done in the West. A few studies have been carried out in Africa for example Ogunniyi (1984), Okebukola and Ogunniyi (1984, 1986), Harlem (1985), Prophet and Rowell (1990), Putsoa (1992), Rantabe (1992), Madome (1998), and Thapisa (1995).

**Statement of the problem**

The purpose of this study was to find out if teachers employed these process skills in the classroom situation. Specifically, the study sought answers to the following questions:

1. To what extent do the primary school teachers use process skills in the teaching of science in the class?
2. What aspects of process skills of science are observable in science lessons?
3. Are pupils able to demonstrate the acquisition of certain process skills as they tackle various tasks in class?
4. Are materials used in science classroom appropriate and adequate enough to facilitate the learning and teaching of process skills?

**Focus of the Investigation**

The literature reviews show that a variety of research instruments exist for assessing different perspectives of scientific process skills amongst, teachers, as well as pupils. Where assessments in process skills are concerned, the range of instruments developed aimed at investigating abilities to identify different process skills. Others focused on the application of process skills on different situations. Therefore, information about their development can be gathered from a wide range of activities. This information can be obtained by either observing both the teacher and the pupil when they are carrying out activities and/or developing test items that measure the process skill. The present study was of the first type (identifying process skills). It focused on both the teacher and the pupils, the purpose being to document the extent to which teachers used process skills in their teaching and the extent to which the pupils exhibited them.

**Procedure**

This study set out to assess the extent to which the primary school teachers in Botswana were able to use process skills in the teaching of science. A series of steps was taken, and included designing of a classroom observation instrument and teacher's questionnaire, determining their validity and reliability, selection of the population and sample, obtaining permission to conduct the study in the schools, classroom observation, administration of the teacher's questionnaire and analysis of data.

The sample of the study constituted 27 teachers and 27 classes with 38 pupils each. Five schools were randomly selected and in each school two classes were also randomly selected. The school selection process was to achieve a sample that would be representative of all school types. That is new and old, large and small schools existing in the country. The total sample constituted of 27 teachers and 27 classes each with 38 pupils.

There being no appropriate instrument, two instruments were constructed by the investigators and used for the study: (a) A classroom observation technique schedule and (b) Teacher's questionnaire. Both instruments were developed and validated to suit the kind of study undertaken. Both instruments sought to answer the four research questions for the study.

**Classroom Observation Instrument**

The classroom observation instrument comprised seven skills to be observed. They consisted of observation, interpretation, investigation, measurement, hypothesis, raising questions and recording/communication. Each skill was divided into five sub-skills. These skills were assessed by observation during science activities. The instrument was a modification of Flander's (1970) interaction analysis. Flander's interaction analysis is a systematic approach to analyse verbal classroom interaction in three-second unit intervals. The instrument is confined to only verbal behaviours that form the two categories that make up the instrument as (a) teacher's verbal behaviour and (b) student's verbal behaviour. Flander's interaction analysis instrument lacks the non-verbal aspects that are crucial in practical science activities. The instrument was modified to suit the present study by creating components of the instrument as sub-skills to be observed. During observation certain activities (making tallies) were ticked every minute they occurred during the lesson.

**Teacher's Questionnaire**

The teacher's questionnaire was designed to find information to answer the research question number four that is "Are the materials used in classroom appropriate and adequate to facilitate the learning and teaching of process skills?" Which could not be answered by the use of a classroom observation instrument. It also sought some demographic information and methods used in teaching science.

**Validity and Reliability of Questionnaire and Classroom Observation Instrument**

A panel of science educators in the Department of Mathematics and Science Education of the University of Botswana was asked to view the instruments, and find out if they were liable to collect data of the study. Some modifications were made. A pilot study was conducted to determine the reliability of the instrument. Four teachers from the two primary schools and about 120 pupils were used. The purpose was to determine if items on the classroom observation instrument and the questionnaire could be used.

**Data collection and analysis procedure**

Permission to carry out the study in the selected schools was sought from the Regional Education Officer of the Ministry of Education, and was granted. After the permission was granted, contacts were made with the heads of schools for the sake of making observations at the scheduled dates. Individual teachers were observed and all pupils in their classrooms. The lessons observed lasted for 30 minutes each. All the lessons were in the morning. The questionnaire was distributed to the various teachers observed. Each observation and questionnaire sheet was coded according to the name of the school and district. The frequency counts were also converted to percentages.

**Results and Discussion**

The results of the present study are organised and presented in four sections. The first section deals with comparisons of major process skills. The second section deals with comparisons within each skill. The third section deals with comparisons of major process skills by type of class (upper or lower). The fourth section deals with the analysis from questionnaire responses.

The data are presented in frequencies and percentages and additional information about the questionnaire responses is presented in a descriptive form. For ease of interpretation and presentation of data, the different aspects of skills were analysed per skill. Then the comparison was later made for all the skills. This was done to map out the difficulty levels of each skill from the pupil's point of view. In the following tables, the letters in the key represent the skills indicated.

*1. Comparison of Major Process Skills*

This section deals with the descriptive analysis of the seven major process skills, namely observation, interpretation, investigation, measurement, hypothesis, raising questions and communication. The occurrences are for each activity for each observation and for each skill as shown. As the table is examined, the mean percentage of the skills of observation is highest while the skills of recording and communication ranked second highest. The results indicated that the teachers used the skill of observation by the magnitude of 31.9% followed by the skill of recording and communication with 26.7%. More aspects of the skill of communication are hidden behind the skill of observation where more talking was done between teachers and pupils as lessons progressed.

The skill of investigation followed with 20%. This skill dominated most of the upper classes as pupils carried out some experiments. The lower class's performance in the skill of investigation was low as compared to the upper classes, because pupil's manipulative skills are less developed and they could not think rationally. The skill of hypothesising was used by 7.8% magnitude, measurement 6.5% Interpretation 5.9% and Raising questions by 0.6%. This was the least skill used by pupils because only one teacher encouraged the pupils to ask questions.

**Table 1:** A Comparison of Acquisition of Science Process Skills.

| PROCESS SKILLS | Frequency | % |
|---|---|---|
| **OBSERVATION** | | |
| 1. Features using senses | 265 | 10.6 |
| 2. Notice details of objects | 119 | 4.7 |
| 3. Focus on observations | 130 | 5.2 |
| 4. Notice differences | 175 | 7.0 |
| 5. Notice similarities | 110 | 4.4 |
| **SUB TOTAL** | **799** | **31.9** |
| **INTERPRETATION** | | |
| 1. Associating a factor with another | 104 | 4.1 |
| 2. Interpret available data | 31 | 1.2 |
| 3. Check interpretation against new data | 5 | 0.2 |
| 4. Interpretation on relationship | 5 | 0.2 |
| 5. Justify prediction on investigation | 5 | 0.2 |
| **SUB TOTAL** | **150** | **5.9** |
| **PROCESS SKILL** | | |
| **INVESTIGATION** | | |
| 1. Initial actions relevant to investigation | 95 | 3.8 |
| 2. Carrying out manipulation | 195 | 7.8 |
| 3. Identifying variable measured | 130 | 5.2 |
| 4. Select and use measuring instrument | 25 | 1.0 |
| 5. Working with appropriate precision | 25 | 2.2 |
| **SUB TOTAL** | **500** | **20.0** |

| | | |
|---|---|---|
| **MEASUREMENT** | | |
| 1. Comparison (using non- standard unit) | 28 | 1.1 |
| 2. Comparison (standard -- unit used | 56 | 2.2 |
| 3. Select measuring unit | 26 | 1.0 |
| 4. Measurement of relevant variable | 10 | 0.4 |
| 5. Improve accuracy by repeating measure | 4 | 1.8 |
| **SUB TOTAL** | **166** | **6.5** |
| **HYPOTHESIS** | | |
| 1. Mention relevant features for explanation | 105 | 4.2 |
| 2. Explanation: Scientific knowledge | 50 | 2.0 |
| 3. Application of previous knowledge | 35 | 1.4 |
| 4. Tentative nature of explanation | 0 | 0.0 |
| 5. Concept/skills for designing investigations | 5 | 0.2 |
| **SUB TOTAL** | **195** | **7.8** |
| **RAISING QUESTIONS** | | |
| 1. Ask any questions | 15 | 0.6 |
| 2. Question in the form to be investigated | 0 | 0.0 |
| 3. Scientific Skill/Simple question | 0 | 0.0 |
| 4. Answered by investigation | 0 | 0.0 |
| 5. Reformulating of a question | 0 | 0.0 |
| **SUB TOTAL** | **15** | **0.6** |
| **PROCESS SKILL** | | |
| **RECORDING/COMMUNICATION** | | |
| 1. Talking, Listening/Writing ideas | 501 | 20.1 |
| 2. Making note of observation | 110 | 4.4 |
| 3. Using charts conveying information | 35 | 1.4 |
| 4. Choosing charts to convey information | 15 | 0.2 |
| 5. Providing written account | 5 | 0.2 |
| **SUB TOTAL**<br>**GRAND TOTAL** | **666**<br>**2491** | **26.7**<br>**100%** |

*2. Comparisons Within each Skills*

The aspect of features using all senses was rated the highest of all the five aspects of the skill of observation at 10.6%, followed by notice of differences' 7.0% and least being notice of differences' 4.4%, a point observed by Harlen et all 1989. This indicates that pupils have a problem in identifying similarities between objects as they make observations when they tackle various activities.

The above mentioned is akin to the lecture method, which dominated most of the upper classes. Teacher-talk method confined pupils to observing and listening passively without engaging in activities that is what science lessons should be like. The contention here is not an outright rejection of the lecture method. It is a useful method that could provide the necessary theory to practical activities. A collaboration of a variety of methods is necessary for effective teaching because not all students learn equally through the same strategy. Aspects of this skill of observation were also found to be interwoven in other skills, because almost any scientific activity begins with "observation" and so it is an integral part of the other process skills (Harlen, 1992).

The first aspect of associating a factor with other is the dominant one in the skill of interpretation. The rest are really not significant since they were rated at 0.2% magnitude. Pupils were able to associate factors, and failed to find relationship, interpret available data and new data. The skill proved to be of a high order level of thinking to pupils, since it could not be used fully.

The second aspect of carrying out the manipulation of objects of the investigation was the highest used by 7.8%. This indicates that pupils found it easy to manipulate objects as they tackled various activities assigned by teachers. The fourth aspect that is select and uses measuring instruments was attained least at 1.0% of all the five aspects. This indicates difficulty in selecting appropriate instrument too. The instruments used in investigation were only those selected by the teacher, which also reflects teacher dominance on science lessons.

The measurement skill was lowly used at 6.5% magnitude. All aspects demonstrated, ranged among 0% - 2%. The best that is measuring using standard unit was 2.2%. The third aspect that is selecting measuring instrument was 1.0%, which indicates that pupils have problems of selecting instrument on their own, is very synonymous with the previous skill, where pupils could not select instruments to investigate.

The first aspect of mentioning relevant features in an attempt to explain idea was highly rated at 4.2%. The rest were difficult for the pupils since they could not be used as pupils tackled the science activities. Pupils could only mention the features and could not explain or reason scientifically. One explanation of such a behaviour is that the methods adopted by teachers when teaching science are such that pupils are offered few changes to show initiative or even a speculative thinking.

Raising questions was the least use skill. Just one teacher encouraged pupils to ask questions, but even then pupils could not ask questions that could be answered by investigation. This would probably be the most dominant skill because its first aspect of talking, listening and writing ideas was hidden in the other skill of observation, where talking and listening was dominant. This first aspect was rated 20.1% that shows teacher dominance of the classroom lessons, where children are passively listening and writing notes without questioning. These results agree with those in the study of Tawana and Yandila (2001). The study revealed that (i) pupils and teachers were aware of the problems associated with asking and answering questions, (ii) most pupils had difficulties to communicate in English, (iii) both pupils and teachers tended to ask low-order questions, and (iv) most pupils were not encouraged by their parents to develop communication skills.

The data reveals that the first and the second aspect in each skill were utilised most. In most cases the last three aspects were least used. This shows a low level of sophistication when going down and very easy aspects at the top that creates a hierarchy level in the acquisition of skills.

*3. Comparison of major process skills by type of class (upper or lower)*

Table 2 indicates a comparison of skill performances in the lower-classes (Standards 1-4) and in the upper classes (Standard 7). This table reveals the dominance of the lecture method by teachers in the upper classes and the learner-centredness adopted in the lower classes. Pupils reveal this in the percentage acquisition of skills in the lower classes as compared to the upper classes. The results revealed that skills were incorporated most in the lower group than in the upper group. Teachers in the upper classes tend to lecture, and give notes to the pupils, most of the time. Pupils too, tended to respond either by answering recall questions or listening passively.

Although this kind of results is not expected in a normal science lesson, they have been found in many studies. For example Ogunniyi (1984) found that the teacher dominated verbal behaviour in science lessons. Students in the lower classes performed better than the upper classes because they were engaged in science activities and thus exposed to "hands-on" experience. Rantabe (1992) also fond the dominance of teachers in science lessons. Likewise, Maluke, Modise and Yandila (2001) found that, despite the insistence on learner-centredness of the new syllabus, teacher dominated in senior secondary school science lessons. Students were almost passive, except in few instances.

Pupils' observational and experimental skills can be greatly enhanced when they have the opportunity to interact with the teacher and the materials in a non-threatening way. Where teachers dominate, learning is reduced to rote activities.

**Table 2:** A comparison of skill acquisition between the lower classes (Standard 1-4) and the upper classes (Standard 5-7).

| SKILL | Lower | Classes | Upper | Classes | Total Counts |
|---|---|---|---|---|---|
| | Counts | Percentage | Counts | Percentage | |
| Observation | 539 | 67 | 260 | 32.5 | 799 |
| Interpretation | 130 | 86.3 | 20 | 13 | 150 |
| Investigation | 245 | 49 | 255 | 51 | 500 |
| Measurement | 105 | 63.2 | 61 | 36.7 | 166 |
| Hypothesis | 120 | 61.5 | 75 | 38.4 | 195 |
| Raising | 0 | 0 | 15 | 100 | 15 |
| Questions | 380 | 57 | 241 | 36.1 | 666 |

<u>Key:</u> Questions* Recording/Communication

One is compelled to think that hypothesis is a more challenging skill, and expect the upper classes to perform better in it. The results above revealed that the lower classes still excel in the skill of hypothesising, a point observed by Le Butt (1992);

> ... Even in the third grade students can for example, hypothesize how much their plants will grow and then check the hypothesis several weeks (p.14).

The overall result in this study indicates that the process skills are used in the teaching of science in the Botswana Primary Schools. Even, then, the trend or extent of usage differs between the lower and upper classes. The lower classes were engaged in activities where they exhibited the skills, as they manipulated objects. The upper classes were taught by the lecture method. And, most of the time, the pupils did not participate except to listen passively. This makes science lessons boring and not exciting as they are intended to be.

*4. Analysis of questionnaire Responses*

The fourth section deals with the analysis of the questionnaire responses from teachers. The questionnaire sought to find out the methods used by the teachers when teaching science. This would help to tell the extent to which the primary school teachers used process skills in the teaching of science. The other thing the questionnaire sought to find was whether teaching materials were available and enough to facilitate the learning of science. Information on teaching methods, reasons for liking science and the availability of teaching materials are presented as teachers gave it. The demographic information was used to describe the population and sample.

All the 27 teachers responded to the questionnaire stated that the schools had enough materials to be used for science experiment in each of their schools. Despite the availability of teaching materials in schools, upper class-teachers still preferred to use the lecture method, much more than the other methods. One is tempted to argue that perhaps the lecture method was adopted as a way to cover the syllabi in the shortest time possible in order to prepare pupils for national examinations. Some teachers thought that the lecture method was adopted to avoid unnecessary interruptions and noises that could incur through group work when pupils are engaged in experiments.

The most common reference books available in schools were "Break through to science" by Sylvia Witt (1989) and "Macmillan science for primary school" by Nicholson (1989). The former was used in all schools in lower standards and the latter by upper standards. Some schools did not have this. There were a few cases where teachers referred to only to the syllabus and their notebooks. Some teachers expressed that they did not know how to use textbooks, especially the new one on "Breakthrough to science" while the latter was used in the upper classes.

Question number five sought to find out which method was employed most by teachers. Almost all, teachers claimed that they used the inquiry method, which encourages process skill attainment. This was contrary to what was observed in class. And unfortunately no teacher mentioned that they used the lecture method. Teachers find it difficult to adopt new strategies in their teaching. Hence they stick to the traditional method of teaching which is talk and chalk or the lecture method despite the weakness of that method of teaching. Indeed the new science curricular invariably demands a more pragmatic approach than the usual teacher dominated lesson. Six teachers indicated that they incorporated process skills in their teaching of science.

Out of 27 teachers, two denied being trained in the method they used in class. The rest admitted that they were trained in the method they used. This indicated that Teacher Training Colleges trained teachers to use scientific method of teaching science. The reason teachers preferred to use the lecture method to others could not be due to lack of exposure in their training.

Only one teacher indicated that she had attended a workshop on the teaching of science. The rest had not attended a workshop on the teaching of science that is after training, there has never been any inservice whatsoever. This might be lack of personnel forum such workshops, time, and financial constraints.

Table 3 shows the reasons given by teachers, on "Why science lessons are meaningful and enjoyable?" These are ranked sequentially according to the most frequent.

**Table 3:** Analysis have reasons, "why science lessons are meaningful and enjoyable."

| | REASONS | % |
|---|---|---|
| 1. | Pupils do what they already know from the environment | 14.5 |
| 2. | Science teaches pupils important skills. | 12.9 |
| 3. | Pupils are encouraged by reaching conclusion as they carryout experiments | 12.9 |
| 4. | In most science lessons, pupils make experiments. | 12.9 |
| 5. | Science helps pupils solve simple practical problems. | 9.7 |
| 6. | Pupils use all their five- (5) senses when studying science. | 4.8 |
| 7. | Pupils observe things and think for themselves. | 3.2 |
| 8. | Science promotes the skills of life. | 3.2 |
| 9. | Science is a child-centered subject. | 3.2 |
| 10. | Pupils understand most when doing science. | 3.2 |
| 11. | Science develops pupil's manipulative skills. | 1.6 |
| 12. | Pupils are aware of how science correlates with other subjects | 1.6 |
| 13. | Pupils share ideas as they tackle various tasks. | 1.6 |

From the above reasons, it could be concluded that teachers have some ideas the nature of science. That is, science is about practical skills in the environment. From the responses of teachers it can be argued that teachers are aware that science is a child-centred subject, even though in practice it is teacher-centred.

## Conclusion

The primary aim of the study was to investigate whether primary school teachers in Botswana use process skills in their teaching of science, and whether pupils were able to demonstrate the acquisition of certain process skills as they tackled various tasks. With this aim in mind, a classroom observation instrument was developed to assess aspects of process skills of science observable in science lessons. Twenty-seven teachers participated in the study and were from Gaborone, Ramotswa, Lobatse and Molepolole.

An analysis of the results shows that pupils in the lower classes used skills for learning science better than the pupils in the upper classes learn. One is obliged to argue that the pupils in the lower classes did not only acquire skill but also enjoyed their lessons. This shows that pupils' involvement somehow determines their interest and motivation in the lesson. The results also reflected a view of learning in the upper classes in which the teachers adopted the traditional chalk and talk method. In this kind of situation the teacher is the initiator of knowledge while the pupils are passive recipients. These results are similar to the studies carried out within the Botswana primary and secondary schools by Rammung (2000), Rantabe (1992), Maluke, Modise and Yandila (2001), Tawana (2001), Mogapi and Yandila (2001). It is sad that despite claims of change in teaching orientation in the new syllabuses at both primary and secondary school level, teaching is still teacher-dominated.

### Implication of the study

The outcome of the study has revealed that though the process skills are used in the teaching of science, some of their aspects are not fully utilised. For example, the study revealed that children's observation skills are underused; children are capable of seeing detail and detecting sequences in events, but fail to notice these things unless they are brought to their attention.

Observation is an important means by which we gather information about the world around us. Therefore, teachers need to develop this skill amongst children so that they can effectively learn directly from the objects and materials around them. Concerning the skill of hypothesising the results revealed the tendency of pupils not to continue any further than stating relevant ideas or procedures, without describing, justifying or explaining the relationship between the scientific ideas and the event. One is compelled to think that this was because hypothesising is a higher order skill, but despite this fact, Putsoa (1992) found the same observation in Swaziland working with high school leavers.

Raising questions was the least use skill. The low performance in this skill indicated that pupils were not encouraged to ask questions by their teachers, because children learn their question asking habits from teachers, If there are to be encouraged to raise questions, then teachers must make an effort to ask questions. The general performance throughout the seven process skills indicated that the majority of the pupils were unable to demonstrate ability for rational thinking. Therefore teachers need to provide a climate of inquiry in their classrooms for children to work in (Harlen et. al 1985). It is hoped that teachers would give more emphasis to skills that stimulate thinking of a higher order level among learners.

Although this study was carried out among the 1991 and 1993 Primary Teacher graduates, the trend of teaching could still be the same with teachers with ore experience. This view is held because there has not been any report on efforts to change existing teaching and learning styles in local schools. Workshops on new methods of teaching would help improve the situation.

## Recommendations

From the results of the present study, the following recommendations are made.

1. Science teaching-learning situations can be improved if teachers exhibit all the lesson activities in a balanced way, incorporating all skills rather than emphasising only a few skills at the expense of others.

2. Pupils should be given chance to have practical experience in the science lessons in order to acquire skills in handling apparatus and to conduct experimental investigations.
3. Pupils should be highly involved in classroom activities.
4. The Curriculum Development Unit should mount workshops for in-service teachers to up-date them on the teaching of science through process skills.
5. The workshops would also help teachers in the usage of new textbooks in conjunction with the new syllabuses
6. All classes (lower or upper) should be provided with textbooks that emphasise process skills to help learn on their own, even without the teachers.
7. Teachers are also urged to be more enthusiastic in their teaching to encourage pupil learning.

**References**

Carey, R.L. and Strauss, N. (1970). An analysis experienced science teachers' understanding of the nature of science. School Science and Mathematics. May 70:366-76.

Gagne, R.M. (1965). The conditions of learning. New York: Holt, Rinehart and Wiston.

Harlen, W. (1985). Teaching and learning primary science. London: Paul Chapman Publishing Ltd.

Harlen, W. (1992). The teaching of science. London: David. Fulton Publishers.

Harlen, W. and Elstgeest, Jos. (1990). Environmental science in the primary curriculum. London: Paul Chapman Publishing Co. Ltd.

Harlen, W. and Rusell, T. (1990). Assessing science in the primary classroom: Practical Tasks. London: Paul Chapman Publishing Ltd.

Hurd, P.D. (1969). New directions in teaching secondary school science. Chicago: Rand McNally and Company.

Johnson, P.G. (1962). The goals of science education. Theory into practice December, p239-44.

Maluke, K. ; Modise, T. & Yandila, C. D. (2001). A Paper presented at the Biannual National Conference on Teacher Education, held at Tonota College of Education in August, 2001.

Mogapi, M. & Yandila, C. D. (2001). Assessment on the New Senior Secondary School Syllabuses. A Paper presented at the Biannual National Conference on Teacher Education, held at Tonota College of Education in August, 2001.

Ogunniyi, M.B. (1984). An investigation of the nature of verbal bahaviour in science lessons. Science Education. Vol. No. 68(5): pp. 595 - 601.

Ogunniyi, M.B. (1986). Teaching science in Africa. Ibadan: Salam Media Publishers Ltd.

Ogunniyi, M.B. (1993). Policy issues in science education: The African scene. (Paper presented at the Boleswa Regional Conference Science and Mathematics, 17-21 October, University of Botswana.

Peacock. A (1986). Science skills: A problem solving activities book. London: Macmillan Education Ltd.

Putsoa, B. (1992). Investigating the ability to apply scientific knowledge though process skills among high school leavers in Swaziland. Unpublished Phil Thesis University of New York.

Putsoa, B. (1993). A Gap between the theory and practical of Science teaching and learning in Local Classroom. (A paper presented at the BOLESWA Regional Conference on Research in Mathematics and Science Education, 17-21 October, University of Botswana.

Rammung, L. (2000). Course-work Assessment in the New Senior Secondary School. Unpublished B.Ed (Science) Project Report. University of Botswana.

Rantabe, D.R. (1992). Teacher Behaviour in the Classroom: An Analysis of Primary School Science Teaching in Botswana. Unpublished Masters Thesis. University of Botswana.

Robinson, J.T. (1965). Science teaching and the nature of science. Journal of Research in Science Teaching. Vol. (3) pp.37-50.

Robinson, J.T. (1996b). Philosophy of science: Implications for teacher education". Journal of Research in Science Teaching. Vol. 6, pp.99-104.

Roth, W. and Roychoudhury, A. (1993). The development of science process skills in authentric contexts. Journal of Research in Science Teaching. Vol. 30 No. 2 pp. 127-152.

Rowe, R.E. (1976). Conceptualization of the Nature of Scientific Laws and Theories held by Middle School and Junior High School Science Teachers in Wisconsin. PhD. Thesis. Madison: University of Wisconsin.

Schwab, J.J. (1962). The teaching of science as enquiry. The Teaching of Science, edited by Schwab, J.J. and Brandwein, P.F., Cambridge: Harvard University Press.

Taiwo, A.A. (1981). Attitude Scores as determinants of teaching practice: Performances of pre-service undergraduate ScienceTeachers. Science Education. Vol. 65. No. 5 pp. 485-492.

Tamir, P. and Lunetta, V. (1979). Matching laboratory activities with teaching goals. The Science Teacher. Vol. 46, No. 5, pp.22-24.

Tawana, C. & Yandila, C. D. (2001). Classroom Communication: Questioning and Answering Skills in Science Lessons. A paper presented at the 9th Boleswa International Educational Research Symposium at the University of Botswana. July 28-August 4, 2001.

Wellington, J. (Ed). (1987). Skills and processes in science education:A critical analysis. London: Routledge, Mackays of Chatham.

Yandila, C. D. (1995). Science Teaching in Botswana. Gaborone: Printing and Publishing Company.

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# COGNITIVE LOAD IMPOSED BY INTEGRATING INFORMATION AND COMMUNICATION TECHNOLOGY IN A TEACHER EDUCATION COURSE

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## Abstract

Prospective teachers necessarily need formal training in integrating different technologies in the teaching-learning environment. In this paper, we report on findings regarding primary student teachers' attitudes about the use of technology in education, their frequency of software use such as the Internet and Hyperstudio, and the extent to which the use of web-based tools, such as Filamentality, affected their perceived cognitive load.

Three questionnaires were administered to 41 fourth-year primary student teachers to collect data. These students were divided into two intact groups formed during registration. At the beginning of the semester, students were given a short questionnaire to indicate how frequently they used the technologies of the Internet and Hyperstudio. Students were also administered a 15-item questionnaire measuring their attitudes towards ICT and its integration in the classroom. The cognitive load imposed by technology was measured with a questionnaire, at the end of the semester, in terms of: (a) the mental effort they exerted to learn Hyperstudio, (b) the mental effort they exerted to search the Internet and collect quality information for their projects, and (c) the mental effort they exerted to design instructional activities using Hyperstudio. One group was deliberately instructed and guided to use Filamentality, and organize the information collected in a Hotlist and a Scrapbook, while the other was not. The results of the study showed that the majority of students had favorable attitudes towards technology-enhanced instruction. In addition, there were initial differences in students' frequency of using the Internet and Hyperstudio. An analysis of covariance on students' perceived cognitive load was conducted with the variables of Internet and Hyperstudio use as covariates. The difference in cognitive load between the two groups was statistically significant, with $F = 4.32$, $p < .05$, after adjusting for the differences in frequency of Internet and Hyperstudio use. Only the Internet as covariant was found to be statistically significant with $F = 4.75$, $p < .05$. Both, familiarity with Internet and the cognitive tool of Filamentality can lower the perceived cognitive load.

Clearly, the theory of cognitive load has important implications for the design of technology-enhanced learning environments. The issue of ICT integration cannot be sidestepped in educational reform efforts, and teacher educators should carefully investigate the contextual variables that accompany the integration of ICT.

## Aims and Significance

As we evolve deeper in the information age, learners and future citizens need more skills for complex cognitive tasks, but they also need support to develop a wider range of types of learning, such as emotional development, character development, and spiritual development. In the traditional paradigm of instruction, the focus was almost exclusively on the cognitive domain and within that domain the emphasis was on dissemination of information. Information and communication technology and information-age roles have made these kinds of learning less important. Higher levels of learning are continuously becoming more and more important and necessary for functioning in a modern society that is totally dominated by science and technology. In addition, interest in student-centered learning coupled with technological developments, such as the World Wide Web (WWW), have initiated a shift in instructional paradigm in ways that were previously infeasible or unimaginable. The new paradigm requires a shift from passive to active learning making it necessary to take full advantage of instructional technology, remote resources (e.g., those available through the Internet), and local real-world resources (e.g., science museums, practitioners, etc.). Instruction is thus defined as anything facilitating learners to build their own knowledge as opposed to (or in addition to) a process of merely conveying information to learners. There is thus an urgent need that must allow not only for customization of the learning experience, but also for systematic integration of ICT at all levels of education.

Integrating technology in higher education is an issue, which according to the 1998 National Survey of Information Technology in Higher Education, looms as the single most important issue confronting universities (Green, 1998). Nonetheless, it is documented that universities, thus far, have not made any real progress toward achieving technology integration in their programs since most university faculty do not use technology in any systematic way to enhance their curriculum and instructional practices (Caffarella & Zinn, 1999). As Massy and Zemsky (1995) state, most technology integration efforts at the university level have been directed toward using technology as a productivity tool or as a delivery vehicle to support existing practices. Specifically, university professors use the computer to (a) electronically process documents, (b) post information on the Internet for their students to access, and (c) exchange messages with students via email or listservs. It is a rare occasion to find a faculty member who uses the computer as a cognitive tool to cultivate learners' thinking and support their knowledge construction activities.

Attempts to integrate ICT in the teaching-learning environment are thus quite necessary especially for education departments. Prospective teachers should not only be acquainted with the capabilities of ICT, but they should have formal training about how to take advantage of different information search tools and knowledge construction tools that can easily be employed in the teaching-learning environment. Carefully designed studies should also be conducted in order to investigate different contextual constraints in integrating ICT in the classroom environment. If technology is to be effectively integrated in the classroom, then teacher educators should provide prospective teachers with the knowledge, the skills, and the confidence required to use the tools of ICT available to them. The training of preservice teachers will be pivotal in determining the future role of technology in education (Byrum & Cashman, 1993).

Within the context of tertiary education, we undertook efforts to integrate ICT in a fourth-year science education course for primary student teachers. In this study, we approached technology integration in higher education from a cognitive perspective to scaffold students' thinking and understandings. Three decisions guided our technology integration plan. First, we decided that it was important to work with affordable technologies our students could find and use in the elementary schools of Cyprus. Second, we decided to utilize the vast amount of up-to-date information found on the World Wide Web (WWW) and guide our learners to intentionally search and locate information related to the elementary science curriculum in Cyprus. Lastly, students were asked to use the information found on the web and design instructional activities using Hyperstudio, a hypermedia knowledge-construction tool.

The study we describe in this paper reports on findings about students' attitudes, when they attempted to integrate ICT in their teaching lessons, and the extent to which the use of web-based tools, such as Filamentality, affected students' perceived cognitive load. Students' frequency of using the Internet and Hyperstudio were also measured and taken into consideration. However, this study is part of a larger research study, which includes the integration of an electronic communication system for the purpose of promoting students' conceptual understanding of science concepts included in the elementary science curriculum. The effects of the communication system on students' conceptual development as well as their conceptual progress in understanding science, as it was manifested through the instructional design of various in-class learning activities, will be treated elsewhere.

**Cognitive Load Imposed by Technology Integration**

We regard the concept of cognitive load highly relevant and important to the task of integrating technology in an educational context. Cognitive load is the amount of mental energy imposed on working memory at an instance in time (Cooper, 1990). Cognitive load theory views the limitations of working memory to be an impediment to learning and attempts to improve the quality of instructional design by considering the role of and limitation of working memory (Sweller, 1994). Accordingly, instructional activities or materials can impose two types of cognitive load on learners' working memory, namely, intrinsic and extraneous. Intrinsic cognitive load is directly related to the difficulty of the content to be learned and cannot be modified by instructional design. On the contrary, extraneous cognitive load is caused by the characteristics of the instruction or the way an activity is organized and presented to the learners and it is much easier to influence. If the total amount of cognitive load exceeds learners' mental resources then learning will be impeded. When the intrinsic cognitive load is high and the extraneous cognitive load is high, then our efforts should be directed toward instructional design manipulations for lowering extraneous cognitive load so that the resulting total cognitive load falls to a level within the bounds of learners' mental resources. Any attempt to eliminate or limit the sources of extraneous cognitive load contributes to more efficient and effective instruction.

When technology is integrated in a course, there is an additional cognitive load related to technology and its integration in the teaching-learning environment. This additional load is caused by the technological tools to-be-learned (intrinsic cognitive load), and by the way these tools will be integrated in the instruction (extraneous cognitive load). If learners are not experienced users of technology, novices in other words, then technology integration will make considerable demands on learners' cognitive processing activities. In this study, we intended to manage the amount of cognitive load by integrating (or not integrating) cognitive tools in the learning environment for management of the extraneous cognitive load related to technology that may adversely affect their processing capacity. We do not argue that these tools will make the task easier, but we do argue that these tools may help learners organize their thinking processes more efficiently and effectively. The bottom line seems to clearly suggest that any decrease in cognitive load increases the portion of working memory that is available to attend to the learning process, taking into consideration that working memory is extremely limited in both capacity and duration.

**The Computer as a Cognitive Tool**

Cognitive tools or mindtools (Jonassen, 2000) engage learners in meaningful thinking to analyze, critically think about the content they are studying, and organize and represent what they know. Mindtools include various computer-based applications, which can be learned in a relatively short amount of time, such as databases, spreadsheets, information search engines, hypermedia construction tools, and others. Here, for the purposes of the current study, we focus only on the two types of tools, namely, intentional information search tools and knowledge construction tools that were employed in the present study.

*Information Search Tools*

Undoubtedly, the WWW has so many interesting topics to explore that it is easy for learners to loose awareness of where they are in hyperspace and what links they followed to get there. Moreover, for learning purposes a bigger problem is that learners may feel overwhelmed by the vast amount of information found on the web and thus fail to integrate and synthesize new information with their existing knowledge. According to Jonassen (2000), the educational secret to the Internet is intentionality. The argument is that if learners have a clear purpose in mind, an intention, they will most likely stay focused and construct ways to locate and retrieve only the information needed to fulfill the intention or the goal they have in mind. A popular tool for intentional searching is a search engine. A search engine is considered a mindtool, because it triggers reflective thinking as learners must constantly reflect and assess the quality of the information located as well as the merit of the information found for constructing and representing ideas. Moreover, web-based tools such as Filamentality [www.kn.pacbell.com/wired/fil] help manage the load that is caused by searching the web by enabling a learner to create a web page to record the results of a search and thereafter to use these resources to create instructional activities, such as a Hotlist and a Scrapbook. A Hotlist is a list of links to text-based materials for a topic organized meaningfully into categories. A Scrapbook is a list of links to a variety of media such as images, sound, video clips, and virtual reality tours as these relate to a topic. Learners can use a Hotlist to read about a topic and thereafter a Scrapbook to explore aspects of the topic they feel are important. The resources found in a Hotlist and a Multimedia Scrapbook can be downloaded into a Hyperstudio stack and manipulated accordingly by the learner.

*Knowledge construction tools*

Knowledge construction tools, such as hypermedia, are tools that actively engage learners in designing and creating representations of knowledge, as they understand it, and not as the teacher understands it. Hyperstudio is a well-known hypermedia-authoring tool that is widely used by teachers and students to communicate ideas in visual form by bringing together text, sound, graphics, and video. From a theoretical perspective, hypermedia authoring follows the tenets of Papert's (1990) constructionism, which asserts that the learner must build knowledge. According to Perkins (1986), the rationale for constructionism is knowledge as design, which affirms that learners should become designers of instructional materials and artifacts, and not interpreters of facts and information given by a teacher.

## Methodology

### *The Context of the Study*

The study took place in a teacher education department in the fall of 2001. Forty-one undergraduate student teachers, enrolled in a fourth-year science education course, participated in the study. The course was designed around two major objectives: (a) to teach students about current trends in science teaching, and (b) to capitalize on the interrelationships among science, technology, and society. The instructor of the course wanted students to understand science in terms of their real life and not as inert knowledge in the form of isolated facts and information. Over the course of the semester, there were 13 two-hour lectures, and 13 90-minute laboratory meetings. For the lectures, all students met as a group, whereas for laboratory work students were divided into two groups. These two groups were intact groups formed during registration without any involvement from the instructor of the course. Laboratory work included experiments and technology training. There were five 90-minute technology workshops for each group devoted to technology integration, and were scheduled at times students felt they needed the training.

### *Procedures*

The authors, first, identified 100 web sites that were related to science and technology literacy appropriate for elementary education, and, then, evaluated randomly 50 of them based on multiple criteria, such as (a) accuracy, (b) depth, (c) breath, and (d) relevance to students' lives. The list with the web sites, the evaluation criteria, and the evaluation outcomes were communicated to students via a web site. Each participant had to (a) select a different topic from the elementary science curriculum, (b) identify and evaluate web sites suitable for teaching this topic, and (c) develop an technology-enhanced 80-minute lesson, for ages 7-12, to be taught in a real classroom setting in conjunction with other planned activities. Students were guided to design their lessons based on principles of learning theories that place the learner at the center of the learning process as the constructor of knowledge. Students were also instructed to integrate into their lessons Hyperstudio, an easy to learn application by both teachers and students.

As mentioned above, each group had five technology integration training sessions. Two kinds of training sessions for each group were administered: (a) Hyperstudio Training and (b) Internet Training. Even though students were familiar with both Hyperstudio and Internet they asked for the extra training. Therefore, each group of students had three workshops about Hyperstudio and its added value in the teaching and learning process, and two workshops about the Internet. Internet training differed between the two groups. The first group learned about how to employ different strategies to effectively search the WWW as well as which engines were most appropriate for locating different kinds of information such as images, video clips, sounds, animations, etc. The second group had the same basic Internet training that students in the first group had, with the difference that they also learned how to organize the results of their searches using the tool of Filamentality. Specifically, each student in the second group created a Hotlist and a Scrapbook, using Filamentality. Students were expected to use the information collected in their Hotlists and Scrapbooks to design their lessons using Hyperstudio and other in-class activities.

### *Instruments*

Three questionnaires were used to collect data. At the beginning of the semester, students were given a short questionnaire to indicate how frequently they used the technologies of the Internet and Hyperstudio. A Likert scale from 1 to 5 (never, rarely, sometimes, often, very often) was used for this measurement. Students were also administered another questionnaire measuring their attitudes towards ICT and its integration in the classroom. This questionnaire included 15 Likert-type questions from 1 to 5 (disagree a lot, disagree, neutral, agree, agree a lot). At the end of the semester, students were given a questionnaire to measure their perceived cognitive load. A Likert scale from 1 to 5 (very small mental effort, small mental effort, neither small nor large mental effort, large mental effort, very large mental effort) was also used for this measurement. There were two forms of this questionnaire, one for each group. The cognitive load imposed by the technology for the first group of students was measured in terms of: (a) the mental effort they exerted to learn Hyperstudio, (b) the mental effort they exerted to search the Internet and collect quality information for their projects, and (c) the mental effort they exerted to design instructional activities using Hyperstudio. Similarly, the cognitive load imposed by the technology for the second group of students was measured in terms of: (a) the mental effort they exerted to learn Hyperstudio, (b) the mental effort they exerted to use Filamentality for searching WWW and organizing the information collected in a Hotlist and a Scrapbook, and (c) the mental effort they exerted to design instructional activities using Hyperstudio. Thus, the difference between the two groups was that the second group was deliberately instructed, and guided to use Filamentality and organize the information collected in a Hotlist and a Scrapbook, while the first group was not.

**Results and Discussion**
Table 1 shows the frequencies of students' responses to the 15-item attitude questionnaire. There were no statistically significant differences between the two groups in terms of their responses to the attitude questionnaire, and the results were collapsed over the two groups.

**Table 1:** Students' Initial Attitudes about Technology (n=41)

| Item | Disagree a lot% | Disagree % | Neutral % | Agree % | Agree a lot% |
|---|---|---|---|---|---|
| I feel comfortable learning the new technologies | 2.4 | 9.8 | 9.8 | 39.0 | 39.0 |
| Using the computer constitutes a skill that students must learn | 0.0 | 0.0 | 0.0 | 17.1 | 82.9 |
| The computer imposes stress on me because if anything goes wrong I would know what to do | 19.5 | 53.7 | 12.2 | 9.8 | 4.9 |
| I feel comfortable with my abilities to be able to learn how to use the computer | 2.4 | 9.8 | 4.9 | 58.5 | 24.4 |
| The use of computers in education makes me skeptical | 9.8 | 24.4 | 9.8 | 46.3 | 9.8 |
| The use of computers in education makes me enthusiastic | 0.0 | 2.4 | 7.3 | 53.7 | 36.6 |
| The use of computers in education interests me | 0.0 | 2.4 | 0.0 | 51.2 | 46.3 |
| The use of computers in education scares me | 26.8 | 41.5 | 14.6 | 14.6 | 2.4 |
| Computers confuse me | 34.1 | 48.8 | 7.3 | 9.8 | 0.0 |
| I don't think computers will be valuable in my profession | 82.9 | 14.6 | 0.0 | 0.0 | 2.4 |
| I enjoy learning how to use the new technologies | 0.0 | 2.4 | 12.2 | 39.0 | 46.3 |
| The integration of computers in my teaching will result in more work for me | 0.0 | 9.8 | 14.6 | 56.1 | 19.5 |
| I believe computers will change the way I teach | 0.0 | 2.4 | 9.8 | 56.1 | 31.7 |
| I believe computers will influence how my students learn | 0.0 | 2.4 | 2.4 | 53.7 | 41.5 |
| Whatever the computer can do I can do it equally well with another way | 7.3 | 68.3 | 22.0 | 2.4 | 0.0 |

The overwhelming majority of students felt the need for employing new technologies in the learning environment, felt enough confident in learning how to use new technologies, were rather enthusiastic to learn how to integrate the computer in their teaching, clearly understood that technology has the power to change the teaching and learning environment, and were not hesitant about the value of computer-enhanced instruction in learning, although there was some skepticism expressed related to using new technologies in education. Therefore, there was overall, a positive attitude and a positive momentum towards technology integration at the beginning of the study, and no resistance from the participants.

Table 2 shows descriptive statistics about how often students were using the technologies of Hyperstudio and Internet prior to the study, and Table 3 shows descriptive statistics about students' perceived cognitive load when they used these tools to carry out an instructional design task.

**Table 2:** Descriptive Statistics for Students' Frequency of Software Use (n=41)

| | Group | M | SD | n |
|---|---|---|---|---|
| Internet | 1 | 4.48 | 0.75 | 21 |
| | 2 | 4.85 | 0.37 | 20 |
| Hyperstudio | 1 | 2.29 | 0.64 | 21 |
| | 2 | 2.70 | 0.57 | 20 |

**Table 3:** Descriptive Statistics for Students' Perceived Cognitive Load (n=41)

| Group | M | SD | n |
|---|---|---|---|
| 1 | 10.00 | 1.70 | 21 |
| 2 | 8.55 | 1.23 | 20 |
| Total | 9.30 | 1.65 | 41 |

Students in the second group were using more often both the Internet and Hyperstudio, while the first group reported a higher amount of cognitive load than students in the second group did. To control for initial differences in the use of software, an analysis of covariance on students' perceived cognitive load was performed, where use of Internet and use of Hyperstudio were both used as covariates. The results of the analysis of covariance are shown in Table 4.

**Table 4:** Analysis of Covariance on Students' Perceived Cognitive Load (n=41)

| Source of variation | SS | df | MS | F | Signif. |
|---|---|---|---|---|---|
| Intercept | 118.87 | 1 | 118.87 | 60.73 | .00 |
| Use of Internet | 9.30 | 1 | 9.30 | 4.75 | .036* |
| Use of Hyperstudio | 1.60 | 1 | 1.60 | 0.82 | .37 |
| Intervention | 8.45 | 1 | 8.45 | 4.32 | .045* |
| Error | 72.42 | 37 | 1.96 | | |

*Statistically significant at p<0.05.

The difference in cognitive load between the two groups was statistically significant, with $F = 4.32$, $p < .05$, after adjusting for the differences in frequency of Internet and Hyperstudio use between the two groups, as they were measured at the beginning of the study. Only the Internet as covariant was found to be statistically significant with $F = 4.75$, $p < .05$. According to the results of the analysis of covariance, the null hypothesis of no differences in cognitive load attributed to how much each group was using the Internet could not be rejected. This finding is important because it indicates that expertise in using a tool or better familiarity with a tool, as a result of more frequent use, *may* reduce the amount of cognitive load. In addition, students, who were instructed to employ Filamentality in their work, reported lower cognitive load. The cognitive load remained significantly lower for those who employed Filamentality in their work, even after adjusting for initial differences in the use of Internet. This signifies that the tool of Filamentality alone is a powerful tool in managing the mental effort needed to accomplish an instructional task.

When students in the second group were asked to explain the amount of cognitive load Filamentality imposed on them in carrying out their task, eleven of them stated that the amount of mental effort was much lower than what it would have been without using Filamentality. They explained that Filamentality was very easy to learn and enabled them to organize the results of their searches into categories. Therefore it was easy for them to access the information, when they needed it. The remaining nine students also stated that Filamentality was a user-friendly tool to learn, and that the mental effort they put into the task with Filamentality was lower than what they would have put without Filamentality, because all data were already organized and ready to be used for their Hyperstudio stacks and other activities.

The results of this study indicate that the amount of cognitive load imposed by technology integration can be managed effectively and efficiently by integrating cognitive tools in the learning environment to help learners organize their thinking processes more efficiently and effectively. Clearly, students who used the tool of Filamentality experienced a smaller mental effort in completing their task than those students who completed the task without using Filamentality. The tool of Filamentality served as a cognitive tool that helped students organize their thinking effectively, and facilitated the retrieval and use of information, when students needed to use the information at a later time. Therefore, it made the task of searching the Internet less chaotic and overall it reduced the amount of extraneous cognitive load imposed by integrating ICT in the course.

**Implications for Instructional Design**

ICT cannot be sidestepped in future educational reform efforts. Consequently, teacher educators should make efforts towards integrating ICT in preservice coursework. The integration of ICT in teacher education programs is not an easy matter, while lack of substantive research evidence plagues any fruitful discussion related to the affordances of new technologies in the classroom. If technology is viewed as an add-on that is pursued for the sake of the technology alone, then technology will never change education. On the other hand, if technology is viewed as a tool with an added value in certain instructional situations, then technology will manage to become part of the microcosm of the classroom. Clearly, the theory of cognitive load has important implications for the design of technology-enhanced learning environments. Based on our experiences, technology integration in teacher education programs should be planned carefully to ensure the following. First, the tools integrated should be affordable and easy to learn so that the amount of cognitive load is best managed. Second, learning how to use the technology should not be the major focus of the course, but learning how to integrate the technology for the purpose of meeting instructional objectives should be. Finally, prospective teachers should learn how to design technology-enhanced activities so that the amount of extraneous cognitive load is controlled and kept within the limits of young learners' mental resources. Careful design of instructional use of ICT is necessary, in any attempt to take advantage of learners' possible initial positive attitudes towards using ICT in their teaching.

There is no doubt that even though support for ICT use in education is gradually increasing, there is only scarce evidence for its effectiveness. The most relevant issue *is not whether technology is effective, but when and how it can be used advantageously.* Consequently, coordinated research efforts should be undertaken to investigate these questions. This line of research seems very promising in providing guidelines for designing technology-enhanced powerful learning environments.

## Bibliography

BYRUM, D. C. & Cashman, C. (1993). Preservice teacher training in educational computing: Problems, perceptions and preparation. *Journal of Technology and teacher Education, 1*, 259-274.

CAFARELLA, R. S., & Zinn, L. R. (1999). Professional development for faculty: A conceptual framework for barriers and supports. *Innovative Higher Education, 23*(4), 241.

COOPER, G. (1990). Cognitive load theory as an aid for instructional design. *Australian Journal of Educational Technology, 6*(2), 108-113.

GREEN, K. C. (1998). *1998 Campus Computing Survey*. [Online] Available: http://www.campuscomputing.net/summaries/1998/index.html.

JONASSEN, D. H. (2000). *Computers as mindtools for schools: Engaging critical thinking (2nd Ed.)*. Upper Saddle River, NJ: Prentice-Hall.

MASSY, W. F., & Zemsky, R. (1995). *Using information technology to enhance academic productivity*. Presented at the 1995 CAUSE conference: [Online] Available: http://www.educause.edu/nlii/keydocs/massy.html.

PAPERT, S. (1990). Introduction by Seymour Papert. In I. Harel (Ed.), *Constructionist learning*. Boston: MIT Laboratory.

PERKINS, D. N. (1986). *Knowledge as design*. Hillsdale, NJ: Lawrence Erlbaum Associates.

SWELLER, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction, 4*, 295-312.

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010

# LESSONS FOR TEACHING BOTANY: WHAT MIDDLE SCHOOL STUDENTS KNOW ABOUT PLANTS

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**Abstract**

Students' alternative conceptions arise out of an interconnected system of beliefs: about the nature of science, of learning, of the natural and social world. Cross-cultural perspectives on these world views are therefore essential. This study probed middle school students' conceptions about plants.

Tribal students were found to have a richer and more varied knowledge base about plants both in comparison with the textbooks at their level and urban students. While textbooks emphasized detailed structural descriptions, students focused on gross shapes, environmental features, seasonal variations, and feelings, which in turn they related to the uses of plants. Data for urban and tribal students showed that mere presence of plants in the environment did not result in students being aware of them. Everyday use and socio-cultural significance of plants played a greater role. The direct dependence of tribal cultures on forests for shelter, food and medicine, was reflected in their positive attitudes towards plants, and in their more detailed knowledge of ecological interdependencies as compared to urban students.

## Introduction

School students' conceptions form an interconnected system of beliefs: about the nature of science, of school, of learning, and of the world around. Knowledge is constructed through interaction with the physical as well as the social environment. Alternative conceptions therefore need to be seen in terms of the context of learning, including the local environment and the socio-cultural background of students, and its relation to the classroom climate. This was one of the goals of the DLIPS Project - Diagnosing Learning in Primary Science, undertaken at the Homi Bhabha Centre for Science Education. The DLIPS project studied three main themes that are intimately connected with primary (grades 1 through 4 in Maharashtra State) and middle school (grades 5 through 8) science: students' ideas related to living and non-living, students' ideas about plants and the role of experiments in school science [Chunawala et al, 1996; Natarajan et al, 1996; Ramadas et al, 1996].

Students in India grow up in a variety of economic and socio-cultural backgrounds. Although in school they follow a common curriculum, research and other observational evidence suggests that the experience of schooling may actually differ for students from differing home backgrounds. Their life-styles and environmental experiences may also differ. It is possible that these factors besides the curriculum and textbooks influence students' worldviews and shape their conceptions. Our study of students' conceptions was motivated by these rather complex considerations.

### Context, cognition and the study of plants

Cognition in natural and social settings has been the subject of many research studies. Implicit in these studies is the view, developed by Lave [1988], Brown and others [1988], that cognition is 'situated' - that knowledge is closely intertwined with the activity, the context, and the culture within which it is developed. This view is particularly relevant in situations where there is a wide gap between the culture of school and home. The study of botany for tribal school students in India is a case in point.

Tribals typically regard humans as part of a community of beings that include other living creatures as well as elements of the landscape. Tribals in India, many of whom live in the outskirts of forests, supplement their meagre earnings as tenant farmers/ labourers, with the sale of fuel wood, and minor forest produce like herbs and honey. *Ashramshalas*, or residential schools, are an attempt by the government to educate the tribals and integrate them with the mainstream. Lack of effective linkage between informal experiences and formal education leads to classroom learning limitations.

In rural and indigenous cultures, even children under 12 years of age participate in agriculture and collection of forest produce. Urban students on the other hand, merely use plant products in their daily lives. In schools, both tribal and urban students go though a common curriculum, in which the study of plants is an important component from grades 1 through 6.

Anthropological and ethnobotanical studies, which have documented names for plants, show that adults in rural and underdeveloped societies have names for many wild plants in their environment [Berlin et al, 1966; Tull, 1993]. Other studies [Dougherty, 1979] find that urban students have a poor knowledge of names of plants and cannot identify as many different varieties as tribal students of the same age. Hunn [1985] points out that "biological taxonomies only lexicalize a small portion of the total number of available plant and animal taxa, and what is lexicalised are the plants and animals that have some special importance to people".

Scribner and Cole [1973] see a juxtaposition of formal and informal education as a source of problem in bringing about cognitive change. Their thesis is, "... *that school represents a specialised set of educational experiences which are discontinuous from those encountered in everyday life and that it requires and promotes ways of learning and thinking which often run counter to those nurtured in practical daily activities.*"

Informal education in traditional societies is contextualised and person-oriented - each task is taught by a particular person, and the position of the person, say a family or group elder, imparting the skill is as important as the task to be learned. On the other hand, formal school education demands that children relate only to the subject matter, which is not only decontextualised, but often taught by a different teacher each year. This problem is compounded, in education of tribal children, by the schools representing a culture that has historically oppressed and maligned the indigenous people. Besides, the organization of knowledge in subjects like formal mathematics, grammar and the sciences often conflicts with the traditional ways of understanding and interpreting the world [Harris, 1992].

Informal learners lack explanations for how and why they perform a task, while school learners know the words but not the referents, because they have never encountered a practical situation related to their knowledge. These arguments lead to a strong plea for making a connection between everyday life of students and the decontextualised learning in the classroom [Brown et al, 1988; Brown, 1989]. It has been recognized for over a decade now that students' understandings include non-semantic aspects, like, emotions, values, beliefs, interpretive frameworks and personal experiences [Gilbert et al, 1982], which are also deeply embedded in the physical, social and cultural settings of the students. The school, and evaluations therein, are only concerned with the formal propositional (semantic) knowledge.

The present study was motivated by the observation that tribal students are seen to be at a disadvantage in formal school in terms of performance. Their life-style, and the knowledge of plants and forests on which it has depended over the years, remains unrecognised and under-valued. By documenting students' ideas, we hope to see if a connection is possible between the situated knowledge of students, and the requirements of the curriculum.

**Sample and tasks**

The study was done with middle school students from generally deprived socio-economic backgrounds. The data was collected over two academic years from three residential schools, one in Mumbai city (*Urban*) and two tribal schools in rural areas (*Tribal*) of Maharashtra State. The urban school is run by a charitable organisation and has a mix of students from poor and lower middle-class families. The data analysis was largely qualitative, with testing for statistical significance where appropriate.

Both urban and tribal students belonged to grades 5 and 6, and ranged in age from 10 to 15 years. About a hundred students each in the tribal and urban groups participated in the study. The actual number of participants varied for the different tasks. The ratio of girls to boys was about 1: 2 in the urban school and 1: 4 or less in the tribal schools, reflecting a severe gender bias in schooling opportunities. The gender ratio decreased further in the higher grades. The medium of instruction was Marathi, the language of Maharashtra State. The tribal students' mother tongue was a dialect of Marathi.

Our experience has been that these students, particularly in the school situation, are not used to expressing their own ideas freely. Through the medium of classroom discussions along with a variety of written tasks, games and activities, students were encouraged to express their ideas related to a topic. Games that required the students to form teams and compete, served to open up interaction channels with the students. In one such game, played outside the classroom during early interactions, students formed teams and identified living things found on land, water, or in the air. The fact that tribal students were able to give more than 150 plant names provided the impetus to probe the students' knowledge of plants in greater depth. Several tasks were subsequently designed, of which the analysis of two tasks that focus on the aspects of situated cognition are reported here. A brief description of each task is given below.

*Herbarium collection*
In the 'herbarium' task, 58 urban students of grade 6 and 99 tribal students of grades 5 and 6 participated. Each student was asked to select one plant from the environs of their school or home, preferably different from that of her/his classmates, and bring a twig containing a few leaves and a flower, fruit or seed, if it had any. The students then filled out a questionnaire which asked for information about the plant selected by them: its name, the surroundings where it was found, if the plant was a vine, the support of the plant, their 'thoughts and feelings' about the plant and any stories about it that they may be aware of. They were also asked to give the colour of the flowers when fresh, and human uses of the plant and its parts.

*Drawing and writing about a plant*
The participants for the drawing and writing task consisted of 104 urban students from grade 6 and 108 tribal students from grades 5 and 6. The students were asked to first draw the overall shape of the plant and its features, and then to fill out its surroundings. They also drew in detail, on a separate sheet, a branch, a leaf, flower, fruit and seed, of the same plant. Unlike the herbarium task, different students could draw the same plant. After completing the drawings, every student wrote about each aspect of the plant. The writing task was complementary to the drawing task and helped in probing students' ideas about the plants beyond the limitations of the drawing task.

**Results**

*Herbarium collection*
Students collected a great variety of plants distributed over many categories. The plants chosen by the tribal and urban students differed in two ways: the total number of plants in each category, and the variety, or the number of distinct names, within each category. The salient features of the responses to the herbarium questionnaire are given in Table 1 and tribal and urban students' responses are compared below.

There was a greater variety in tribal students' responses: majority of their choices (>70%) were evenly distributed over fruit trees, flowering trees and garden plants. They also gave a significantly greater number of fruit ($z$=2.46) and flowering ($z$=3.34) trees. There was a greater variety of flowering trees ($z$=2.51) as well. Tribal students chose many trees, which have a social and religious significance (socially significant trees). The tribal students in this study are dependent on a wide variety of plants. Thus, it is not surprising that they selected a large variety of plants from several categories.

**Table 1:** Number (No.) and variety (Var.) of plants in the herbarium task

| Category | Tribal | | Urban | |
|---|---|---|---|---|
| | No. | Var. | No. | Var. |
| Fruit trees | 27 | 16 | 7 | 4 |
| Flowering trees | 25 | 16 | 4 | 3 |
| Garden Plants | 21 | 15 | 24 | 12 |

| | | | | |
|---|---|---|---|---|
| Veg. Plants | 7 | 5 | 13 | 8 |
| Grass/Water plants | 4 | 4 | 2 | 2 |
| Other socially significant plants | 15 | 10 | 8 | 2 |
| Total | 99 | 66 | 58 | 31 |

Forty percent of all plants chosen by urban students were common garden plants, significantly greater in number ($z$=2.63) and variety ($z$=2.09) than the garden plants given by tribal students. They also chose a larger number of vegetable plants (22%) than did tribal students (7%), whose choices were different.

Several of the trees found in the tribal environs are also found near the school of the urban students in this study. Yet the urban students chose only a few fruit trees, the fruits of which they like to eat! Their choices in the garden variety were dominated by the plants that they use in their everyday lives. Complementarily, although a large variety of vegetable (and garden) plants are found around the *Ashramshalas*, tribal students chose them less frequently than did urban students. In the urban students' case, all 'useful' plants may not be found in their surroundings, while in the case of tribal students, the mere presence of a variety of plants in the forest has traditionally led to their use in the everyday life of their community.

Tribal students often expressed positive feelings about the plants they had chosen, in addition to their uses. It appeared that students' feelings were often linked to the uses of plants, as food, medicine or fuel. At other times they described the flowers as beautiful and 'gladdening'. Both urban and tribal students' responses had only a few structural descriptions like, "*chini gulab* leaves stand erect". This is in contrast to textbooks that abound in structural descriptions and underplay feelings.

It appears likely that, in the herbarium collection task, more than the availability of a variety of plants in the environment, the perceived dependence on the plant, and its everyday relevance, influenced students' choices. Their perceptions of use and 'feelings' about the plants were also an important factor that influenced the variety and number of herbarium samples.

One might expect that four years of formal schooling with similar textbooks would have a certain homogenising influence on urban and tribal students. This was not found to be so. Tribal students brought herbarium samples of many plants that did not appear in the textbooks, largely in the categories of fruit, flowering and socially significant trees. About two thirds of the plant samples brought by the tribal students, and about half those brought by urban students, were different from those given in the text. Textbooks, on the other hand, cite a large number of trees and plants of several categories, possibly in an effort to cater to a majority of rural and urban students.

**Drawing and writing about a plant**

This activity was meant to probe students' observations about a plant of their choice: the overall shape of the plant or tree, the details of its parts like, leaf, flower, fruit and seed, the surroundings in which the plant may be found, and any other ideas about the plant that they would want to write about. The activity had two distinct parts: drawing, followed by writing.

*Choice of plants - number and variety*

The predominant categories of plants chosen by the students were analysed on the same lines as in the herbarium collection activity. In this case too, each student drew only one plant. The salient differences in number and variety of plants chosen by tribal and urban students for this task are discussed below. The total number of plants in each category (No.) and the number of distinct names in each (Var.) are given in Table 2.

**Table 2:** Number (No.) and variety (Var.) of plants in drawing and writing task

| Category | Tribal | | Urban | |
|---|---|---|---|---|
| | No. | Var. | No. | Var. |
| Fruit trees | 60 | 13 | 67 | 7 |
| Flowering trees | 18 | 8 | 0 | 0 |
| Garden Plants | 14 | 5 | 32 | 11 |
| Veg. Plants | 1 | 1 | 0 | 0 |
| Grass/Water plants | 0 | 0 | 1 | 1 |
| Other socially significant plants | 15 | 6 | 4 | 3 |
| Total | 108 | 33 | 104 | 22 |

There was less overall variety in the plants chosen by both tribal and urban students in this task than in the herbarium task, probably because variety was not insisted upon. The nature of this task required the students to visualise the plant and draw it. Their observations, ability to visualise and draw, and a tendency to copy from neighbouring students, may all have reduced the variety of plants in students' responses to this task.

There was a greater variety of plants in the drawings of tribal students than in urban students' drawings. Most students (60%) drew fruit trees, with a greater variety in tribal students' drawings ($T$=13, $U$=7). Garden plants figured less in tribal students' drawings, both in number ($z$=3.8) and variety ($T$=5, $U$=11).

Urban students largely drew either fruit trees or garden plants, and no flowering trees or vegetable plants. The fruit trees were mostly the three stereotypical ones; *coconut* palm, tamarind and *mango*. *Coconut* palm is often perceived to be easy to draw and is part of all typical 'rural scenes' in books. The sour tamarind fruit is inexpensively available with roadside vendors in urban areas and is a favourite with children. The *mango* is a summer treat. Interestingly, no tribal student drew a tamarind tree.

Textbooks cite names of several plants, but give few pictures of specific plants or trees with notable exceptions of a *hibiscus* plant and a rose plant. Some nondescript trees not attributable to a particular variety are drawn in the textbooks as part of scenery. There are also pictures of fruits, vegetables, a few flowers, leaves and roots as independent structures.

Only about half the varieties of plants drawn by tribal students and about two-thirds the varieties drawn by urban students were the same as plants mentioned in textbooks. Most of the socially significant trees drawn by the tribal students were different from textbook ones. Urban students drew all the garden plant varieties drawn by tribal students, some mentioned in the textbooks and not drawn by tribal students, and more.

Students' drawings thus may indicate many things: their observations of plants around them, picture books, their ability to visualise these plants in the classroom, and their ability to draw. They collectively drew a large variety of plants from memory. Clearly, in this task, as in the herbarium task, textbooks have had marginal influence. Hence, students' drawings can be analysed for patterns that could reveal their ideas about plants.

*Students' drawings*

In a study of emotional and cognitive developmental features in the drawings of young children, Jacqueline Goodnow [Goodnow, 1977] states that, "No drawing is an automatic print-out of some perceptual world ... What is seen or intended must be translated into the action of drawing, and we need to understand fully the nature of translation and the nature of action".

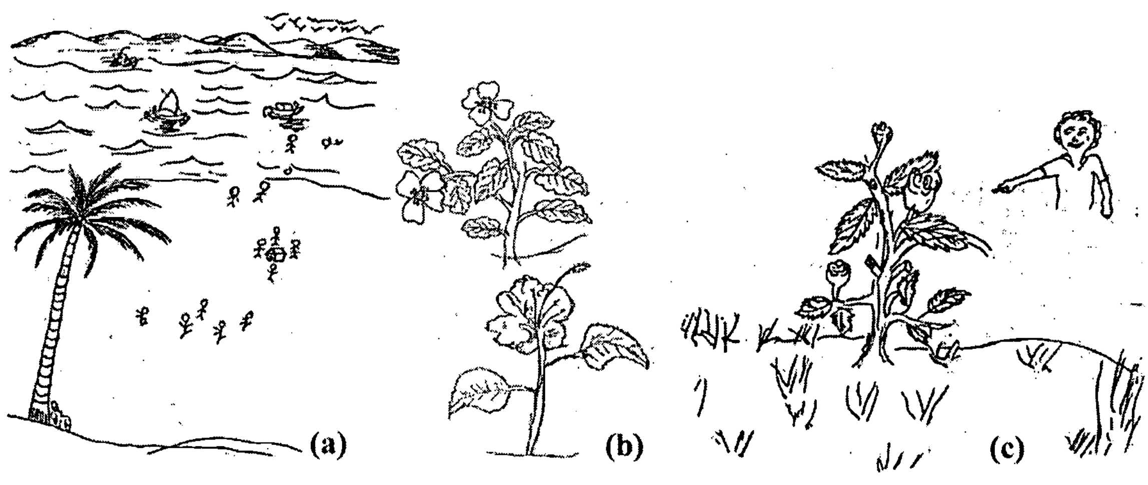
The following analysis focuses not on cognitive development, but on 10-15 year old students' observations and knowledge about plants. In particular, we look for evidence for realism, and attention to details of structure. The analysis starts from the premise that students' drawings of plants are their translation of what they see and 'think' about plants, and hence provide clues to their understanding of plants. Certain features of the drawings indicate possible lacunae in the teaching of botany in classrooms. The nature of these features, or 'patterns' in them, may help us understand what needs to be addressed if school botany is to form a useful scientific basis for the students to understand their environment. The salient features of the drawings of urban and tribal students fall in the categories of cases of accuracy in urban and tribal students' drawings, kinds of inaccuracies, like gross inaccuracies, wrongly directed venation and exaggerated proportions, and ecological features and realism. These are discussed below.

Drawings of big trees by tribal students had the correct overall shape. Shape of leaves, leaf arrangement on branches, and position and shape of fruits were mostly correct for different kinds of trees.

About 40% urban students drew the *coconut* palm and most drew it correctly: ribbed trunk, location and shape of leaves and fruits. Besides, these trees were shown, curving artistically, in very picturesque surroundings, by a stream or river, with a boat in the stream. A typical drawing is given in Fig.1(a).

Several urban students drew leaves of common garden plants, like the *hibiscus* in Fig.1(b) or rose in Fig.1(c) accurately and in great detail - relative size, position, serrated leaf margins, and thorns at the nodes. In urban areas, potted plants around the house, courtyard or even on balconies and their everyday use for decoration and worship afford students an opportunity for close observation of such plants. Some features, like the *hibiscus* flowers in Fig.1(b), were exaggerated. This plant has been drawn in textbooks, and the one in grade 6 textbook is a small-sized plant with rather large flowers.

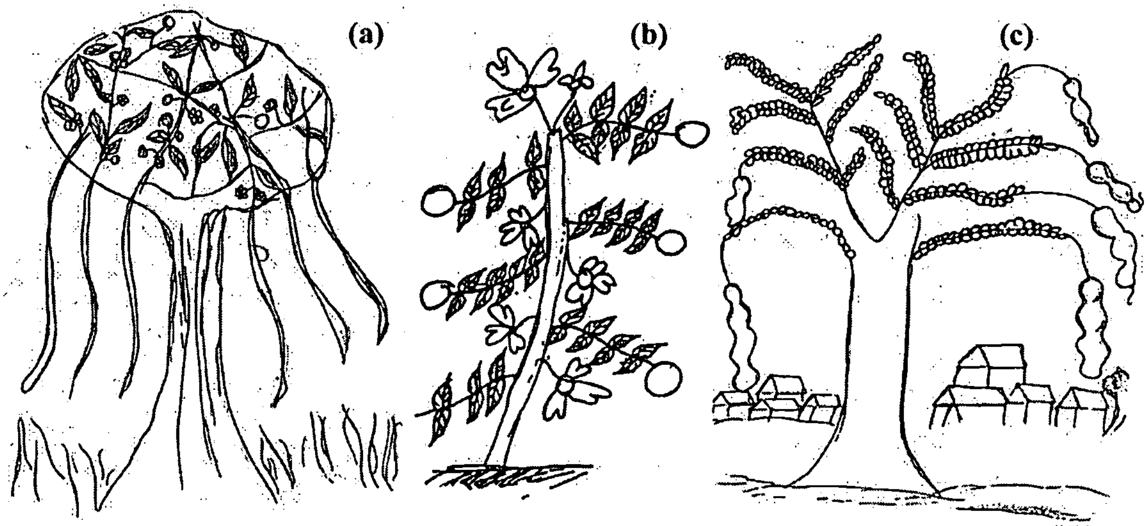
**Figure 1:** Drawings by urban students: (a) *Coconut* palm showing scenic surroundings, (b) *Hibiscus* plant and (c) Rose plant.




There were several kinds of inaccuracies in the drawings, which could serve as teaching learning opportunities. An urban sixth grader inaccurately drew prominent adventitious roots on the *peepul* tree (Ficus religiosa) (Fig.2(a)), which belongs to the generic class of trees characterised by adventitious roots. The student in this case may have overemphasised the roots, or made an observational error. The round fruits were attached to the branch by a stalk, rather than growing directly on the branch. The leaves were oblong instead of the well-known shape of a heart with an elongated and pointed apex. The drawing had stereotypical flowers, also at the end of stalks.

Another urban sixth grader drew a *guava* tree, with flowers growing on stalks from the main trunk, whereas round fruits - rather than the actual pear-shaped ones - were shown growing at twig terminals Fig.2(b). The student did not make any connection between the flower, the fruit, and the seed, the flowers were oversized, and the fruits were smaller than the flower.

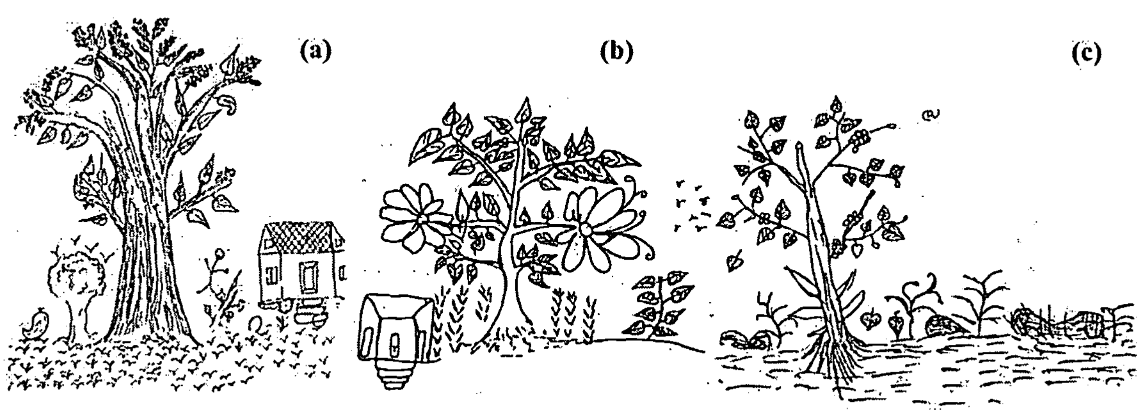
**Figure 2:** (a) *Peepul*, (b) *guava* and (c) *tamarind* trees by urban students.




There were many instances of students, both tribal and urban, drawing some parts of plants in exaggerated proportions (Fig.1(b), Fig.2.(a and b)). Fruits were prominent on every drawing of *mango* tree as in Fig.3(a). A *tamarind* tree (Fig.2(c)), drawn by an urban sixth grader showed large fruits and leaves. Placed in the foreground of the picture, the tree was large, 'having compound leaves, long and slender with 10-20 pairs of nearly stalkless leaflets' [Bole and Vaghani, 1986]. Juxtaposed with this accuracy of drawing were fruits placed incorrectly at the tip of leaves, correct in shape but highly exaggerated in size. The beautiful red flower of the *hibiscus* plant and the sour fruit of the *tamarind* tree happen to be favourites, especially with children. The size of these features may be an indication of the relative importance of these parts of the plant.

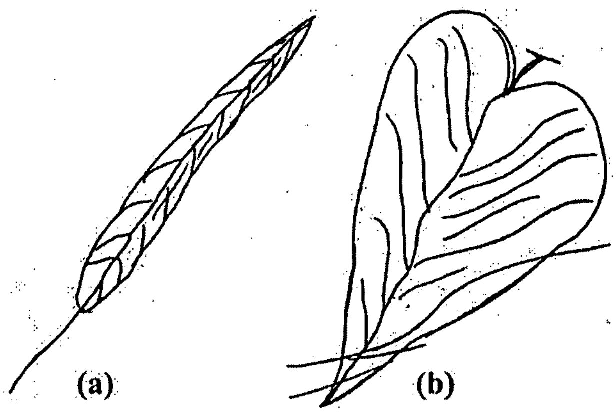
The drawing of a *bhendi* tree (Thespesia pupulnea) (Fig.3(b)) by a sixth grade tribal student was another striking example, where the flowers of the tree were incorrect in shape and were oversized. The sapling next to the tree, and the root structure near the ground indicated that it was a large tree. The leaves were of appropriate shape, but with opposite venation. In the herbarium task, students who chose this tree mentioned that they liked the tree for the attractive yellow flowers that changed to purple when about to wither. Thus the students did perceive the flowers as the most prominent part of this tree, and possibly attempted to depict that in their drawings.

**Figure 3:** (a) *Mango*, (b) *Bhendi* and (c) *Fig* trees by tribal students.



Students drew the leaf shape and leaf margins more accurately than other parts. One of the striking features of students' drawings was the venation of the leaves. While more urban students drew the veins in the right direction (z=3.0), many drawings of tribal students indicated veins in the opposite direction. This is illustrated in the two different leaves drawn by fifth grade tribal students Fig.4: an elongated (lanceolate) one of *biti* (Thevetia nerlifolia) plant and a heart-shaped leaf of the *bhendi* tree. It is amazing how correct they could be about the overall shape of the leaf, and yet draw all the veins in the opposite direction! While drawing a bunch of leaves, for example on a branch of a tree, there was often utter confusion about the direction of veins.

**Figure 4:** Leaves drawn by two tribal students (grade 5): (a) elongated leaf of *biti* plant and (b) heart-shaped leaf of *bhendi* tree.




The confused venation could have arisen either because of lack of observation of details, perceived irrelevance of the venation in making gross identification of plants, or perhaps a difficulty in drawing oppositely oriented diagonal lines [Olson, 1970]. The latter possibility was ruled out when they reproduced accurate venations when asked to collect a leaf and draw it. Hence, one may argue that the confusion may originate in a lack of attention to the details of venation.

Ecological features and realism were largely evident in tribal students' drawings, although urban students' drawings of *coconut* trees in scenic surroundings would also fall in this category. Many tribal students drew large trees with saplings of the same variety growing nearby (Fig.3(a and b)). Fig.3(a), showed a realistic shape of the tree, inflorescence and fruit. The *mango* fruit was shown as a prominent part of the tree, as well as of the whole scene, for example, a *mango* on the ground with a child running to get it.

In the drawing of a *fig* tree in Fig.3(c), roots were shown above ground, saplings around the tree, and logs of wood strewn around. The fruits were attached in clusters to the main branches. The leaf shape was distinct and correct. The drawing clearly indicated that it was the season for shedding of leaves. A few leaves were floating to the ground from the large tree, while the saplings were already bare. But the fruit, indicated separately, though of the correct shape, was incorrectly positioned on the branch, and a lone seed was drawn inside the fruit.

The science textbook for grade 6 describes many parts of plants in great detail, including apex, veins, margins and stalk of leaf, and style, stamen, stigma and pollen in flowers. Detailed descriptions of the parts of a stem, leaf, and flower, are given, but the book says little about how all these are connected to each other. There are very few pictures of the whole plant or tree. All the factual knowledge about parts of a plant is usually taught within the classroom, with neither field trips nor collection of plants for demonstration in the classroom. The facts are then rote learned in the confines of students' homes. Given these circumstances, one is left to explain how the students got it so right.

Tribal people have had intimate links with the trees in their environs. They have thus evolved ways to distinguish between the different trees in their daily lives, using the visual criteria of shape, size and distribution of leaves, besides smell, texture and other non-visual criteria. These are often used implicitly rather than in an explicit manner in identifying trees. The tribal students probably 'know' these by 'situated learning'. This was evident from the discussions with them during the game on identifying living things in their surroundings. Tribal students also expressed this knowledge in their drawings.

Urban students relate to plants in their daily life through watering their garden plants, picking flowers of garden plants and throwing stones to drop edible fruits from road-side trees. Most students also know and use many parts of the *coconut* tree. The distinct shape of the *coconut* palm is most familiar to the urban students of Mumbai.

In the drawing task the use of a plant and plant products in everyday life, and interactions with the plant, seemed to decide the plant chosen and the accuracy of drawing. Since textbooks had very few drawings of whole plants, they did not help students in responding to this task. That may also explain why the students did not give the details that the textbooks give, unless they were details of familiar plants, like garden plants for urban students. There is apparently a wide gap between students' spontaneous ideas about plants - which were varied and rich in ecological content - and the knowledge in the textbooks.

*Students' writing about plants*

The students were asked to describe the plant they had drawn, including its overall shape, its surroundings, its trunk, branches, leaves, flowers, fruits and seeds. They had to describe characteristics like colour, smell, texture (feeling to touch), periods of flowering and fruiting, and whether the plant shed its leaves. They were also asked to write about the uses of the plant and its role in the environment. Students may have used some of the relevant expressions from their textbooks.

Urban students, who gave too few items to be analyzed in any detail, mostly gave gross structure and functional features, and little else. In general, most tribal students wrote much more about the plant they had chosen to draw than did an average urban student. The description of plants given by the students was analyzed in the light of some aspects that are commonly found in the textbooks, and others that the task specified.

Textbooks give many plants as examples while discussing variety in leaves, root, stem, the general structure of plants or functions of plants and their parts. They abound in definitions, classifications and statements of cause and effect. Textbooks also describe processes like germination of seeds and give procedures for growing plants. There are a few nonvisual descriptions and do not have descriptions of a single plant on the lines requested of the students. They are devoid of affective statements or imagery and metaphor, especially in grades higher than the fourth. Time references, like, fall of leaves or flowering seasons are absent in textbooks.

The predominant feature in the writings of students was description of gross structure, such as colour and size of tree trunk, stem, leaf, flower, and fruit. Students' writings closely modelled the textbooks in four aspects - gross structure and gross anthropocentric functions, details, and process descriptions. Tribal students gave several uses, most of which were human uses, of the plants and their parts.

Students rarely referred to the subparts other than *cotyledons*, although there are many references in the textbooks to stamens, style, margins of leaves, etc. Students described processes more often than procedures, and most cases pertained to germination of seed and plant growth. This is not surprising, since textbooks deal with this in some detail, and even suggest that students try the activity of germinating some common seeds. Some of the teachers claimed to have done this in the classroom, and some students too mentioned that they had done it.

There were a large number of instances where students referred to seasonal variations in plants. Most tribal students wrote about time of flowering, when leaves were shed, and when they sprouted anew. Some students wrote a few sentences about the surroundings in which the plant was to be found and described them with feelings. The students' writings were relatively high on feelings and references to seasons in contrast to textbooks. Students did not make many classificatory or cause-effect statements, nor did they give definitions or procedures in their writings. In this task, students gave a few instances of nonvisual descriptions (a tree trunk is strong), or imagery (umbrella shaped, half-moon, like a chicken egg). These descriptions as well as environmental details and gross function are rare in both students' writings and in textbooks.

## Conclusions

The study of students' ideas about plants was done in the context of a science curriculum, which is sometimes excessively formal in its approach particularly when seen against students' spontaneous conceptions. The study found a mismatch between textbook science and students' conceptions. Nevertheless, the conceptions held by students did show some internal coherence and also consistency within groups of students.

Students' ideas about plants were seen to be influenced by physical and social settings and by textbooks. Mere presence of plants in the environment did not result in students being aware of them. Everyday use of, and interactions with, plants and plant products had a greater influence on students' ideas about plants.

There was a wide gap between students' spontaneous ideas about plants - which were varied and rich in ecological content - and the knowledge in the textbooks. Tribal students incorporated in their drawings of plants, many features that reflected their understanding of ecology. Tribal students' keen observations were further evidenced in the many instances they gave of seasonal features. In contrast to textbooks, students gave few detailed structural descriptions, focusing rather on gross shapes. Tribal students drew realistic pictures of a large variety of forest trees, often correct in placement of leaves, fruits and flowers. They frequently expressed their feelings towards plants and related their feelings about individual trees to their uses, unlike textbooks, which tend to underplay feelings. The uses, which the students gave, compared well with those cited in advanced botany textbooks.

Textbooks however depict very few whole plants or trees, and do not incorporate affective or ecological features in the pictures. Classroom intervention is necessary here. The study of botany can become meaningful to students only if ecological features, seasonal variations and affective factors are woven into classroom teaching through appropriate activities and interactions that highlight the relevance of this knowledge in everyday living.

Because of the widely different ecosystems that the country is endowed with, it may not be possible for textbooks to cover all available varieties of trees. Nevertheless, the tropical forests of the *Sahyadri* range, which are home to the tribal students in this study, is an important and geographically prominent ecosystem of the country and has been discussed in the geography textbook of grade 6. Yet, the connection with biology is unlikely to be made, since teachers rarely go beyond the textbooks, and different subjects are often handled by different teachers. It is unfortunate that there is scant attempt, either in the textbooks or in the classrooms, to address this gap between students' awareness of their surroundings and the formal knowledge of botany required of them.

## References

BERLIN, B., Breedlove, D., and Raven, P. (1966). Folk taxonomies and biological classification. *Science*, 154: 273-275.

BOLE, P. and Vaghani, Y. (1986). *Field Guide to the Common Trees of India*. Oxford University Press, Bombay.

BROWN, J. (1989). Toward a new epistemology for learning. In Frasson, G. and Gauthiar, J., editors, *Intelligent Tutoring Systems at the Crossroad of AI and Education*. Ablax, Norwood, NJ.

BROWN, J., Collins, A., and Duguid, P. (1988). Situated cognition and the culture of learning. Technical Report Rep.No.IRL 88-00088, Institute of Research for Learning.

CHUNAWALA, S., Apte, S., Natarajan, C., and Ramadas, J. (1996). Students' ideas about living and non-living. Technical Report TR.No. 29, Homi Bhabha Centre for Science Education.

DOUGHERTY, J. (1979). Learning names for plants and plants for names. *Anthropolical Linguistics*, 21: 298-315.

GILBERT, J., Osborn, R., and Fensham, P. (1982). Children's science and its cnsequences for teaching. *Science Education*, 66: 623-33.

GOODNOW, J. (1977). *Children's Drawing*. Harvard Univ. Press, Cambridge, MA.

HARRIS, S. (1992). Going about in the right way - decolonising aboriginal school curriculum proceses. In Bob, T. and Jenny, T., editors, *Voices in a Seashell - Education, Culture and Identity*. UNESCO.

HUNN, E. (1985). The utilitarian factor in folk biological classification. In Dougherty, J., editor, *Directions in Cognitive Anthropology*. University of Illinois Press, Urbana, Ill.

LAVE, J. (1988). *Cognition in Practice: Mind Mathematics and Culture in Everyday Life*. Cambridge University Press, London.

NATARAJAN, C., Chunawala, S., Apte, S., and Ramadas, J. (1996). Students' ideas about plants. Technical Report TR.No. 30, Homi Bhabha Centre for Science Education.

OLSON, D. (1970). *Cognitive Development: The Child's Acquisition of Diagonality*. Academic Press, NY.

RAMADAS, J., Natarajan, C., Chunawala, S., and Apte, S. (1996). Role of experiments in school science. Technical Report TR.No. 31, Homi Bhabha Centre for Science Education.

SCRIBNER, S. and Cole, M. (1973). Cognitive consequences of formal and informal education. *Science*, 182: 553-559.

TULL, D. (1993). Elementary students' responses to questions about plant identification: response strategies in children. *Science Education*, 78(4): 323-343.

011

# EDUCATION FOR SUSTAINABILITY: A MODEL FOR COLLABORATION BETWEEN SCIENCE TEACHERS AND NON-SCIENCE TEACHERS AND THEIR STUDENTS USING PARTICIPATORY METHODS AND ACTION RESEARCH

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## Abstract

This action research project was carried out in the UK during 2001. The purpose was to develop a model for addressing the needs of science teachers and their non-science colleagues with responsibility for education for sustainability (EfS) within the school curriculum for students of 13-15 years. The aim was to help science teachers to understand how they could make a contribution to EfS which is complementary to the work of teachers from other disciplines. It was recognised that topics related to EfS have components that are economic, political, social, cultural, aesthetic, ethical and spiritual as well as scientific and technological and the problem is to provide students with a coherent and comprehensive appreciation of environmental issues. An essential part of the project was to enable science teachers to use their expertise to teach relevant aspects of science that support EfS. They would also work collaboratively with non-science colleagues who could in turn use their expertise to contribute different aspects to the same topic.

The research was based on participatory appraisal, participatory action research and co-operative enquiry methods; working with teachers and their students. Using these approaches the teachers explored ways of maintaining and enhancing the integrity of their subject discipline yet contributing to education for sustainable development. The outcomes are offered as a model for the post-experience professional development of teachers and it is considered that it can be applied to teaching many curricular areas, particularly those that relate to students' values, attitudes and behaviours.

The teachers set their agenda for achieving their objectives using the researcher as a facilitator. Lists of key areas related to knowledge, skills and attitudes were drawn up. The contributions of science teachers were identified and similarly for other colleagues. This initial framework was applied to a particular topic, which for practical reasons was decided should be waste management. This was used to devise an approach to teaching that was trialed using a collaborative approach with a cohort of students. A practical project was set up in which teachers worked with their students in planning, implementating, communicating the outcomes and evaluating the effectiveness of the project. The evaluation involved criteria for knowledge, skills and attitudes suggested by the teachers and later considered by their students. The results showed that the methodology was effective in addressing most of the evaluation criteria identified within the aims. Also it was considered that there is wide potential for using this approach with other pedagogical issues.


## Introduction

This paper is concerned with the professional development of practising teachers. It discusses an action research project using participatory methods that enable science teachers to work with colleagues from other subject areas in order to address aspects of education for sustainability (EfS). The project, of which this paper is only part, is to develop new approaches to helping teachers to include EfS in their courses in a way which draws on their own expertise and is meaningful to their students. The approach is innovatory in a school context and therefore the description of the methodology is central to research. The project offers a model for this particular type of approach in relation to many different topics.

### Background

Science has a major role in the delivery of environmental education and EfS in many countries. The high status given to science in the curriculum may make it appear particularly appropriate for this purpose. However, science syllabi are already over-loaded and science teachers can give only a limited amount of time to EfS. Also, effective EfS requires a broad range of understandings and skills, not all of which are scientific. Much of EfS relates to economic, political, social, cultural, ethical and spiritual matters as well as the scientific and technological. Because science education is best suited to developing scientific understanding and skills and science teachers are often poorly prepared for the task of teaching outside their area of expertise, this often causes them particular problems and reduces the effectiveness of EfS.

As well as the traditional curriculum subjects schools in the UK have for some years included programmes within their curricula that have various titles, among these are '*personal and social education*' or '*personal, social and health education*' and more recently '*citizenship education*' (called collectively for the purposes of this paper PSE type courses). Such courses are taught by a broad spectrum of teachers within each school, many of whom are not science teachers. The inclusion of aspects of EfS is optional in these courses but many schools ensure that it is included. The possible strength as well as a weakness of these courses is that they are not assessed through public examinations. Emphasis is frequently given to providing opportunities for students to explore issues which affect themselves, their local community and the wider world. Much of this type of content is not well suited to formal assessment. However, students and their parents often consider such courses to be less important compared to those involving preparation for examinations.

**The study**

The study set out to address the concerns of science teachers and those involved with PSE type courses when involved with EfS. The science teachers stated that they lacked the time and expertise to deal with the full range of issues related to EfS. At the same time they were clear that they were able to teach essential knowledge and skills which were both central to scientific understanding and contributed significantly to EfS. The teachers of PSE considered that their expertise in the scientific aspects of EfS was generally too limited and also they lacked sufficient time to provide appropriate scientific background understanding. However, their courses were well suited to flexibility and extension to meet the needs of much of EfS, particularly that related to certain skills, attitudes and values.

In this study 16 teachers from a large urban school, eight science specialists teachers and eight non-science specialists teaching PSE type courses, worked together to explore their possible respective contributions to EfS. The students involved were 13-15 years of age. From the outcomes of this study there is good evidence that this approach to working collaboratively with teachers and students has applications in many parts of the curriculum where attitudes and behaviours are concerned.

The participatory methodology used was derived from a mixture of a) participatory appraisal methods (Chambers, 1992; Gayford, 1996 & 2000), b) participatory action research [PAR] (Tandon, 1989) and c) co-operative enquiry (Heron, 1992). The literature indicated that these approaches are likely to be successful with people, such as teachers, who are encouraged to feel relatively empowered by the process and who wish to explore and develop their practice together (Reason, 1994).

The underlying principles of the approach are to a) empower participants b) place value on their experience as practitioners and c) help them to work collaboratively with colleagues from other disciplines. From these principles the intention was to develop knowledge and action which could be shown to be directly useful through a process of collective self-enquiry and reflection (see Fals-Borda, 1988). The benefits were that it should enable teachers to draw from their own collective fund of knowledge about sustainability and to appreciate the value of their own expertise. Initially teachers were encouraged to think broadly about methodological approaches with as few constraints as possible. Throughout the process participants were encouraged and expected to learn from each other.

The role of the researcher was to maintain a 'low profile', listening and acting as the facilitator in the process; rather than acting as a leader or expert. The research was intended to be a vehicle for enabling teachers to reflect on their practice, to work with their students and to use the outcomes to inform future practice. The teachers and their students were involved in the analysis and evaluation of the outcomes.

The project led to a short piece of action research and the purpose of the study was to: -

1. provide practising teachers with the opportunity to clarify their aims and objectives in relation to EfS and to consider their respective contributions,
2. develop a suitable project of short duration with their students,
3. work collaboratively with their students in carrying out the project,
4. consider criteria for evaluating their approach to EfS and ways of extending the work.

The study fell into four distinct parts:

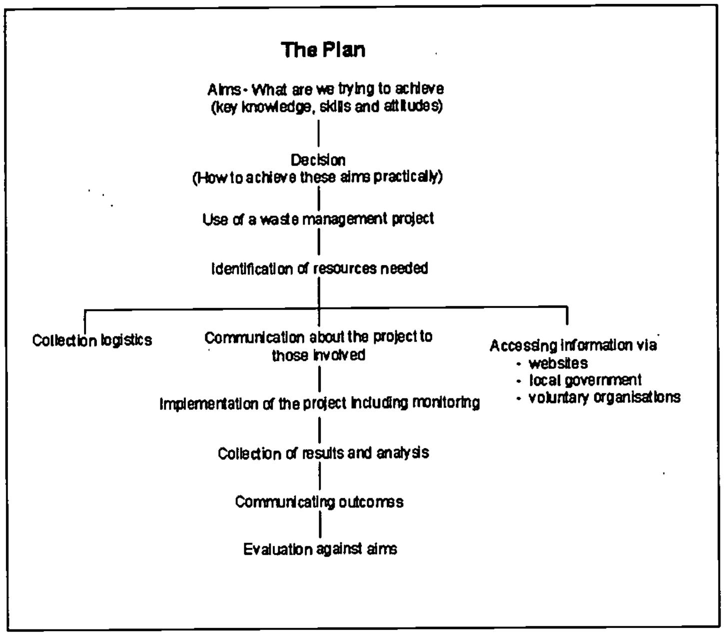
1. Developing a *modus operandi* and exploring some basic aims of EfS,
2. Developing a vehicle for teaching aspects of EfS,
3. Carrying out a piece of teaching as action research,
4. Evaluation of the outcomes and identifying possible ways of extending the work.

To facilitate the process two science teachers and two PSE teachers met on two occasions to consider the basic aims of EfS in item 1 (above) and began the process of developing a collaborative teaching project (item 2 above).

1. The basic aims of EfS were divided into a) key knowledge, b) key skills and c) key attitudes.
   Key knowledge included: -
   developing a basic understanding of the underlying science and technology; understanding the major associated environmental issues; understanding the relationship between local action and global effects; recognising that in order to understand environmental issues it is essential to appreciate that there are scientific, technological, economic, aesthetic, social, political and ethical aspects; knowing how to take action and personal responsibility within a democracy.
   Key skills included: -
   accessing information, analysing information and extracting what is relevant; asking appropriate questions; evaluating with reasons; communicating understanding in a variety of ways; working co-operatively with others; identifying the level of personal and collective control for themselves and their group in relation to particular issues.
   With regard to the key attitudes it is emphasised here that the teachers felt strongly that the experience for students should be both rational and educational; therefore they did not consider it their task to inculcate a particular way of thinking about the environment which conformed to their own views. Emphasis should on enabling students to a) identify their beliefs about the outcomes of their own behaviour in relation to environmental issues; b) to reflect on the norms assumed by their students in relation to their own peer group and those in positions of authority and c) to develop a critical attitude to information.

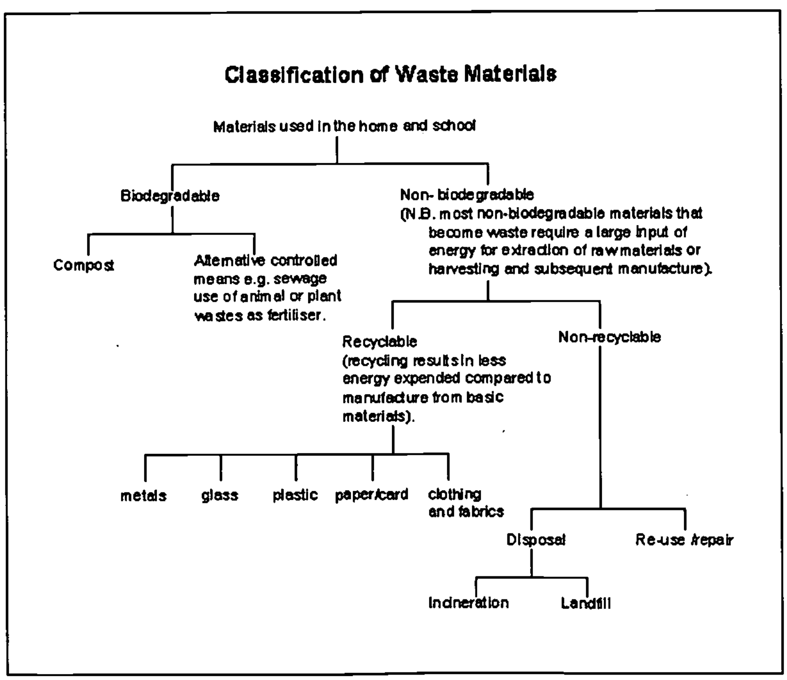
2. For the action research a collaborative teaching activity was developed as a model to test whether the various criteria of key knowledge, skills and attitudes were met. This involved a simple practical waste management programme within their school. They recognised that programmes of this type would be familiar to their students, and therefore it would lack novelty. However, they considered that it had several major advantages, which suited their purpose. In a project of this kind there were distinct scientific and technological aspects as well as economic, social and other types of issues. They could involve a whole cohort of their students, it could be fairly simply put into practice and take place over a clearly defined and short period of time. The outcomes could be evaluated against previously set criteria. Also, they decided to encourage student involvement in the planning process. Planning began with an agreed understanding of the aims in terms of educational outcomes. Students were also involved in the final evaluation.
   The outline programme allowed two weeks for preparation and planning with their students, four weeks for the practical part of the project took and two weeks for analysis, evaluation communication of the outcomes and consideration of ways in which the project could have been extended. A short period between the planning of the project with their students and beginning the practical part of the project was allowed for gathering resources. Rather than plan any further they decided to involve their students in the detail.

**Fig 1.**




3. For students to make decisions about waste management it was considered essential for them to understand the nature and origins of the materials involved. Science classes linked their work to the topic 'materials and their properties'. Materials were classified in different ways according to their composition and origins; their uses; their ability to be changed; disposal, including whether or not they were biodegradable. They also studied the manufacture of familiar materials such as paper, plastic and glass. The use of energy and the environmental impact of extraction, the manufacturing process and different options for disposal were also considered. Charts and posters were made by the students to show particular groupings of materials and how best to manage waste disposal, with particular emphasis on which materials could be recycled.

**Fig 2.**

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The PSE classes emphasised how to use this information to make decisions about waste management. Here students were involved in considering their own beliefs about the outcomes of their behaviour in relation to recycling. Decisions were made initially using the scientific and technological information that they had, particularly whether materials could be recycled, reused or disposed of in a safe way with minimal environmental impact. Following this logistical and economic considerations were thought to be important. For example, the cost-effectiveness of recycling materials and the real costs of recycling or other forms of waste management. In looking at the alternatives for waste management, such as landfill or incineration the aesthetic and social aspects were considered. Furthermore the different impacts on the local environment were reviewed, including both short-term and long-term effects and benefits. Safe and effective collection and storage of materials for recycling were considered. Ethical concerns also involved conservation of resources and the wider impact on more distant environments (both regional and global), particularly with regard to extraction or harvesting of materials such as oil for making plastics and wood pulp for manufacturing paper. Energy concerns, especially related to the topical subject of climate change was regarded as significant. Again students constructed tables and posters to show how thinking had developed.

**Fig. 3**

**Environmental Impacts**

| | |
|---|---|
| **Local** | Safety (e.g. Glass bottles, dangerous chemicals)<br>Water pollution (e.g. oil or chemicals)<br>Air pollution (particles and chemicals from incineration)<br>Soil pollution (from landfill)<br>Subsidence and erosion from landfill<br>Aesthetic from discarded paper, plastics and other materials |
| **Regional** | Water and air pollution become regional problems as pollutants carried in air and water currents<br>Transporting waste materials for disposal causes air pollution and leads to global warming |
| **Global** | Lack of recycling, re-use and repair means that more materials are needed at primary sources, in distant environments. Requiring more extraction and harvesting. Thus more energy require, depletion of resources and removal of habitats.<br><br>Also, the requirement for more manufacture of goods, leading to the need for more energy and creating more pollution. |

Decisions were made about the sort of practical action that should be taken and this resulted in a project in two parts. Firstly they ran a recycling programme in the school, monitoring the actual quantities of each type of material collected over four weeks. The materials collected were glass bottles, paper and cardboard, plastic bottles and metal cans. All of these came either from their homes or from school. The second part was to communicate their findings to others in suitable ways, depending on their audience. After this they evaluated the outcomes with their teachers and considered ways in which the project could be extended.

To assist the practical collection of the materials for recycling students contacted the local environmental health department and obtained temporary loan of suitable containers. After each week students monitored the amount of each type of material that had been collected and decided upon suitable ways of representing this information graphically and in a tabular form.

When the collection phase of the project had been completed students were asked to consider their own attitudes to collection and recycling, how the behavioural norms, expectations and attitudes of their own peer group and of those in authority might have affected the outcome. To assist with this they reflected on the attitudes of others in the group to their involvement in the recycling programme and whether this affected their willingness to become involved. Similarly they thought about the attitudes of their teachers and parents. They also considered what factors might cause them not to recycle materials in the future.

To communicate the outcomes of the project the students produced a website for use in the school, a poster display for the school and local public library, and they made a presentation to a whole school assembly. An officer from the local environmental health department was invited into the school to talk to groups of students.

 

**Fig. 4**

**The Results of Monitoring the relative amounts of each type of Material collected**

| | Paper & Cardboard | Glass (bottles & jars) | Metal (aluminium & steel cans) | Plastic (bottles) |
|---|---|---|---|---|
| Week 1 | 57 | 17 | 17 | 10 |
| Week 2 | 61 | 12 | 18 | 9 |
| Week 3 | 60 | 13 | 18 | 10 |
| Week 4 | 53 | 15 | 16 | 15 |
| Average | 57.75 | 14.25 | 17.25 | 11 |

*Results are expressed as a percentage of the weekly collection by weight.*

*Percentages are rounded up or down to the nearest whole number and therefore may not equal 100%.*

*The overall weight of materials in week 4, when most materials were collected, was 11.5% more than in week 2, when least was collected.*

4. The students were encouraged to evaluate the outcomes of the project. They considered the aims and objectives originally suggested by their teachers, which they thought were generally realistic and most of them had been achieved. Some of these were considered to be of special note, these included; - information from local government about the cost-effectiveness of recycling schemes; an appreciation that social and other considerations are as important as the scientific and economic ones; the opportunity to learn how to access information for themselves from a variety of sources, including the web, local government and NGOs; knowing how to take action co-operatively and taking personal control. The teachers also considered that their students had developed a more constructively critical attitude to information and to the appearance of their local environment and the way that it was managed.
The students stated that the project could have been extended to allow more time to consider the relationship between the effect of their local action and wider global concerns. They wanted to explore different schemes for waste management, including repair and re-use of articles. Also, they would have liked to investigate the effectiveness of local recycling schemes with central pick-up points or kerb-side collection. The economic aspects of the whole process interested many of them. Furthermore, they thought that it would be important to see whether the project had a long-term affect on the recycling behaviour of the students and perhaps their families.
Overall there was general enthusiasm for the project from the teachers and students. This was attributed as much to the way that it was conducted as to the topic chosen. Motivation remained high due to involvement of teachers with their students in much of the planning and implementation. Flexibility and the co-operation of the senior management of the school was identified as being essential and a clear endorsement from the headteacher was considered particularly helpful. All of the teachers involved said that it was good to work with colleagues from different disciplines and although there were few opportunities to work with the same class of students at the same time there were enough benefits for them to want to repeat the experience another time, possibly related to another topic.

**References:**

CHAMBERS (1992) Rural appraisal: rapid, relaxed and participatory. IDS Bulletin 333 (Brighton, Institute of Development Studies, University of Sussex).

FALS-BORDA, O. (1988) Knowledge and people's power: lessons with peasants in Nicaragua, Mexico and Colombia. Journal of Rural Cooperation, 10, 25-40.

GAYFORD, C.G. (1996) Environmental education in schools: an alternative framework, Canadian Journal of Environmental Education, 1, 104-120.

GAYFORD, C.G. (2000) Biodiversity education: a teacher's perspective. Environmental Education Research, 6 (4): 347-361.

HERON, J. (1992) Feeling and personhood: psychology in another key. (London, Sage Publications).

REASON, P. (1994) Three approaches to participative inquiry, in: N.K.DENZIN & Y.S.Lincoln (Eds) Handbook of Quantitative Research. 324-339 (London, Sage Publications).

TANDON, R. (1989) Participatory research and social transformation. Convergence, 21 (2/3): 5-15.

**Keywords:** education for sustainability, participatory methods, action research, collaborative project, student evaluation.

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# AN ANALYSIS OF LIFE CONCEPTS IN BRAZILIAN HIGH-SCHOOL BIOLOGY TEXTBOOKS

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**Abstract**

In a previous work (El-Hani & Kawasaki 2000), we considered how a discussion of life concepts might contribute to biology teaching, stressing their conceptual organizing potential, as they can give the general object of study in the broad area of biology a clear profile, organizing our theories and cognitive models about living beings in an unifying and coherent way (Emmeche 1997, Emmeche & El-Hani 2000). We emphasized how the search for similar features in biological processes and common patterns in the diversity of living beings, which is an inevitable part of any attempt to define life, makes a more integrated approach to biological knowledge possible. The demand for such an integrated approach can be thought of as following from an understanding of the nature of biology, a fundamental feature in any discussion about biology teaching. El-Hani (2000, in press[a]) and El-Hani & Emmeche (2000) argue that biology is a science of living organization, critically appraising the dominating conceptual and theoretical scheme of biological thought, namely, the 'molecular perspective'. An understanding of the organizational patterns observed in living beings indicates how it is important in science and biology teaching to deal with the central, structuring (Gagliardi 1986) concepts in biological thought, in contrast with the encyclopedic tendency of curricula (El-Hani, in press[b]). Among these central concepts, the concept of 'life' deserves special attention, as it refers to the very object of biology, in its more general sense: How can we understand the 'life sciences' without understanding what is 'life'?

The idea that a discussion of life concepts might contribute to biology teaching incited us to pursue new research questions: Is there any concern about life concepts in biology teaching? How the problem of defining life has been dealt with? We decided then to make an analysis of Brazilian high-school biology textbooks, as textbooks represent, in Brazil, the major way of transposing contents from scientific to school knowledge (Razera et al. 1999; Rodrigues & Oliveira 1999; Silva & Trivelato 1999). The books were selected by combining the results of two surveys: a) a survey of the most used textbooks in the city of Ribeirão Preto, São Paulo; b) a survey of the textbooks published by the companies that dominate the selling market in that same city. We have already analyzed 8 from a total sample of 20 books. Therefore, the results reported in this paper should be regarded as partial. The analysis of the textbooks was performed by applying a standard protocol, in order to guarantee a standardized appraisal of how the textbooks dealt with the problem of defining life and life concepts (Figure 1).

From the 8 books analyzed, 5 presented a definition of life. Four books defined life on the grounds of an etymological definition of 'Biology' as the science that studies living beings or life, in opposition to non-living or inanimate beings. One book (that also employed the definition of 'Biology') defined life on the grounds of an etymological definition of the term '*vitae*', interpreted as referring to a set of attributes that maintain the living beings in endless activity. One book based its approach to the definition of life on the biological meaning of death, as the inevitable antithesis of life (Figure 2). All books agreed about the complexity involved in trying to define life, given that some organisms cannot be properly placed in the set of living beings through certain lists of common characters.

All the books analyzed put forward some characterization of living beings. Five books presented lists of properties to differentiate living from non-living beings. Three books characterized living beings by means of a general description of taxonomic groups that highlighted the attributes of each group (Figure 2). In six books (Figure 2), the lists of properties were interpreted as essentialist (Emmeche & El-Hani 2000), as they intended to enumerate necessary and sufficient conditions for an entity to be classified as a member of the set of living

beings, with no theoretical justification for the choice of the properties or explanation of their coexistence on the grounds of some underlying theory. An emphasis on the description of morphological and anatomical features characterizing groups of plants and animals reinforced the search for lists of essential properties. In two books (Figure 2), the lists of properties were interpreted in terms of a paradigmatic view of life definitions (Emmeche & El-Hani 2000), given that the choice of properties seemed to be based on a theoretical (paradigmatic) justification, and the properties showed clear interrelations with one another. In this case, the meaning ascribed to the term 'life' or its derivatives emerged from its connections to the other elements of a network of concepts included in a given paradigm. When the properties listed are interconnected in the context of some paradigm, the list is no longer, as in the case of essentialist definitions, something like a medical syndrome, a collection of symptoms with no underlying cause. Rather, it is possible to explain the characteristic coexistence of that list of symptoms of life on the grounds of some set of causes. To put it differently, when a definition of life is embedded in a biological paradigm, it is possible to find underlying causes to what previously seemed to be merely a syndrome (Bedau 1996). In the textbooks where we found paradigmatic definitions, the paradigms could be implicit or explicitly stated. Amabis & Martho (1997), for instance, clearly presents the idea of evolution as an unifying principle of Biology, as it gives coherence to the biological knowledge produced in several different areas and allows one to understand the phenomenon of life through its interconnections to the evolutionary process. They write that "to comprehend the evolutionary process is fundamental to an understanding of the phenomenon of life" (p. 549). The same is not true of Paulino (2000), who presents a coherent set of interrelated properties, based on a view of the scope of the Biological Sciences as well as of the way the living world is organized, from the simplest to the most complex levels of organization, suggesting the existence of some theoretical justification for their choice; nonetheless, the paradigm at stake is not explicitly stated.

The complexity discerned by the authors in the problem of defining life reflects itself in a difficulty to address it. Only three books include a specific chapter or section about this issue (Figure 2). Some authors explicitly state the difficulty of defining life: "But, as it is exceedingly hard to define what is 'life', from a strictly scientific point of view, with no philosophical or religious influences, we believe that a good way of conceptualizing Biology is to recognize it as the science that studies living beings. Because, at last, to say what are living beings is quite easy. It is enough to say that they are all beings in Nature which present a series of common characteristics..." (Soares 1999:28. Our translation). In this interesting passage, we find several issues worth discussing, as, for instance, the fear of any philosophical influence on a scientific discussion about life definitions, which is not compatible with a thoughtful analysis of concepts so general as that of 'life'. Or the paradoxical claim that it is easy to say what are living beings, while it is exceedingly hard to define what is 'life'. And, finally, we have in this passage a very clear example of an essentialist approach to a characterization of living beings. Here, it is worth observing that Soares (1999:52) also conceives heredity in connection with an essentialist view when he claims that the living beings transfer to their descendants a set of characteristics that define life and are not observed in inanimate bodies. Laurence (2000:16), by his turn, recognizes the difficulties faced by any attempt to propose lists of distinctive characteristics of living beings: "In Science, it is very difficult to define or even characterize some thing or phenomenon, because we often find exceptions. Thus, when studying, we should be aware of the fact that the statements, generally speaking, refer to what is more frequent, to what happens in the majority of the cases or individuals. Although it is quite interesting to know the exceptions, we should not emphasize these exceptions in a high-school level course" (our translation). This passage is found in a chapter about the definitions of Biology and life, and is explicit about the difficulties resulting from an essentialist view of definitions. The existence of 'exceptions' is regarded as so huge a problem that it becomes difficult to define or even characterize the phenomena studied by the sciences. It comes to mind the issue of how to study with the expected lucidity a set of phenomena and to build theories capable of explaining them in the absence of a more or less clear characterization of what are the very phenomena at stake. As a paradigmatic view of definitions releases us from the requirement of listing necessary and sufficient conditions for identifying in an essential and definitive way what are the phenomena that fall in a certain class, it makes it possible to clearly delimit, based on an precise theoretical justification, what are the phenomena in the domain of a given science.

Although most books do not include a chapter or section on the concept of life, it is possible to draw some general ideas about this issue from the texts, through an analysis of how the authors think of biology, the making of science, the scope of the field, the organization of the contents, etc.

It is usual the classification of living beings in a growing order of complexity, from the simplest to the most complex, so that they are arranged in groups of 'lower', 'intermediate' and 'higher' beings. This view is reminiscent of one of the most influential ideas in Western thought, that of a *scala naturae* or Great Chain of Beings (Lovejoy 1936), which persists in the views about the evolutionary process emphasizing progress and perfectability. Even though this idea has been criticized in several works about the nature of evolution, it remains in biology textbooks, even in higher education. When the living beings are thus presented in the textbooks, one can discern a tacit idea that the understanding of small entities, in the micro-levels, is fundamental to the understanding of larger entities, in the macro-levels. Nonetheless, a mere discussion of living beings in supposedly higher and higher levels of complexity (*cf.* Salthe 1985:34) does not guarantee any understanding, say, of the intricate relationships between micro- and macro-level structures in multicellular organisms.

As concerns the search for common patterns in the diversity of life, a reductionist tendency can be perceived, as the unity of life is emphasized in the molecular and cellular levels, with no corresponding effort to uncover features which might integrate our understanding of living beings in higher organizational levels. One cannot lose from sight, however, that such a problem is also found in university biology textbooks. If the cell was formerly the unit of life, now we have the gene, DNA and even proteins. It is not that there would be any problem in searching for a unity in the diversity of life. Rather, this endeavor could foster an integration of biological knowledge, especially if supported by some paradigmatic understanding of the phenomenon of life. The problem lies in the disproportionate emphasis on the micro-structure of biological systems, usually in an approach tending to isolate molecular and cellular structures from the organismic and environmental contexts. This approach can be verified in the fragmentary way the textbooks deal with the levels of complexity, making it difficult to understand, for instance, that the relations of living beings to each other and to their environment depend on their internal organization.

Another reductionist tendency is found in the way the phenomenon of life and the molecular or biochemical level are presented as closely related, while other views on life are relegated to a less important rank. It is likely that this view follows from a fallacious reasoning based on the true premise that to grasp the basic features of the organisms' chemistry is fundamental to a deeper understanding of life. Soares (1999:66), for instance, states that "the study of the chemical composition of the cell constitutes what we call Cytochemistry, Molecular Biology, or Cellular Biochemistry. It is a vast, modern and intrepid study in which we seek to understand the most intimate nature of each phenomenon that takes place inside a cell, in a fascinating investigation to explain each normal or abnormal process of the organism, justifying the nature of diseases, trying to correct or avoid them, and understanding life itself better. It is clear that the biochemical nature of living beings is quite particular to each species or individual. But we can perform a global evaluation and thus have a general view of this spectacular chemistry that so well differentiates the living systems from the inanimate matter, that is, the living from the non-living" (our translation). This passage suggests that life will be better and better understood as our inquiry delves more and more into the micro-structural levels of living beings. Nevertheless, when assuming such an approach, we should not underestimate the risks of losing from sight the need for an understanding not only of the molecular and cellular components of living systems, but also of the organizational principles by means of which the very systems which we classify as living can emerge from those components. Notice, for instance, the claim that diseases can have their nature 'justified' simply through research in cellular and molecular biology. Such a view about diseases overlooks the focal level (*sensu* Salthe 1985) where pathological processes themselves usually take place, involving not only cells and molecules, but, above all, tissues, organs, and organic systems. It conflates the molecular and cellular mechanisms involved in the pathological process with the pathological phenomenon itself.

We also found in the analyzed textbooks an informational view of life. Amabis & Martho (1997:142), for instance, claim that "the nucleus stands for the 'information center' of the cell. It can be compared with the memory of a computer and stores thousands of instructions to make cellular proteins. Given that these molecules rule almost all activities of the cell, the nucleus plays the role of an indirect controller of the cellular metabolism. One of the greatest recent scientific discoveries was the deciphering of the 'language' employed by the nucleus to communicate with the cell. This language is the genetic code" (our translation). All the instructions to the functioning of the cell would be written, in code, in the DNA molecules. The genetic program metaphor, much criticized in the literature (*e.g.*, Levins & Lewontin 1985; Nijhout 1990; Smith 1992, 1994; van der Weele 1995; El-Hani 1995, 1997; Oyama 2000), is clearly stated in this characterization of the genetic material as a controlling program of the cellular metabolism. Among several misunderstandings and difficulties resulting from this metaphor, we have the problem that it emphasizes a purely informational conception of life. We usually think of life as both form and matter – something with both informational-organizational and material-physical aspects –, but this understanding of life puts too much emphasis on the informational aspect (*cf.* Emmeche 1997).

The textbook sections about the origins of life contain important issues concerning life concepts. The treatment of this problem revolves around the possibilities of an origin by divine creation, or chemical evolution, or in some extraterrestrial place. In these sections, the question of the evolution of processes that would make life possible is raised, *e.g.*, how energy could be obtained by a system in order to maintain itself aggregated and organized for some time, isolating itself from the environment and multiplying itself (Amabis & Martho 1997). Life would appear when an aggregate of molecules, endowed with the ability to perform ordered chemical reactions, extracting from the environment raw materials and energy, managed to maintain its organization and isolate itself from the environment. Soares (1999:71), for instance, states that the cell individuates itself through the differentiation of the intra- and extracellular media. It appears, then, the idea of closed and self-organized systems, which could be explored by means of Maturana and Varela's theory of autopoiesis. We did not find, however, any book that addressed the circular, self-referential organization of living systems by employing the conceptual resources of this theory.

The textbooks call attention to the alleged borderline instances between living systems and inanimate matter, in particular, to viruses, understood as exceptions. Viruses and other molecular structures showing distinctive properties of both inanimate matter and living beings seem to be exceptional because they contradict our intuitions about the distinction between these two classes of entities. As living beings, we have a deep conviction that, in principle, we do know what is life and no remarkable difficulty should appear when we try to distinguish between a living being and something inanimate, or between the living and the dead states of organisms. This distinction becomes difficult, however, when we consider equivocal cases such as viruses, viroids, prions, or a biochemical soup of RNA fragments in a laboratory. To cast them aside as exceptions seems to be, at first, quite a natural and easy solution. But a thoughtful analysis can suggest that this solution is not so adequate. Emmeche (1997), for instance, does not consider viruses as borderline cases, but as pathological forms of life, a kind of ultimate parasites, as they presuppose in the functional and evolutionary sense the existence of living cells. Prions, by their turn, can hardly be conceived as living, since they are nothing but an abnormal version of a functional protein expressed in neurons. Due to a mistake in the post-translational modification of this protein, a non-functional version is produced, the prion protein. The gene that codifies the prion protein is in the host itself, so that the prion lacks genetic material and, in fact, *cannot* do copies of itself *in the same sense as* typical living beings do. The prion protein simply catalyzes the very chemical reaction that results in itself. Surely, it may exist, and maybe even necessarily exists, borderline instances between living beings and non-living matter. Nonetheless, what seems strange in the above solution is that it follows necessarily from the attempt to propose lists of necessary and sufficient conditions for life. Thus, the characterization of viruses and other structures as borderline cases may be a reflection more of the inadequacy of our defining procedures than of the nature of what we are trying to define.

It is also interesting to examine the difficulties that follow from the classification of viruses as living beings. Amabis & Martho (1997), for instance, claim that, even if viruses do not show a cellular organization, they are not exceptions to the Cell Theory, as they obligatorily needs a living cell to live and reproduce. This argument is not sufficient, however, for avoiding a violation of the Cell Theory by viruses, as this theory states that the cell is the basic structural unit of all living beings, and this does not hold in the case of viruses, no matter whether they are strictly dependent on cells or not.

Two textbooks (Amabis & Martho 1997, Marczwski & Vélez 1999) address the Gaia hypothesis, in which the Earth is seen as a planetary living being and our own species as a part of this living wholeness, as one of its tissues. It is important to stress, however, that the claim that the Earth is living strains the ordinary concept of life (Bedau 1996), and demands a justification through a proper conceptual analysis. Lima-Tavares & El-Hani (2001,

2002) made such an analysis, showing how difficult it is to justify this claim and suggesting that it should be clearly detached from the hard core of the Gaia hypothesis or even eliminated.

Finally, one finds in the analyzed textbooks a discussion about death, from the biological point of view, as the inevitable antithesis of life. Or, to put it differently, a characterization of life from its counter-example, death. Laurence (1999:17) observes that one of the characteristics of living beings is death, and, then, casts doubt on the claim that an amoeba dies, since it divides itself indefinitely. After concluding that, in favorable conditions, amoebae never die, he raises the question: "Or do they die always?". Amabis & Martho (1997:601) claim that a deep reflection about life should take death in due account. At last, all living beings are subjected to death. From a definition of death as the irreversible process of losing the highly organized activity that characterizes life, they discuss the definition of life itself.

Emmeche (1997) observes that definitions of life are seldom discussed in depth or even mentioned in biology textbooks and dictionaries. Emmeche (1997), Emmeche & El-Hani (2000) and Bedau (1996), among others, regret the fact that critical and systematic reflections about the nature of living beings and life concepts are rare in the history of biology. Emmeche (1997) and Emmeche & El-Hani (2000) discuss the skepticism about the possibility of defining life that is frequently found among biologists. Therefore, it should be regarded as a positive aspect that the biology textbooks we examined here, albeit recognizing the difficulties involved in defining life, do not avoid the discussion about how one can characterize living beings, differentiating them from inanimate matter. Moreover, it is even more pleasing to notice that some books explicitly deal with the problem of defining life. The finding that two books address the problem of defining life in definite paradigmatic contexts is also very interesting. Nonetheless, essentialist efforts to define life through lists of necessary and sufficient properties still predominate in the analyzed textbooks. At least part of the skepticism about the attempts to define life is related to the difficulties faced in proposing definitions of life in such an essentialist manner (Emmeche & El-Hani 2000). It is desirable, then, to address this problem in a non-essentialist manner, inasmuch as this is compatible with population thinking. Paradigmatic approaches to the definition of life can be very fruitful in the pedagogical transposition of the discussions about life concepts from theoretical biology to school knowledge. In particular, the neo-Darwinist paradigm, in which life is understood in terms of the natural selection of replicators (Emmeche 1997, Emmeche & El-Hani 2000), seems to be especially adequate for such a transposition. The theory of autopoiesis may also be used as a basis for a discussion of life concepts in high school, when issues such as the origins of life and cellular metabolism are dealt with.

## Analyzed textbooks

AMABIS, J. M.; MARTHO, G. R. Fundamentos de Biologia Moderna (2nd ed.). São Paulo: Moderna. 1997.

LAURENCE, J. Biologia (1st ed). São Paulo: Nova Geração. 2000..

LOPES, S. Bio (1st ed). São Paulo: Saraiva. 1999.

MARCZWSKI, M.; VÉLEZ, E. Ciências Biológicas. São Paulo: FTD. 1999.

MORANDINI, C.; BELLINELLO, L. C. Biologia. São Paulo: Atual Editora. 1999.

PAULINO, W. R. Biologia – Série Novo Ensino Médio (5th ed.). São Paulo: Ática. 2000.

SILVA, CÉSAR; SASSON, SEZAR. Biologia (1st ed.). São Paulo: Saraiva.1998.

SOARES, J. L. Biologia no Terceiro Milênio: Biologia Molecular, Citologia e Histologia. São Paulo: Scipione. 1999.

**Figure 1:** Standard protocol to analyze life concepts in biology textbooks

1. Textbook identification:
   Code:
   Title:
   Publisher:
   Author(s):
   Edition:
   Publishing year:
   Number of pages:
   Grade:
   Teacher's Manual ( ) Yes ( ) No Activities Manual ( ) Yes ( ) No

2. Does the textbook discuss the problem of defining life?
   ( ) Yes ( ) No

3. Does the textbook somehow discuss some characterization of living beings?
   ( ) Yes. How? ( ) No

4. As to the nature of the life definition(s) presented (if there is any):

   ( ) The definition of life proposed is limited to a list of properties, seeking to characterize what a living being essentially is and what a non-living being essentially is (essentialist view). To put it differently, it is the case of trying to find a list of sufficient and necessary properties for a system to be characterized as living, with no theoretical (paradigmatic) justification for the choice of properties.

   ( ) The definition of life proposed includes a set of properties chosen under the light of an implicit theoretical (paradigmatic) justification, forming a coherent set of interrelated properties.

   ( ) The definition of life proposed explicitly situates the life concept in a biological paradigm, trying to give this concept a meaning by connecting it with other concepts in that paradigm.

5. What is the list of properties presented by the textbook (if there is any)?

6. What is the paradigm in which the textbook includes, implicitly or explicitly, the life definition (if there is any)?

7. What is the definition of life presented by the textbook, if there is any?

8. Are the remarks about the definition of life reflected on the treatment of other issues in the textbooks, or are they isolated from the remainder of the book?

**Figure 2:** A summary of the findings. Question 1: a. Textbooks that defined life on the grounds of an etymological definition of 'Biology'. b. Textbooks that defined life on the grounds of an etymological definition of the term '*vitae*'. c. Textbooks that based its approach to the definition of life on the biological meaning of death. Question 4. a. Textbooks that presented lists of properties to differentiate living from non-living beings. b. Textbooks that characterized living beings by means of a general description of taxonomic groups highlighting the attributes of each group. Question 5. E. Essentialist list of properties, allegedly including sufficient and necessary conditions for a system to be living. T. Set of properties chosen under the light of an implicit theoretical (paradigmatic) justification. P. Life concept explicitly situated in a biological paradigm.

| Questions/ Books | 1: Does the textbook present a definition of life? | | | | 2: Does the textbook discuss some characterization of living beings? | | 3. Does the textbook discuss the problem of defining life? | | 4. Does the textbook present a list of properties to characterize living beings? | | | 5. What is the nature of the life definition or characterization presented? | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | YES | | | NO | SIM | NÃO | SIM | NÃO | SIM | | NÃO | E | T | P |
| | a | b | c | | | | | | a | b | | | | |
| 1 | | | | X | X | | | X | | X | | | X | |
| 2 | | | | X | X | | | X | X | | | X | | |
| 3 | | | | X | X | | | X | X | | | X | | |
| 4 | X | | | | X | | | X | | X | | X | | |
| 5 | | | X | | X | | X | | | X | | | | X |
| 6 | X | | | | X | | X | | X | | | X | | |
| 7 | X | | | | X | | X | | X | | | X | | |
| 8 | X | X | X | | X | | | X | X | | | X | | |

Analyzed textbooks:

1) PAULINO, W. R. Biologia – Série Novo Ensino Médio (5th ed.). São Paulo: Ática. 2000.
2) LOPES, S. Bio (1st ed). São Paulo: Saraiva. 1999.
3) SILVA, CÉSAR; SASSON, SEZAR. Biologia (1st ed.). São Paulo: Saraiva.1998.
4) MORANDINI, C.; BELLINELLO, L. C. Biologia. São Paulo: Atual Editora. 1999.
5) AMABIS, J. M.; MARTHO, G. R. Fundamentos de Biologia Moderna (2nd ed.). São Paulo: Moderna. 1997.
6) SOARES, J. L. Biologia no Terceiro Milênio: Biologia Molecular, Citologia e Histologia. São Paulo: Scipione. 1999.
7) MARCZWSKI, M.; VÉLEZ, E. Ciências Biológicas. São Paulo: FTD. 1999.
8) LAURENCE, J. Biologia (1st ed). São Paulo: Nova Geração. 2000.

**References**

BEDAU, M. A. The nature of life, in: BODEN, M. A. (Ed.). The Philosophy of Artificial Life. Oxford: Oxford University Press. pp. 332-357. 1996.

EL-HANI, C. N. Explicações causais do desenvolvimento: São os genes suficientes? Cadernos de História e Filosofia da Ciência 7(1):123-168. 1997.

EL-HANI, C. N. Níveis da Ciência, Níveis da Realidade. São Paulo: FE-USP. Doctoral thesis. 2000.

EL-HANI, C. N. Sistema triádico básico: Um referencial teórico heuristicamente fértil para o ensino de biologia, in: Coletânea do VII Encontro Perspectivas do Ensino de Biologia. São Paulo: FE-USP. In press[b].

EL-HANI, C. N. Uma ciência da organização viva: Organicismo, emergentismo e ensino de biologia, in: SILVA FILHO, W. J. (Ed.). Epistemologia e Ensino de Ciências. São Paulo: DP&A. In press[a].

EL-HANI, C. N.; KAWASAKI, C. S. Contribuições da biologia teórica para o ensino de biologia. I. É possível definir vida?, in: MARANDINO, M.; AMORIM, A. C. R.; KAWASAKI, C. S.; BIZZO, N.; TRIVELATO, S. L. F. Coletânea do VII Encontro Perspectivas do Ensino de Biologia e I Simpósio Latino-Americano da IOSTE. São Paulo: FE-USP. 2000.

EL-HANI, C. N.; EMMECHE, C. On some theoretical-grounds for an organism-centered biology: property emergence, supervenience, and downward causation. Theory in Biosciences 119(3-4):234-275. 2000.

EL-HANI. C. N. O Insustentável Peso dos Genes. Salvador: FACED-UFBA. Master's Dissertation. 1995.

EMMECHE, C. Autopoietic systems, replicators, and the search for a meaningful biologic definition of life. Ultimate Reality and Meaning 20(4): 244-264. 1997.

EMMECHE, C.; EL-HANI, C. N. Definindo vida, in: EL-HANI, C. N.; VIDEIRA, A. A. P. (Orgs.). O Que é Vida? Para Entender a Biologia do Século XXI. Rio de Janeiro: Relume Dumará. pp. 31-56. 2000.

GAGLIARDI, R. Los conceptos estruturales en el aprendizaje por investigacion. Enseñanza de las Ciencias 4(1):30-35. 1986.

LEVINS, R.; LEWONTIN, R. The Dialectical Biologist. Cambridge-MA: Harvard University Press. 1985.

LIMA-TAVARES, M.; EL-HANI, C. N. A cientificidade da hipótese Gaia e sua introdução no ensino de ciências: Uma análise da proposição de que a Terra é viva. Paper submitted. 2002.

LIMA-TAVARES, M.; EL-HANI, C. N. A Terra é viva? Hipótese Gaia e definições de vida, in: OLIVEIRA, E. C. (Ed.) Lógica, Epistemologia e Filosofia da Linguagem. Coleção de Ensaios em Filosofia Contemporânea. Feira de Santana: NEF-UEFS. 2001.

LOVEJOY, A. O. The Great Chain of Being. Cambridge-MA: Harvard University Press. 1936.

NIJHOUT, H. F. Metaphors and the role of genes in development. Bioessays 12(9):441-446. 1990.

OYAMA, S. The Ontogeny of Information (2nd Ed.). Durham: Duke University Press. 2000.

RAZERA, L. C. C.; TEIXEIRA, P. M. M.; CAMPOS, M. C. A.; CONTI, S. R.; ARRUDA, M. S. P. Aspectos evolutivos do conceito de vacina nos livros didáticos do ensino fundamental, in: MOREIRA, M. A.; OSTERMANN, F. (orgs.) Atas do II Encontro Nacional de Pesquisa em Educação em Ciências. Porto Alegre: ABRAPEC. 1999. p. 53.

RODRIGUES, C. D. O.; OLIVEIRA, M. .P. A abordagem da relatividade restrita em livros didáticos do ensino médio e a transposição didática, in: MOREIRA, M. A.; OSTERMANN, F. (orgs.) Atas do II Encontro Nacional de Pesquisa em Educação em Ciências. Porto Alegre: ABRAPEC. 1999. p. 70.

SALTHE, S. N. Evolving Hierarchical Systems: Their Structure and Representation. New York: Columbia University Press. 1985.

SILVA, R. M.; TRIVELATO, S. F. Os livros didáticos de Biologia do século XXI, in: MOREIRA, M. A.; OSTERMANN, F. (orgs.) Atas do II Encontro Nacional de Pesquisa em Educação em Ciências. Porto Alegre: ABRAPEC, 1999, p. 59.

SMITH, K. C. The Emperor's New Genes: The Role of the Genome in Development and Evolution. Durham: Duke University. Doctoral thesis. 1994.

SMITH, K. C. The new problem of genetics: A response to Gifford. Biology and Philosophy 7:331-348. 1992.

VAN DER WEELE, C. Images of Development: Environmental Causes in Ontogeny. Amsterdam: Vrije Universiteit. Doctoral thesis. 1995.

# 013 GLOBALISATION, TRADITIONAL KNOWLEDGE AND HIV IN SOUTH AFRICA: CHALLENGES FOR SCHOOLS AND CURRICULUM

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**Abstract**

South Africa is in a complex transition, following the birth of democracy and a 'new nation' in 1994 and re-entry into the global economy. Science education faces critical responsibilities. In cities, townships and rural communities, it must bring together the demands and opportunities of globalisation, the re-energizing of local knowledge and lifestyles, and the crisis of HIV/AIDS. The demands are often antagonistic. Education for the global economy assumes students have high confidence in their futures and creativity, but with HIV/AIDS, perhaps 25% are terminally ill. Western science, especially in the context of globalisation, presents itself as an imperative and superior way of knowing, yet often contradicts African beliefs. Many in rural communities are only dimly aware of globalisation and HIV/AIDS, seeing them skeptically, as threats to established beliefs and lifestyles.

Education policy in South Africa has been keenly attuned to economic development, multiculturalism and redress of inequities, but not to the development of HIV/AIDS. Curriculum policy has as its foundations learner-centred, outcomes-based education. The set outcomes strongly support the globalisation agenda, and guide the development of local cultures. To achieve learner-centredness, curriculum design and assessment are largely devolved to schools and teachers. Innovation and discussion have sought curriculum designs that bring together Western sciences and indigenous knowledges. However, there has been little exploration of the ways in which students' interests, motivation and educational purposes might be affected by the HIV/AIDS pandemic. How might schools and curriculum respond? This paper explores these issues in the South African context.

## Introduction

In the mid 1980s, a number of shifts emerged internationally with profound effects in South Africa. Cracks appeared in the economies and structures of communist states in Eastern Europe, the USSR and China, heralding the spread of capitalism across the world. Business and governments, especially in UK and USA, seized upon market shifts from primary and secondary industries to 'value-added production', and supported them with laws that promoted 'free markets', individuality and competition. Computer-based technologies became cheaper and more powerful, and found applications in all dimensions of business and education. In South Africa, international sanctions and pressures on the Apartheid government combined with the power of the liberation struggle, paving the way for the nation's first democratic elections. Blacks, Coloureds and Indians – who comprise nearly 90% of the population – in 1994 became full participants in the nation's governance. The new government emphasised reconciliation and participation, promoted through institutions such as the interim Government of National Unity, and the Truth and Reconciliation Commission. It was a time of hope, joy and confusion. Meanwhile, also in the mid eighties, the existence and threats of HIV/AIDS were identified, locally and internationally, and the disease was quietly spreading (Coombe 2001).

For South Africans in 1994 the immediate experiences of liberation were freedom of movement, freedom of association, and new relationships with the police and government. For government, the tasks were to dismantle the structures and laws of Apartheid, develop new policies, invent systems of governance and administration, integrate the nation into the world economy, and, through it all, maintain a functioning system (Department of Education, 2001a). The work was begun in the face of national debt, a struggling economy (still based in primary industries), and a shortage of skilled people (for education under Apartheid had greatly privileged the White minority).

In all of this activity, the tensions between globalisation and localization, economic development and social/ cultural development were (and are) critical. South Africa rates as the most inequitable country in the world, after

Brazil (Department of Education, 2001a; May, 1998), with disparities in education, health, income, infrastructure and services still tied to ethnicity, gender and location. Social transformation depends on engaging cultural diversity and building participation. The lives, histories and cultures of Black South Africans had to find expression. Economic development depends largely on individuals with skills, confidence and creativity, and access to technologies, capital and infrastructure (Castells, 2001). The new South Africa had to support existing talents, and also bring into the economy those who had been marginalized, historically.

My purposes are to explore ways in which globalisation and multiculturalism can be brought together in the science curriculum, in the light of the HIV/AIDS pandemic. I will consider the three phenomena separately, and then together.

**Globalisation: creativity, production and inequality**

At the center of globalisation is the globalisation of financial markets (including movement of capital and the integration of capital with markets), enabled by financial deregulation and the liberalization of cross-border transactions. Globalisation of trade, production, science, technology and information have arisen in parallel. The essence is networking: sharing information and enabling cooperation, production and management across national borders (Castells, 2001). Networks are not uniformly distributed within or across nations: they can reach into any nation, for any stage of the production process, and at any scale of production. The values that drive the networks are production, creativity and efficiency – all market related values (Carnoy, 2001, Castells, 2001). The market often presents itself as a kind of democracy and moral judge: if the people buy that product or service, it must be 'good'.

Globalisation has dramatically increased productivity and innovation; shifted the economic value of industries and skills; and promoted the restructuring of labour and education. Individualism, competition and the 'morality' of the marketplace have been important ideologies, encouraged by governments and business (Carnoy, 2001). Unions and the 'community of the workplace' have been weakened. Similarly, because education and the search for talented individuals reach across social classes, class definitions of identity have been weakened.

In spite of increased productivity, poverty and inequality – within and between countries – have deepened. As Illbury and Sunter (2001) observe, "to the victor the spoils". Castells (2001) distinguishes between inequality, poverty, polarization and social exclusion. Inequality might be acceptable, if riches and opportunities were distributed so that the poor as well as the rich were better off. This is the oft-promoted 'trickle down' effect. The number of people below the poverty line has declined in some countries, such as India, China and Chile (who were starting from a low base), but in others, such as USA, Germany and South Africa, it has increased (Castells, 2001). Polarization has also increased: the rich are getting richer and the poor poorer. Social exclusion has also increased. Most of the poor are left to seek other ways of surviving and shoring up their self worth. Promotion of cultural identity and local community become especially important, for individual well-being and for the nation.

Governments in developing countries are under pressure. They have to join the global economy, knowing it can increase productivity, markets and national development, and that isolation is impossible. They reduce taxes and tariffs in order to attract investments, and distribute control so as to facilitate flexibility and creativity. These choices reduce the funds available for social spending, and the state's control over national development. To become competitive (Carnoy, 2001) governments must raise education levels (especially in sciences), extend infrastructure and access to technologies, and build social cohesion, trust, health and well-being (including the containment of crime.) This requires social spending. So does HIV/AIDS. In South Africa, these strategies are planned, but hampered by resources and capacity (Department of Education 2001a, 2001b).

In education, the provision of qualified teachers, buildings, electricity and school toilets is improving, participation in general education in nearly universal, though achievements are poor (Department of Education, 2001a). In higher education, between 1991 and 1998, the number of Black graduates increased by a factor of 2.7 (SAIRR). However, inequities persist in sciences. In higher education, Whites (who comprise about 10% of the population overall) outnumber Blacks 2:1 in engineering, 3:1 in computer science, and 8:1 in industrial arts (SAIRR, 2001).

Inequality amongst the Black population is now almost as high as for the nation overall (May, 1998).

The management and nature of globalisation will change (Carnoy, 2001, Castells 2001, Illbury and Sunther, 2001). The current system is not sustainable, even in its own terms. The global financial system is rickety, and satisfactory methods of regulation do not exist. Second, ever-increasing production requires ever-increasing markets: the 30% of the world's people who are rich need the buying power of the others to maintain the system. Third, polarization, inequity and exclusion create conditions of instability where malaise, crime and revolution threaten economic activity itself.

There are also moral arguments. People around the world are more aware than ever of human connectedness, and cultural diversity. They know also the depth of inequities and atrocities, and can join in a moment international networks of protest. Kofi Annan, in his acceptance of the 2001 Nobel Peace Prize, said it clearly:

> *No-one today is unaware of this divide between the world's rich and poor. No-one today can claim ignorance of the cost that this divide imposes on the poor and dispossessed who are no less deserving of human dignity, fundamental freedoms, security, food and education than any of us. The cost, however, is not borne by them alone. Ultimately it is borne by all of us... Today's real borders are not between nations, but between powerful and powerless, free and fettered, privileged and humiliated. Today, no walls can separate humanitarian or human rights crises in one part of the world from national security crises in another...*
> *Annan, 2001.*

Globalisation requires of the science curriculum a strong emphasis on technical competence in Western science and skills in problem-solving, applications, etc, but more. In working towards that emphasis, it has also to respond to the cultures and experiences of diverse groups – as a means of involving them in science education, and as part of strengthening their communities in and beyond the school.

**Cultural differences**
Colonialism and Apartheid wounded South Africans deeply. For centuries, Whites asserted the superiority of their sciences, cultures and wisdoms – through rule, law, social structures and public administration; through language, education and attitude. The effect for Blacks was damage to their beliefs in their names, cultural histories, struggles and achievements. Many responded ambivalently, proclaiming their own cultures, yet in the same breath distancing themselves from their roots. New clothes, new languages, new sciences. Barbara Kingsolver captures the confusion in her novel, *The Poisonwood Bible.* Leah is upset because the African boys at the local school refuse to let her teach them. She talks about it with their African teacher.

> *"Understand first, you are a girl... And second, you are white."*
> *"White", I repeated, "Then they don't think that white people know about long division either?"*
> *"Secretly, most of them believe white people know how to turn the sun on and off and make the river flow backward. But officially, no..."*
> *Kingsolver, 1998:p280*

The birth of South African democracy provided a keenly awaited space for African cultures. Ancient myths were revived and histories reframed, traditional rites and dances moved into the open. People reclaimed their African names, and the new government declared eleven official languages. Cultural development and cultural borrowing were now choices. Western science is one of those choices.

The place of Western sciences in the curriculum is not in doubt (Department of Education, 2001b). The predictive accuracy of their theories, and the power of the procedures that generated them, are unquestioned. Whether of not the theories are 'true' representations of 'reality', they say important things about reality, and warrant serious study. Secondly, Western sciences – notwithstanding blunders along the way – have demonstrated the contributions they can make to production, communication, travel, environmental management, medicine, agriculture and war. Western sciences have instrumental value. Third, they are central to international discourses on science-related matters.

On the other hand, Western sciences often conflict with African ways of knowing – especially as they are usually presented in schools. Curriculum materials, texts and examinations usually present science, simplistically, as reductionist (understanding complex systems by studying their component parts), compartmentalized (this is science, that is religion, or sociology, or politics), objective (independent of the observer), positivist (describing reality 'out there'), and mechanistic (change occurs through interactions and energy transfer). These tenets do not sit well with African worldviews, which emphasise the continuity of subject and object, matter, mind and spirit, human and non-human, living, once-living and non-living, natural and supernatural, individual and community (Jegede, 1998; Ogunniyi et al, 1995). These continuities are central to ubuntu: "I am through others; because we are, therefore I am." Ubuntu is about harmony (Boon, 1996; Schneider, 1997). Further, contrary to the usual scientific axiom of reproducibility, African experience is that some people have 'special hands', so that one cook will always produce better food than another, one gardener better vegetables than another, one experimenter different results from another (Khumalo, 2001). These variations are not reducible to chance or failure to follow instructions, but depend on powerful influences (for which supporting evidence is available). Chance and coincidence are dismissed as causal explanations: the interesting question is not whether the anopheles mosquito spreads malaria, but why that mosquito bit that woman. Western science shrugs off such questions; sangomas and inyangas don't. Thus, for many Africans, Western sciences are limited at heart by their axioms, their compartmentalisation and the narrow scope of their explanations.

Conflicts between African beliefs and Western sciences also arise as part of day-to-day activity. While most African sayings and teachings – about nature, environmental management, production, human relationships, health and safety – are consonant with Western sciences, some are not. For example, many Africans believe that covering water containers or sprinkling muthi (special potions) around a house provide protection from lightning. These teachings come with the authority of traditional wisdom, and have implications for safety. More serious is the oft-quoted belief that having sex with a virgin cures HIV/AIDS – a belief that not only spreads the disease, but promotes male domination and child abuse. Instances such as these bring the science curriculum face to face with moral responsibilities: to what extent should the curriculum question and seek to change such beliefs?

School science in South Africa, until recently, avoided such conflicts by treating science as discipline-based sets of abstractions and algorithms derived from laboratory experiments. Where links were sought to 'daily life', they usually privileged European and urban experiences – billiard balls, cars, electrical appliances, industrial processes. Students responded, for the most part, by regarding their school science as a closed system of texts, problem sheets and tests, not meant to connect to life outside. At a personal level, they practiced various forms of 'border crossing'(Aikenhead 1996), 'collateral learning' (Jegede, 1998) and 'contiguity learning' (Ogunniyi, 2002). And in all domains of science learning, African students have to contend with working in a language (and culture) other than their own.

The science curriculum has to link Western sciences to students' lives, beliefs and languages, and raise for critical discussion different beliefs and knowledge systems. These requirements go beyond the demands of globalisation, but are compatible with it.

**HIV/AIDS**

The dreams, plans and lives of South Africans are all threatened by HIV/AIDS. Millions of South Africans are HIV-positive. In 2000, 40% of deaths for people aged between 15 and 49 – the productive years – were due to HIV/AIDS. Incidence levels are estimated at about 25% nationally. In KwaZulu Natal Province, the rate is about 33%, and in some districts more than 50% (Badcock-Walters, 2001). Prevalence rates are as high or higher in universities, technikons and nursing colleges as in the general population, striking at the country's future leaders as surely as the general workforce. The estimates may be conservative, and in any case, are so high that infection rates could escalate rapidly. Even if the spread of HIV were curtailed, the progress of current infections will shortly yield horrific social, personal and economic devastation. In families, communities, workplaces and schools, children and adults will increasingly be called on to tend to their sick, and divert money, time and emotional energy to the dying. By 2015 orphans are likely to constitute over 10% of the population (Coombe, 2001).

The nation's response over the last two decades has been half-hearted and largely biomedical, focused on preventive drugs, community awareness and safer sex (Coombe, 2001). The response has been inflected with denial and compounded by silence, because of the social stigma widely attached to the disease and the behaviours that spread it. Religious groups, with notable exceptions, have not helped, by refusing to promote condoms and, in some cases, defending HIV/AIDS as 'God's punishment' to the infected. The President and the government have added to the confusion by questioning the relationship between HIV and AIDS and arguing about the statistics (Coombe, 2001).

The biomedical emphases, the focus on "AIDS awareness" and the provision of condoms have had little success; the disease continues to spread and is now pandemic. HIV/AIDS strains in South Africa, though different from strains in other parts of the world, appear to be no more infectious, suggesting that the pandemic here has arisen through social, economic, cultural and political conditions (Coombe, 2001). Values, knowledge, actions and the interactions between them are critical, and to some extent social/cultural. Unsafe sex and abuse of females continue, and women aware that they are HIV positive have babies and breast-feed them, in spite of knowing about the disease and the possibilities of infection.

Understanding of the complexity of 'HIV/AIDS the pandemic' is only beginning to emerge. Absenteeism and attrition from work and school are increasing, under a growing cloud of sadness, trauma, lives lost and lives diverted. Simply to maintain schools, businesses, health services, transport systems, etc. – quite apart from developing them – is now grasped as a formidable challenge.

Forward planning is not easy. Science teachers will be lost from the system not only as a result of infection, direct involvement and emotional stress, but to fill vacancies in business and industry. Modelling teacher supply and demand is fraught, because of inaccuracies in measures of incidence, uncertainties in the ways the pandemic will develop, and the complexities of forward projection. Existing projections, however, suggest that an immense shortage of science teachers will emerge, in spite of reductions in student numbers (Badcock-Walters, 2001). It takes 3-4 years to train a teacher, longer for a head of department, principal or regional manager.

Provision of personnel is only one aspect of the pandemic. Schools and teachers are at the 'front line' through their direct involvement with children and families. Principles and teachers will need skills, management structures and emotional strength not foreseen in their training. The first responsibility will be education about living with HIV/AIDS – not only as part of "Life Skills" programmes, but throughout the curriculum. Science has obvious roles in this. One thrust will be to curb the spread of the disease, through better knowledge and the development of values and behaviours that address health, identity and interpersonal respect. Another will be to help those directly affected by the disease optimize their physical, emotional and spiritual health. Schools are well placed to serve as community centres, and will be called on to do so – working with other groups in personal care and community education. Schools must also rethink the 'normal' curriculum. HIV/AIDS presents new dimensions of 'diversity' and 'inclusion' to which curriculum and teaching must respond. Schooling when a significant percentage of the students, teachers, and their friends and families are terminally ill cannot be the same as education in an AIDS-free society. Should science teachers simply proceed with 'business as usual', explaining the electric circuit, the wonders of the prism, the reproduction of flowering plants? How should 'curriculum delivery' be revised, in the light of increasingly sporadic attendance as children are drawn to responsibilities at home, or are struggling to survive as orphans? Inclusiveness goes beyond shaping pedagogy and content; it becomes a desired outcome in itself.

At the same time, responses to the pandemic must sit alongside other curriculum purposes, such as economic and cultural development and social transformation. Learners who will become leaders in business and community – with all of the confidence in their futures that that entails – will work beside learners who are terminally ill. We know little about how students' and teachers' educational purposes and interests will be affected by HIV/AIDS.

**A policy framework: learner-centred and outcomes-based**

Since 1994, curriculum policy development in South Africa has proceeded boldly, keenly attuned to the demands of multiculturalism and globalisation, economic and social transformation and cultural development, barely aware of the HIV/AIDS pandemic. In 1997, the government heralded *Curriculum 2005* (Department of Education, 1997) as a symbol of the new South Africa (Jansen 2000). The vision was learner-centred and outcomes-based.

"Learner-centred education" was promoted especially for its foundations in human rights, respect for diversity, and classrooms that model democratic processes (Department of Education, 1997, 2001a). The policy also promotes effective learning – shifting the focus from teaching to learning, through curriculum designs that build from learners' knowledge, purposes and contexts. The South African outcomes-based strategy, following countries such as Canada, Australia and UK, is one in which outcomes and standards are set centrally, and curriculum design and assessment are largely devolved to schools. The single, national set of outcomes symbolized a unified system (an important aspect of equity, in the wake of Apartheid). The outcomes also enabled redefinition of 'content', to suit the demands of economic and social transformation, and provided a technology to support learner-centred education. Outcomes could be defined broadly enough to allow local interpretations and variations, but narrowly enough to still claim common achievements for all students. *Curriculum 2005* was accompanied by policies on teacher education that emphasized the roles of teachers as subject experts and curriculum designers, and programmes of in-service education.

The requirements of globalisation and multiculturalism are reflected in the *Curriculum 2005* outcomes. Overarching all learning areas is a set of 'critical outcomes' – critical in the sense of important and critical in the sense of critique. Problem solving, critical thinking, communicating, personal management, teamwork, and responsible use of science and technology promote the globalisation agenda; responsible citizenship, cultural sensitivity and 'understanding the world as a set of related systems' lean towards the multicultural agenda. Within each of eight learning areas, the policy sets 'specific outcomes' which proscribe the learning areas. Science is defined broadly. Alongside the conceptual knowledge and process skills from Western sciences, there are outcomes concerning the relationships of science to culture, environment and economic development; ethics, bias and inequities that arise from the sciences; responsible decision-making in science; and the contested [problematic] nature of knowledge in science (Department of Education, 1997).

**Curriculum design: Bridging globalisation and African sciences**

*Curriculum 2005,* with its lofty visions, hard-to-understand documentation, devolution to teachers, and inadequate support systems (Chisholm, 2000), represented an enormous and sudden shift from the bureaucratic approaches it replaced. While there was widespread public and professional endorsement of the policy's principles and intentions, most teachers struggled to translate them into curriculum. Many continued with their old ways. Many others (mostly but not only in primary schools) experimented with new approaches. Departments of Education, non-government organizations, curriculum development units and private publishers provided examples (GICD, 2001, 2001a). Although these materials vary in quality, inspection shows resonances with constructivist learning theories, cognitive development theories, the *Science-Technology-Society* and environmentalist literature, critical pedagogy (developed here as "people's education"), and cultural approaches. I will focus on the ways in which African experience has been and might be incorporated.

At the simplest level, African technologies and daily life (in construction, manufacture, transport, agriculture, cooking, medicine, etc.) are used as contexts for developing Western science ideas and explanations, and African languages are part of classroom discourse. These approaches remain 'closed', in their focus on particular concepts, theories and skills from Western science, and continue to privilege Western Science (or view it as a system of thought). At the same time, students respond with pleasure in having their own lives and languages brought into the classroom (Manzini, 1999; Malcolm and Keane, 2001)

At a second level, students explore instances where Western and African science borrow from each other – whether in theories of heating, food preservation, environmental studies, land management, use of resources, or the development of medicines. For example, Zulu science and Western science are similar in their explanations of how storing maize-cobs in especially designed pits helps preserve them. Explorations can address processes as well as 'content', when students consider what it means to 'work scientifically', and ways in which all people, in all cultures, use observation, theorizing, experiment and logic to test ideas. Alternative ways of knowing are admitted to the classroom, but with a view to consonances, not dissonances.

A third level addresses directly issues of philosophy, belief and assumptions, including dissonances. Units can be designed with philosophical aspects as central themes, in topics such as disease, farming, conservation and cultural history. Alternatively, discussion can arise from particular instances. For example, Manzini (1999) reports the experiences of his Grade 11 class, where the students burnt incense (part of religious rites) as a context for discussing convection. At the end of the teaching sequence, some students explained the rising smoke in terms of convection and air currents. Others insisted that the smoke rose to find ancestors, or argued that the smoke rose because of convection, but the ancestors controlled the air currents. The conflicts invite discussion within the class. Interestingly, resolution could not have been achieved by a classroom experiment. First, the smoke did not rise continually in a vertical stream, as predicted by the school rule "Hot air rises". Second, attempts at more carefully controlled experiments – for example, by doing the experiment in a carefully designed box – would have contrived a situation that no longer represented the room and did not have the same interest for ancestors. Resolution, for the class, had to depend on authorities – whether distant scientists and their frameworks, or cultural elders and theirs. The simple appeal to experiment is insufficient; the Western science position depends on experiments done by others with different fluids, and complex theories into which the rule 'hot air rises' fits. The argument is remarkably parallel to the African one: many experiments have been done with rising smoke, and the explanation is framed within more complex theories, which are also supported by evidence. The testing of theories is as much about valuing and appeal to authorities as it is about experience. From discussions such as these, students can come to better understand Western science as a way of knowing. Such discussions also pave the way for handling conflicting beliefs in questions such as protection from lightning or HIV/AIDS.

These approaches are entirely compatible with the globalisation agenda: they promote deep engagement with ideas, connection of theory and experience, critical and imaginative thinking, and a deeper understanding of the nature of Western sciences. Students in a Grade 8 class (Malcolm and Keane, 2001) reported following the trial of one such unit: "We learned to use our head, because not everything we do we actually think." "We learned how to listen more carefully, to have an open mind..." "We learned to work in a team." "We learned to think logically".

**Learner-centred education, students' interests and HIV/AIDS**

Learner-centred, outcomes-based education in South Africa requires knowledge of the perspectives, contexts, concepts, purposes and outcomes that students – especially Black African students – see as worthwhile. There is a paucity of such research – with students or with teachers. While teachers have considerable knowledge about the environments in which students live and the technologies they use at home, teachers generally have little insight into students' educational purposes, interests, and ways of learning. Until now, such insights were not considered especially important. Given that those insights are not readily available from teachers, research into students' interests needs to work mainly with students. The research is difficult, especially with young children. Open questions such as "What are you interested in?" "What do you do after school?" "What stories do you like?" are too general and too abstract. More innovative studies are required.

The situation is deeply confounded by HIV/AIDS. Almost nothing is known about students (and their teachers and communities) living with HIV/AIDS as a daily routine. How does living with the disease influence students' interests? How are their educational purposes and needs affected? How diverse are their responses to the disease? What questions can be asked? How might their interests be coupled with those of students who are well and determined to stay well? How should the needs of students and teachers directly affected by the pandemic be measured against national (and individual) needs for economic and social development, even to maintain a functioning economy and a functioning society?

The science curriculum has three responsibilities directly related to living with HIV/AIDS: to help contain the disease, to help communities live with the disease, and to provide a science curriculum that meets the needs of all students and the nation. South Africa, like some other developing countries, is heading into an extraordinary time. It will require extraordinary imagination, energy and compassion, part of which will be extraordinary research with children and teachers.

## References

AIKENHEAD, G. (1996), "Science education: border crossing into the subculture of science", *Studies in Science Education*, Vol. 27, pp. 1-52

ANNAN, K. (2001), "To save one life is to save humanity", acceptance speech on receiving the Nobel Peace Prize, as reported in *the Star* newspaper, Johannesburg, Dec.12, page 15.

BADCOCK-WALTERS, P. (2001), 'HIV and its impact on the Education sector: The Management Challenge', seminar presented at University of Natal, September 14,

CARNOY, M. (2001), "The role of the state in the new global economy", in Muller, J., Cloete, N. and Badat, S., *Challenges of Globalisation,* Maskew Miller Longman, Cape Town, South Africa, pp. 22-34.

CASTELLS, M. (2001), "The new global economy", in Muller, J., Cloete, N. and Badat, S., *Challenges of Globalisation,* Maskew Miller Longman, Cape Town, South Africa, pp. 2-21.

CHISHOLM, L., (chair), (2000), *The Ministerial Review of Curriculum 2005,* Department of Education, Pretoria.

COOMBE, C. (2001), *Managing the impact of HIV/AIDS on the education sector,* report commissioned by the UN Economic Commission for Africa, University of Pretoria.

DEPARTMENT OF EDUCATION, (1997), *Curriculum 2005,* Pretoria, South Africa.

DEPARTMENT OF EDUCATION, (2001a), *Education in South Africa: Achievements since 1994,* Pretoria, South Africa.

DEPARTMENT OF EDUCATION, (2001b), *National Strategy for Mathematics, Science and Technical Education in General and Further Education and Training,* Pretoria, South Africa.

GICD, (2001), Unpublished report on the evaluation of recent school texts, Gauteng Institute of Curriculum Development, Johannesburg.

GICD, (2001a), *Working together – Scientifically,* Gauteng Institute of Curriculum Development, Johannesburg.

ILLBURY, C., AND SUNTER, C. (2001), *The Mind of a Fox,* Human and Rousseau Tefelberg, Cape Town, South Africa.

JEGEDE, O. (1998), "The knowledge base for working in science and technology education", in Naidoo, P., and Savage, M. (eds), *African Science and Technology Education into the new millennium: practice, policy and priorities,* Juta, South Africa, pp151 – 176.

KHUMALO, G. (2001), Masters work in process, University of Durban Westville, private communication

KINGSOLVER, B. (1998), *The Poisonwood Bible,* Harper Flamingo, NY

MALCOLM, C. AND KEANE, M. (2001), "Working scientifically, in learner-centred ways", paper presented at the Sixth International History and Philosophy of Science and Teaching conference, Denver, USA, November 7-10.

MANZINI, S. (1999), *The influence of culturally-relevant science curriculum on African learners,* unpublished MEd thesis, University of Durban Westville.

MAY, J. (1998), project leader, *Poverty and Inequality in South Africa*, Report prepared for the Office of the Executive Deputy President and the Inter-Ministerial Committee for Poverty and Inequality, Pretoria.

OGUNNIYI, M..B., JEGEDE, O.J., OGAWA, M., YANDILA, C.D., OLADELE, F.K. (1995), "Nature of Worldview Presuppositions among Science Teachers in Botswana, Indonesia, Japan, Nigeria and the Philippines", *Journal of Research in Science Teaching,* 32(8), pp. 817 –831.

OGUNNIYI, M.B. (2002), "Science learning and the contiguity hypothesis", paper presented at the 10th annual conference of the Southern African Association for Research in Mathematics, Science and Technology Education, Durban, Jan 22-26.

SAIRR, (2001), Report on participation in higher education by the South African Institute of Race Relations, described in the *Star* newspaper, Johannesburg, Dec. 12, p7.

SCHNEIDER, C.G., (1997), "From Diversity to Engaging Difference: A Framework for the Higher Education Curriculum", in Cloete, N., Muller, J., Makgoba, M.W. and Ekong, D. (eds), *Knowledge, Identity and Curriculum Transformation in Africa,* Cape Town, Maskew Miller Longman, pp. 101-133.

SEEPE, S. (2001), "Challenged by our times", *The Mail & Guardian* newspaper, Dec. 14, Johannesburg, pp20-21.

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# THE ROLE OF TEACHER PREPARATION FOR INFORMAL SETTINGS: UNDERSTANDING THE EDUCATORS AND TEACHER PERSPECTIVES.

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**Abstract**

In the South of Brazil I teach required education methods and practicum courses to undergraduate biology students. Many students come to the courses with no intention of teaching. They want to have a teaching experience and diploma just in case they need to work while they are looking for a job as a biologist or waiting for a scholarship in the masters program. Despite these aspects, my students are responsive and often want to have a docent or internship experience at the University Natural History Museum (UNHM).

UNHM has a small facility in the Institute of Biology and exhibits are traditional — a reservoir of collections. Caro (1996, p.44) described these conservative science museums as "places where to collect and preserve samples, as a depository for scientists, not for the curiosity of the crowd." The majority of the museum visitors are middle school students on field trips. Thus the tensions among the different perspectives as goals of museum designers, undergraduate students' interest, teacher preparation courses, and middle school curriculum goals are present.

My students have roles as teachers in the museum even if they do not want to call themselves teachers. I want to help them expand their opportunities to teach in different settings. Through this experience they may see that the role of the teacher is very important and the classroom, that this setting can be used to develop, enlighten, and understand the content.

Understanding how teachers are being prepared to use informal settings was the first purpose of this study. However, I could not find enough science educators willing to share their expertise on this topic, so I refocused my question to understand the other side of this story, the science teacher side. Specifically I focused on perspectives of out-of-class activities, as a regular part of the school curriculum. The results of this study have enlarged my perspective of teacher preparation and helped me reorganize the methods and practicum courses syllabi.

## Some Background Information

School field trips to museums, zoos, botanical gardens and aquariums are widely described as activities that enhance motivation by engaging students and promoting learning. However it is not enough to simply take students to these places. Excursions to informal settings need to be well prepared. Science teachers can learn how to plan and manage field trips in a science methods course. These courses help future teachers develop skills needed and required by the National/ State Certification Board. However, many college science teacher educators indicate a lack of time necessary to adequately prepare future teachers to effectively carry out field trips. Research has shown that inadequate teacher preparation leads to the teachers' over emphasizing the use of textbooks. Yager and Penick, (1983) considered that "the supremacy of the textbook is the most serious limit on science learning" (p..22). Furthermore, Yager (1983) noted that "over 90% of all science teachers use a textbook 95% of the time; ... the textbook becomes the course outline, ..." He also claims that "there is no evidence of science being taught by direct experience" (p. 578). Thus the need to understand and develop adequate skills to use informal/outdoor education is imperative.

Informal, non-formal, free choice, outdoor education, and public understanding of science, are some of the terms used by the discipline to explain the activities and learning that occur out of the classroom setting. However these terms are being redefined as the research grows and the field is being shaped. As definitions are being refined other aspects of the informal field need development. One such area is that of teacher preparation to use informal settings. Simmons (1993, p.15), found almost half of the activities suggested by the teachers were recreation related. Thus she emphasized that "without direction, [the teachers] will rely on the previous experience or stereotyped ideas of what can be accomplished in a particular setting."

Olson, Cox-Petersen, & McComas (2001, p.169) said we must "provide preservice teachers with experiences where effective field trip strategies are modeled for them, followed by the opportunity to develop and conduct a field trip with their own students while under guidance of a cooperating teacher and with support from university." The authors stressed "after practicing effective field trip strategies, their concerns tend to shift from a management orientation to a focus on student learning." They found that student teachers "are more likely to take a field trip during their first years as teachers." Furthermore, their student teachers reported the master teachers' comment that they (master teachers) "learned more about how to do field trips by watching the student teachers."

Studies of in-service teachers and their visits to informal settings demonstrated the necessity to "reconsider the relegation of such visits to nonformal learning and to position the visits within the formal learning entitlement of the students" (Smith, McLaughlin, & Tunnicliffe, 1998, p.139). Their main finding is that "a zoo can be an important learning experience for students in the context of formal learning if their teachers are adequately briefed about the topic and opportunities for learning that can be found at the informal science setting."

Manzanal, Barreiro & Jiménez (1999) reported that students who had participated on the field trip acquired a new and deeper scheme of knowledge, and a more solid understanding than the control group. "The field trip gave the pupils concrete data, which fit in with the information that was imparted later in the course" (p. 450).

An examination of the previous literature suggests we need to understand how teachers are being prepared and how they could use informal settings to capitalize on the field trip experience. This study could be useful to science educators who intend to teach pre-service students to use fieldwork more effectively by focusing on students' learning. Furthermore it could provide information that may assist with the reorganization of a science methods course, helping define what should be included/excluded in it.

**Method**

A quantitative/qualitative research design was chosen for this study. The former was intended to assess the science educators' perspectives on including instruction on "out of class" activities in preservice methods classes. The latter described an exemplary teacher (Tobin & Fraser, 1990) and her abilities to capitalize on the field trip experience.

An open-ended survey was sent via e-mail to science methods professors. Seven faculty members, five from North Carolina and two from other states within the U.S answered the survey to science educators. The survey asked for demographic information followed by six major questions. The survey was analyzed to inform the subsequent interview plan and teacher observation. Ethical concerns regarding anonymity and confidentiality led me to avoid mentioning names and universities.

The qualitative part of the study was an intrinsic case study. The subject was an experienced, exemplary science teacher who does field trips as a regular activity in her courses. The subject has been participating in a three-year National Science Foundation (NSF) earth/environmental leadership workshop.

Data collected included interview, field notes, and a college class observation, providing triangulation (Stake, 1995). Triangulation is an essential tool in the qualitative research. In this study triangulation occurred through the field notes I took during two short-term field trips (a 90 minutes class period). I also triangulated my field notes with a methods course class observation at the local university because this teacher participates as a teacher assistant on the university methods course.

Data collected from the teacher plus the survey gave me a broader perspective of the use of informal settings. My ten years experience as a middle school science teacher plus eight years as a science educator could bias my interpretations, especially on the teacher preparation. Nonetheless it helped me understand the difficulties mentioned by the teacher and warranted deeper questioning and probing about the teacher's philosophy. Thus I used constant comparative method of data analysis.

Comparisons between the teacher interview and my observation were done and my focus was concentrated on what the strengths and weaknesses of the field trip activities were, and what student teachers should know in advance to maximize their teaching experiences on field trips. I especially checked out issues concerned with logistics, the issue of choosing students to go to the trips, how the teacher selects the place to visit, teacher and students' role, the pre-visit and the follow up sessions plans, the evaluation plans, and the teacher preparation for informal settings. These issues emerged from the interview and observation phases.

**Presentation of Findings**

The responding science education professors typically middle school teaching experience (from none to eight years with a mean of 3.7). At the high school level experience ranged from one to twenty with a mean of 7.1 years. At the college level experience teaching methods or education courses ranged from none to thirteen years with a mean of 7.9.

The first question was "have you taught an education course that addresses the topic of using informal settings (museums, zoos, aquariums, school backyard, out of class activities) to teach science? If no, could you please explain." Answers for this question were very similar. There was just one "no." The respondent justified her answer mentioning that "the methods course correlated with the professional competencies specified in the professional education guidelines for [my state]." The other answers showed that the educators had devoted part of their courses to address the topic of informal education in some form.

The second question was "how long do you spend on this topic during the semester (how many class periods)?" The answers ranged from zero to ten periods (out of sixty). Only one faculty did not mention a length of time. This person mentioned that she addresses "informal settings as they fit into our other topics."

The third question was "what are the mechanisms that you use to discuss the topic. (Lectures, video, field trips modeling)? Please mention all." In this question many faculty mentioned more than one mechanism. Thus numbers here do not correlate to research subject totals. Again in this question only one person answered "none". The others mentioned at least one mechanism. Five mentioned field trips (four used the words and one gave an example) and two of them use the word "modeling" linked with field trip. Two mentioned guest speakers (or instructors). Two mentioned prior experience perceptions. There was also one reference each for learning cycle, lecture, explore curriculum implementation, and read articles about the informal places as valuable resources.

The fourth question was "how do you address the evaluation plan for the field trip activities?" Although most educators mentioned they do not address the topic directly, there was only one "none" response. Three participants answered that they do not address the topic directly. One addressed the topic as evaluation in general, other evaluated it with the end of course evaluation and one mentioned that she spends "more time discussing the effective implementation of these experiences into the learning experience as opposed to just an 'activity'."

The fifth question was "what phases of the field trip (i.e. pre-visit) do you discuss with your student teachers?" Similarly to question number three there was no correlation between number of answers and number of respondents, because educators listed more than one phase. Two faculty members mentioned that they do "some discussion on what to expect at the site" but mentioned no phases. Two suggested safety/ precautions as a discussed phase of the trip. Two respondents mentioned linking learning to the curriculum as a phase "consider learning factors; ... how to be sure that the field trip contribute to the curriculum" or "stated outcomes". Logistics were also mentioned as a phase for two respondents "check for comprehension on directions/requirements, discuss appropriate attire." Management was mentioned only once "go over rules." Finally, one person mentioned outside people would work directly with student teachers about the phases "folks from the office of field experience work directly with student teachers."

The last question was "how do you evaluate your student teachers on this topic?" Surprisingly four out of seven subjects said they did not evaluate their students. One mentioned a self-assessment portfolio at the end of the semester. Another educator mentioned he evaluated his students by their "ability to set up an effective field trip ... [and] a rubric with points for each category" is used. Again, one respondent delegates the evaluation to outsiders' "folks from the office of the field experience."

The second part of this study was qualitative. Based on an interview and class observations of Ms. Brown (pseudonym), a high school science teacher from North Carolina. She teaches Advanced Placement (A. P.) Environmental Sciences and Marine Sciences for eleventh and twelfth grades. Her school seems to support her field trip activities. During observations and interview, seven major categories emerged from the data.

*Logistics*

Ms. Brown emphasized that a field trip demands a lot of paper work. The first issue is to know the place first, contact people and get permissions of the faculty/ administration, and students' permission forms. Another issue is to determine the field trip costs and collect the necessary money from the students. She also suggested that teachers should have their own bus driver license to have more autonomy. The following excerpt summarizes her thoughts

> "... I think I am the only one willing to do it [field trip]. It takes a lot of work. It is a lot of paper work. I am now also the only one that drives. I am not the only one but I drive a bus, you can't be the only one. We just hired a new teacher and he has been on one field trip. He is the earth science teacher. He, I think, in the future will take field trips. Because it is just too much work. You have to get permission, student permission, faculty or administrator permission. You gotta collect money. You gotta make all the phone calls and stuff like that, so it is a lot of work. It really is. A lot of people don't wanna do that. ...every field trip I am going I have to do the same thing over again"

*Choosing the students*

Ms. Brown considered it a privilege to go on a field trip and because she has large classes she cannot take all her students. Thus she chooses students based on their grades (C or above) and their achievements in other courses. For example if one student is doing poorly in English, she will not allow this student to go, unless this student shows that he/she is struggling but still interested.

On short term field trips taken during class time, everyone participates. However, on the day trips or weekend trips she must be selective:

> "I can only take forty students on a bus. I do the bus driving because it costs twelve dollars and eighty cents an hour to hire a bus driver, so I have my bus license and that keeps the costs down. ... I tell the students that they must be maintaining a C. If they are doing D and F in my class they definitely can't go, and if any other teacher says they are not doing well in their class then we don't let the students go. ...My day trips there is a whole lot of work to do .... For the long distance field trips the money is a little bit more expensive and again I won't take as many students on that because it is a lot of driving and the kids get tired so I won't put as many kids to a seat. If I have forty kids I usually take half which is twenty than they can each have their own sit."

*Choosing the place*

Ms. Brown chooses the setting for her field trips based upon three issues: the National Science Education Standards (NRC, 1996), the A. P. environmental exams, and career exploration opportunity National Standards are linked with the class curriculum and syllabus. Sites that are selected are linked with the class content being taught at that moment. The exception is the Marine class going to the beach twice a year. Then she selects a time when weather is most likely to be favorable. In this case, the content will be given later in the course.

Ms. Brown also chooses places that could help students better understand a concept that will be tested on the A. P. exams. Therefore she may select a specific relevant site such as a water plant treatment. She uses the trips to discuss career perspectives, relying on experts. The excerpt shows how she decided to include one site in her program, and the career program that this site has.

> "I have been down there in another program and so I knew that they do programs for students. They tell the kids what it took for them to be working at the beach. All the kids say, 'Hey this is cool to work at the beach', you know. 'How do you get there?' And 'How they ended up where they were?' And I do believe that careers as well as education is very important because most kids have no clue what they wanna be when they grow up. 'Hey I like that I am gonna be major in geology or something like that and it puts them in new direction.'

<u>Teacher and Students' role</u>

During my field trip observations in Ms. Brown's classes I was given a glimpse of teacher and students' roles. She subdivided the class into four groups and gave assigned tasks for each group. One group would collect benthic animals with a net and identify them; two others would do chemical tests to analyze dissolved oxygen levels in the water. The last one would measure river flow and velocity. She orally listed what each group should carry to the field and reminded them of their responsibility to have all the material on the bus. When we arrived on the site, she checked the time before leaving the bus, "You have 45 minutes here." Students had information sheets describing how to do the activities and she got everybody started when she said "You all know what to do. I'm not helping."

After they finished their activities, on the bus, she reviewed the findings and discussed the data. For instance, that day the pH was more acidic than usual. She asked students for an explanation. She also asks students to compare dissolved oxygen levels. Ms. Brown asked the students to explain the relationship among temperature, dry weather, and low number of species in the river. Next time the groups will rotate their tasks.

Students came to the class knowing that this was a field trip day. They had received information about what to wear and where they would go, and had previously collected data on the site since the beginning of the year. This was now the third group rotation on the site. Everybody left the bus with all the needed material and came to the side of the river. They put on their boots and waded in. The benthic group had a big net. Using their boots they kicked the rocks on bottom of the river in order to move the sand on the river floor and animals into the net. The river flow group measured the velocity of the flow, dropping tennis balls in one point of the river and with a stopwatch they measured how long it took for the ball to move ten meters. The other two groups used chemical kits to identify chemical features of the water.

<u>Pre-visit and Follow up sessions</u>

Pre visit classes are used to describe the content and give the students the spreadsheets. Ms. Brown's field trips are linked with the content and she prefers discussing it prior to the visit. The excerpt shows at what point of the course schedule she plans a visit.

> "I go on this field trips usually during the chapter or at the end of the chapter [so] that I have discussed it. So the kids are aware of why there is a water treatment plant, why there is a wastewater treatment plant. And the fact that solid waste and paper products of human being is a problem."

However this plan is not always feasible for every field trip. In case of long field trips, Ms. Brown relies on the weather and season. In this case the content may not be covered before the field trip. Then when she gets to the topic she reinforces it by discussing issues they observed during the field trip. The excerpt shows how she proceeds with beach (weekend) field trips.

> "[On] My beach trips I can't do that because of the weather. I do a beach trip in the fall when the weather is nice and do it in the late spring right before school is out, mainly because it is a

> weather related. When... we get to that topic I reinforce by saying, 'Remember when we were at the beach we did this and we did that. Do you remember?' And I also have the kids keep a journal when they go on the field trips. And that journal is for them to keep and be able to remember, or help with their test, or remember. Not only it is a memorabilia but it also, when we actually get to the topic in the classroom, they will have no memories from the trip about some of the stuff that we actually did. So, it can help them in their class."

On the follow up activities she reviews and reinforces the content. Ms. Brown usually makes students keep journals for long trips and to bring information back. In the case of short field trips the collected data is recorded in the journal and brought back to the lab to discuss. Snap shots and time line perspectives are used to discuss the data. As for the snap shots, she puts things in the small context, by comparing groups' data collected on that day. She asks students to compare and analyze group results. To have a big picture, however, she recollects the data collected on other trips and puts them on a time line perspective, making connections with seasons, weather change, and development of the region.

_The evaluation Plan_

Ms. Brown usually does not evaluate directly what students have learned on her field trips. In the case of long field trips not all students come, so, she cannot make it required. The impact of short field trips is measured as a component of the summative assessment. The excerpt summarizes the issue of not having all students on the field trip and its consequences for the evaluation plan.

> "I have them keep the journal. Take notes as they go. If they do the journal and they turn in the summary they will get a grade for it. If they go on a field trip with me and don't turn in the journal, then they just went on a field trip. The kids that turn in the journals or the summary of the journal get an extra either homework or test grade for actually doing the extra work. ... I haven't made it required yet because I can't take everybody on all these trips. So at that way I can't make required unless I have the kids that are back in the classroom also doing the required work."

_Teacher preparation._

Ms. Brown had no teacher preparation for informal settings in her preservice years. Her experiences started on inservice summer workshops. However she indicated that previous experience is necessary to raise confidence. She also indicated that short experiences in the school yard could be crucial to give the teachers the ability they need to do the next step and leave the schoolyard for a bigger trip. The excerpt shows how she began, and how important the modeling process was for her.

> "Every field trip I take [reflect] the field trip I took with a teacher workshop. So I went with experienced teachers and college professors. They showed me the areas, the hotels, the locations, the things to do, even their discussion and their lectures, all that I use to help me. I would never have been able to do these trips on my own, so the experience of a teacher doing it first and knowing where to go is the best. It would be the thing that I would suggest the most. For example, I went to the beach with a program called NCSAT. It is a teacher program and they sent us to the beach ... She took us there and we studied the geology, the sand dune and the birds! Which was really kind of nice, and I learnt how to take a ferry with my students over to the location and I learnt all about that area. ... And then, once I have explored and found out different things, then I will either add it to my program or change, but most [emphasis] of the time teachers, I feel, will never do the field trip unless they have had that experience and know that it is a good experience first."

Another issue stressed by Ms. Brown was the camaraderie among teachers during the inservice training and the role of small trips in raising confidence

> "... They [teachers] have done the experience and they will tell you 'hey this is really good'. 'Go to this place.' 'I have done that island before, I have done that field trip before, here is the phone

number, [and] here is how to get there'. So you share! That is what is really nice about it. You share ideas. I always bring a list of my field trips and I'll give those to other people and I'll share that. I love being at teachers workshops, you know, I hate saying but in my college experience years ago, I didn't learn near as much as I do in workshops. But I think teaching has changed over the years and I think colleges today are searching out. I know the professor that I am working with at ... [university] likes to do field activities, she likes to take them outside, and she likes to take them to the rivers and lakes .... When I was there, actually taking her class she made me go to that site [on campus] so I could actually see it and experience it. So the field trips don't always have to be big trips, they can also be short little things just around the campus .... And if a teacher wants to see how kids react, try that first. And if the kids do well and you can take them out of the classroom into another setting. And the teacher is comfortable with that, then try a field trip where you go on a bus to another location, another destination."

## Discussion and Conclusion

Some issues related to field trips were indicated from the survey results. One of them is the lack of consensus about how much time should be allotted for the topic on informal settings. Survey answers varied from zero to ten periods (out of 60). Even though I understand that the respondent who answered "zero" is basing her syllabus on the state professional education guidelines, the National Science Education Standards (NRC, 1996) clearly states in teaching standard D "1D5 Identify and use resources outside the school"(p.45). It also states in the professional development standard 6B learning shall "6B2 occur in a variety of places where effective science teaching can be illustrated and modeled, permitting teachers to struggle with real situations and expand their knowledge and skills in appropriate contexts" (p.62). Furthermore, research indicates that the student teachers lack of experience or their held stereotypic images will impact their abilities to prepare class activities, use textbooks, and make use available resources and materials (Simmons, 1993; Yager, 1983, Olson, Cox Petersen & McComas, 2001).

Another trend that emerged from the survey was the lack of evaluation of student teachers on the field trip topic. Four out of seven respondents did not evaluate their students in this area and the fifth let outside guests evaluate them. Answers like "I consider it an awareness session" or "it is just a bit of orientation" may illustrate educators' level of interests on the issue.

Ms. Brown's recommendations and those found in current literature are in accordance with each other but in opposition to what was said by the educators. One big issue for methods classes is always the limited time. A field trip experience is time consuming and work intense. Thus, educators may choose to minimize this aspect of the recommended curriculum.

Ms. Brown has initiative and independence, as reflected by her suggestion about bus driver license. It is important to notice how Ms. Brown ties content with career opportunities. She mentioned that these could broaden the students' career perspectives beyond the common choices. In fact Ms. Brown maximizes her trip linking different contents with the career choices. She uses the trips wisely trying to reach and engage students by the content and by the science career, too.

In respect to field trip participants Ms. Brown has to make some difficult choices to decide who is eligible to go on a field trip. She decided that grades could be a possibility even though she asserts that students learn more in field trips because they use all senses to learn and experience the concepts, so the words would not be a "memorabilia" anymore. Knowing that sometimes it is impossible for a teacher to take everybody, and considering that A. P. students may have the multiple opportunities for outside experience, it would be worthwhile to further investigate facilitation of providing experiences for low level students or less privileged students.

Regarding the teacher and student roles Ms. Brown models the activities for the students. She requires them to try different group activities and different trips during the year. She believes that the teacher should give opportunities for the students to use their senses, learning by tasting, smelling, and feeling the objects. She mentioned that teachers should involve students and use every teachable moment to do that. She builds rapport while showing herself as an active learner when students and teacher are together collecting, observing, identifying animals, analyzing data. She connects the data with social issues, and uses environmental topics on to discuss decision making and ethics.

Students are active learners with their own tasks and responsibilities. They are developing decision-making skills needed in science. They also act cooperatively communicating and learning together.

Pre-visit and Follow-up sessions are difficult when the content is in a non-flexible schedule. One possibility, instead of having the students try to remember what happened months ago, or come back to their field logs, is teachers using more flexible syllabi so they can reschedule the content discussed on the field trip closer to the actual field trip

Assessment of learning from field trips when you have non-participant students can be solved by videotaping the activity and showing it to the students who did not go. Another alternative is to ask them to create a tridimensional model of the site including the main features. A third possibility, when using chemical tests, is to bring a sample to the lab and do the chemicals analysis there.

## Implications for Teacher Preparation

Using responses from the survey, observations of Ms. Brown classes, interview, and the literature review, some implications for teacher preparations emerged. According to research in teacher education, modeling is central for teachers (Reiman & Thies-Sprintall, 1998). On the survey, only two educators mentioned modeling, however, five mentioned field trips. Ms. Brown also referred to the importance of modeling to her career and to her class plans.

The second implication regards the number of field trips experienced during teacher preparation. Ms. Brown recommended two field trips. She suggested the first site be the school yard for the teachers to have a "comfort zone" and then "have them do a big field trip research project." Olson, Cox-Petersen, & McComas (2001) also suggested two field trip experiences for student teachers. However, no one of the seven professors mentioned two field trips. This, again, reflects the proximity of Ms. Brown's approach to the research findings.

The third implication focuses on assessing student teachers' knowledge about field trips. It seems worthwhile to have students plan and implement a trip as a way to evaluate the effectiveness of the module. Ms Brown's interview was consistent with the research literature (Olson, Cox, Petersen, McComas, 2001; Smith, McLaughlin, Tunnicliffe, 1998) suggest that the student teachers assessment should include planning and implementing a field trip. On the survey only one subject mentioned "the ability to set up an effective field trip and to assess (reflect) on what worked and what must be changed next time." He also included a "rubric with points for each category."

The fourth implication is related to peer experience. Ms. Brown suggests that by sharing experiences teachers can help each other explore ways to successfully implement "out of class" activities. No one of the survey subjects mentioned peer experience.

However, research in cooperative learning/reflection has shown the significance of peer experience. There are even National Teaching and Professional Standards for it (see, for example, NSF, 1996, standards 1A4 [p.32] and 6C4 [p.68]). One possibility in to use peer experience on the preservice level to open the regular methods class enrollment to lateral entry teachers. This could be helpful for both sides, the student teacher with no experience and the lateral entry teacher with no educational background could share their respective expertise.

Finally, three issues emerged from the data that should be addressed by further studies. First is what a teacher could do when it is not possible to take all students on a field trip. Or, how can one choose who is going on the trip in order to be more inclusive and meet the needs of low level students? Second, how should field trips be evaluated in terms of impacting learning? And, of course, we need to survey more teacher educators to see if the seven we surveyed are representative of all.

## References

Caro, P. (1996). Informal education through science museums. *Proceedings of the 8th IOSTE Symposium. Edmonton, 3,* 42-47.

Manzanal, R. F.; Barreiro, Jiménez, (1999). Relationship between ecology fieldwork and student attitudes toward environmental protection. *Journal of Research in Science Teaching. 36* (4), 431-453.

National Research Council. (1996). *National Science Education Standards.* Washington, D.C: National Academy Press.

Olson, J.K.; Cox-Petersen, A.; McComas, W. F. (2001). The inclusion of informal environments in science teacher preparation. *Journal of Science Teacher Education. 12* (3) 155-173.

Reimann, A. J.; Thies-Sprintall, L. (1998). *Mentoring and supervision for teacher development.* New York: Addison-Wesley Longman.

Simmons, D. (1993). Facilitating teachers' use of natural areas: perceptions of environmental education opportunities. *Journal of Environmental Education. 24* (7), 8-16.

Smith, W. S.; McLaughlin, E.; Tunnicliffe, S. D. (1998). Effect on primary level students of inservice teacher education in an informal science setting. *Journal of Science Teacher Education. 9* (2), 123-142.

Stake, R. E. (1995). *The art of case study research.* Thousand Oaks, CA: Sage.

Tobin, K. and Fraser B. J. (1990). What does it mean to be an exemplary science teacher? *Journal of Research in Science Teaching. 27* (1), 3-25.

Yager, R. E. (1983). The importance of terminology in teaching K-12 science. *Journal of Research in Science Teaching. 20* (6), 577-588.

Yager, R. E.; Penick, J. E. (1983). School science in crisis. *Curriculum Review. August,* 21-24.

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# SENSORS: THE MOTIVATION FOR LEARNING, TEACHING AND INNOVATING

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## Abstract

Sensors are chosen as the focus of a new approach for learning, teaching and innovating. The fact that nowadays there are sensors based on all types of physical, chemical and biochemical principles, is the focus that brings all natural sciences and many technologies together.

The idea is explored from historical aspects, such as the difference of doing basic research nowadays and in the eighteen's century, but with emphasis on the recent trends, given by the popularization of personal computers and of Internet. The fundamental aspect played by people feelings on being motivated is considered, and the presentation explores the need for actions that change people attitude more than creating new courses or teaching techniques.

The aspect science-technology-society is approached; proposing a large educational program based on the use of existing sensors in schools, fairs and museums. Because there sensors that detect all types of natural phenomena they bring together all natural science and engineering disciplines, helping people to develop the ability to observe, compare and judge. As far as teaching practice is concerned, the use of sensors are proposed to be the basis of a science teaching program for all school levels and for continuous learning programs. It is discussed the fact that subject "sensors" can be approached at any level from the most elementary proportionality point of view up, to the most sophisticated nanotechnology, and data processing. Well designed sensors based, teaching program can take into account the particular aspects of interest of each community, however keeping a common focus on sensors, but with approaches rather different and adapted to specific characteristics. The role played by this program in each level of learning is listed in a tabular form considering the level, or category, the objective and resources and the expected results. The program proposed here is not a close proposal, but a reflection on an initiative that can have very positive effects on the interest of people for learning about science and technology, creating also new opportunities for business.

The perspective of associating the generation of wealth, with motivation for learning and innovating is discussed within the sensors program proposed. The first step along the lines suggested on this paper is given with the creation of the Laboratory of Innovation on Sensor Technology - LITS.

## Introduction

There was a time when theory of phlogistic was used to support the industry of material transformation, specially metallurgy, and at that time, common people could imagine how the four elements that everyone could sense: air, water, earth and fire, were used in industry and in natural processes. The theory was confusing, but public conferences were regularly addressed to everyone, scientists, politicians, peasants, etc. They were all curious and trying to use this confuse theory to understand the natural world. The idea of the existence of atoms already existed, but chemistry had not been systematically organized.

Just before the French revolution (2nd half of 1700), it was Lavoisier that had the clearest perception that something was wrong and he started a systematic research, measuring carefully quantities that allowed him to relate the world of atoms with the manufacture of better metallurgical products.

If from one hand Lavoisier's great contribution created the basis of the chemical industry revolution, from the other hand the sophistication and the need of a systematic rational and structured approach made things much less attractive to people without the necessary background.

Natural sciences like chemistry, physics and biology have advanced to such a point that, even our best trained and most qualified persons, have a hard time in being able to imagine what happens in areas where he/she is not a specialist. Nowadays, the techniques used for measurements go from the large astrophysical quantities down to the atomic and nuclear scale. The so-called nanotechnology is based on lengths in the scale of one billionth of a meter and in concepts that violate every one common sense.

In this very complex world, the question of how can we motivate our population to understand science and technology, or at least attend to a conference on science and technology leaving the conference motivated, is a very hard one. It has been largely recognized that this is a major problem faced by all of us and it corresponds to the core question addressed at this conference.

The present paper intend to shine some light on this complex situation pointing out a general approach that involves all five sub-themes of the conference.

Focusing on the theme "Sensors", the first sub-theme science-technology-society is approached, proposing a large educational program based on the use of existing sensors in schools, fairs and museums. The second sub-theme, content areas corresponds to the core of what is proposed here, because there are sensors to detect all types of natural phenomena, bringing together all natural science and engineering disciplines. As far as teaching practice is concerned, the use of sensors can be the basis of a science teaching program for all schools and continuous learning programs. It is not obvious, but interesting to note that the subject "sensors" can be approached at any level from the most elementary proportionality point of view, up to the most sophisticated nanotechnology, and data processing. Concerning to assessment, one should consider that each community has its own needs, which can have the common focus on sensors, but with approaches rather different and adapted to specific characteristics. Finally the history and philosophy of science is the aspect mentioned in the beginning of this introduction.

## Measure, quantify and motivate

What really matters are the people's feelings, because, within people's feelings is where motivation "lives" and motivation is what makes people spend time and energy in doing something boring, like measuring and calculating. In 1987 the newspaper Toronto Star of the city of Toronto in Canada promoted a series of meetings on the theme "What We Want From Our Schools"[1]. The meetings had involved schoolteachers, administrators, businessmen and politicians.

Besides all the obvious conclusions of the difficulties and complains, one of the most striking was that society wants people that are able to communicate and able to relate themselves with other people. Relating to other people also means being able to write, read and judge, which frequently implies in having some background on language and ideas of proportionality, for example.

One can say that this is exactly what our schools are doing. However, the question of doing it in the most effective way is what matters. A suggestion of a new approach, in the framework of science and technology, is the aim of what is treated in the following paragraphs and sections.

Personal motivation is linked to someone's personality, but depends strongly on opportunities offered by the society, and also on challenges that people think they can overcome. Most people like to satisfy their curiosity, but also like to be rewarded for their contribution. The next paragraphs intend to show that sensors can be the focus of a new approach that will bring the motivation for people to learn about science, to quantify things and to generate wealth, creating a culture of innovation.

The decade of 1980 was characterized by the spreading of the use of personal computers and it can be considered the decade of the increase in the capacity of storing and processing information [2].

During the 90's the capacity of storing and processing kept increasing, but the availability of Internet was the important leap and that decade can be considered the decade of the popularization of the access to the information [2].

This first decade of XXI century already shows clear signs of the trend described above. The "stars" of the decade, most of the time have very small dimensions, microscopic in many cases, and are produced with a wide variety of technologies and materials, some of them discovered only recently. These new stars are the sensors that provide the information for the already fast, reliable and large capacity systems. The miniaturization and the evolution of informatics are the key facts that have created the new opportunity treated here.

In fact, defining sensor as an element that senses something, making the conversion to a measurable quantity, send us back to the Roman Empire, when devices to measure water consumption were already used. The differences now are the sensitivity, the varieties and sizes available, together with the huge availability of reading, storing and processing information at relatively low cost. One can say that the sensors are providing computers the capacity of hearing, seeing, smelling, tasting and touching the environment. In some aspects the sensors provide the capacity that goes far beyond the human possibilities.

Despite of the promising market for new sensors, there are already a great variety of sensors available and an increasing need to monitor things. The Romans could make mistakes of a few percent in their water control without problems, but nowadays, population has increased to a level that requires very tight monitoring for public services, such as supply of energy and water. Controlling air, water and soil pollution is becoming more and more critical, and a large number and better monitoring systems are a necessity. Many industries, public and private services, and individuals will have increasing benefits from the use of sensors. Therefore, this is probably one of the most promising fields for new enterprises and consequently for the so desirable innovations.

## Technological Opportunities and Difficulties

The proprietary characteristics of sensors, i.e., the technology for each sensor depending strongly on final application of it, is an aspect that makes this field highly attractive for a country like Brazil. In fact, the country can rapidly become self sufficient on adapting existing technologies, even if mastering the technology of production of many sensors is not easily reached, or not even desirable. In fact, this aspect is similar to the situation of personal computers, or automobile industry, where the technology is very internationalized and interdependent, but in the case of sensors there are many possibilities of being self-sufficient.

The other important aspect is the variety of applications ready to apply adapted sensors, which include optimization and continuous control of water, air and energy. The benefits for the environment are limited only by our imagination. Accidents can be avoided by continuous monitoring the physical integrity of industrial equipment and reservoirs.

The technology of making sensors ranges from silk screen methods, with the so called thick film technology to the nanotechnology, so that, one can choose the most convenient technological level.

As an example, sensors based on fiber optics that are produced in Brazil, are obtained making small physical and chemical modification on the commercial optical fiber and they can monitor mechanical behavior of structures and equipment [3], quality of water [4] and bio-specific interactions [5].

This paper does not intend to discuss the technology, but to point out the need to develop a culture on sensors and to start soon to avoid missing the opportunities that are in front of our eyes. These opportunities will be available for people that catch the essence of this new wave.

At first sight the opportunities seam to be open only for first world countries, with a highly educated population, however, considering that microcomputers and internet are being incorporated at all levels of instruction, one can imagine that the use of sensors can also follow the same trend. In fact, it is more a matter of a new attitude than that of specific knowledge. People use well cell phones without knowing any detail of it and sensors are far less complex in many cases.

The variety of sensor types and operation conditions needed, opens possibilities that includes production, but applications and development of new technologies using the market available sensors is likely to be the a more promising aspect, as far as business opportunities are concerned.

Only for the technology of micro-sensors (MEMS) the projected world market is of US$35 billions [6,7].

## Sensors Learning and Teaching Program

Sensors are already incorporated in all living creatures. The human body is full of a variety of sensors, for example, the skin detects temperature, heat, humidity and pressure, the eyes detect light and movement, our nose detects some pollutants of air and the taste of water can indicate many pollutants. Some turtles, bees and birds use magnetic sensors to orient themselves [8]. All this is being used in a very effectively way, without any trouble in understanding details.

Therefore, a first aspect that an ambitious sensors learning and teaching program must consider is that we are copying nature and extending already existing possibilities. A second aspect to be considered is that at Lavoisier's time (2nd half of 1700), one individual could have its own laboratory, make fundamental discoveries and be a successful entrepreneur, however, nowadays fundamental discoveries are made by groups of researchers forming international networks and having first class, very expensive infrastructure. A third aspect is that this is a multifaceted program that can start at all levels at the same time, but must have a clear and motivating focus.

Under these aspects the program must bring up the consciousness of the role of sensors in understanding nature, the large variety of systems that already use sensors, the new opportunities open to people on learning and on generating new business with relatively low investment.

In that sense the authors have proposed the workshop "SENSORS: A Corrida do Ouro do Século XXI" promoted by ABINEE-PR (Associação Brasileira da Industria Eletro-Eletrônica), LITS (Laboratório de Inovação em Tecnologia de Sensores), TECPAR (Instituto de Tecnologia do Paraná) and UFPR (Universidade Federal do Paraná), sponsored by IFM-Electronic, IEL (Instituto Euvaldo Lodi), Renault do Brasil, PETROBRAS, Rede Paraná Autotech, Paraná-Tecnologia and MCT (Ministério de Ciência e Tecnologia), and supported by SMAR Sensores, SINAEES-PR (Sindicato Nacional da Industria Eletro-Eletrônica), TURCK Sensores, CTA (Centro Técnico Aeroespacial), SIMEPAR (Instituto Tecnológico Simepar), SETI (Secretaria Estadual de Ciência Tecnologia e Ensino Superior) and FINEP (Financiadora de Estudos e Projetos) and organized by HAWK BRASIL, at Curitiba during the 20th and 21st of November of 2001. During that workshop the "LITS - Laboratório de Inovação em Tecnologia de Sensores" (Laboratory of Innovation on Sensor Technology) was officially created with the mission of disseminating the culture of sensors use in our society, develop sensor applications and research new sensor technologies. The LITS is planned to act on all levels of education and research, keeping a wide network of collaboration with schools of all levels, industries and government.

In order to fix some of the ideas presented the teaching levels involved and action are presented in a tabular format.

| Category | Objective and resources | Results |
|---|---|---|
| Elementary | Dissemination of the idea and awake of curiosity.<br>Schools laboratories, fairs and museums. | School children motivated to understand sensors.<br>Common people curious to learn about sensors and its possibilities. |
| Technical Level | Train people on use and maintenance of sensors available.<br>Technical schools & Companies | - Competence + knowledge of market.<br>- Optimization of processes.<br>Innovation of process & product |
| University Level | Qualify engineers and scientists in sensor technology and market.<br>National and International Universities, Companies and Research Institutes. | Development of products and processes.<br>Innovations with sensors including software, products and processes. |
| Professional Graduate Program | Business and Technical directed Research.<br>National and International Universities, Companies and Research Institutes, including business and administration. | Development and adaptation of new processes and products.<br>Innovation of products and processes, including managing. |
| Academic Graduate Program | Basic Research in Materials, Processes and New Concepts.<br>National and International Universities, Companies and Research Institutes. | New advanced Technologies.<br>Radical Innovation.<br>Highly Technology Updated People. |

This program must have a strong emphasis on the formation of networks with other research centers, universities and companies around the world. The sensors program is designed to create opportunities for people to grow as persons, learning an updated subject that opens opportunities for them, but also knowing other people, places and cultures. The dissemination of entrepreneurship and the capacity of generating Innovations are intrinsically linked to this view of sensors.

This is an ambitious project and several steps are to be overcome. As a result of consistent actions, an already constructed area of 200 $m^2$, was assigned to the LITS in the TECPAR (Instituto de Tecnologia do Parana) in Curitiba-PR. Paraná State Government already provided an initial budget of almost three hundred thousand reais, for infrastructure and equipment. An agreement on transfer of technology in sensors is already established with the CTA (Centro Técnico Aeroespacial).

As far as, the educational part is concerned the team involved is analyzing other programs already established. There are a number of very interesting isolated initiatives, but as for our knowledge there is no parallel in the world, to the global approach as proposed here.

At the University level, a specific degree similar to the French, Diploma de Etudes Scientific Superior-DESS on the Physique des Capteurs et Systemas de Mesure of Université du Paris VI, VII in collaboration with the Conservatoire de Arts et Metiers-CNAM, is under consideration to be implemented in Curitiba-PR. Similarly to the French system this shall be a new complementary partial degree directed towards training people for companies or for them to open their own business with a strong support of private sector. The international cooperation with exchange of students, professionals an opportunities for internship are being considered, together with the different and complementary realities.

## Conclusion

The idea of using sensors as a focus for a new view of science and technology teaching, is based on developing the motivation due to the challenge the sensors pose to peoples understanding, and also because they may lead to new low cost and high profit business. From the point of view of public politics, there are enough evidences that society will depend more and more, on precise monitoring of consumption of energy and water and also on measurements of quality of air, water, soil and food.

A first step on creating a culture where people is motivated to learn about what happens around them, is given with the creation of the LITS (Laboratorio de Inovação em Tecnologia de Sensores). The authors hope this paper will stimulate new initiatives along the same line, and that this will form an effective network of learning, teaching and innovating.

## References

[1] – Report card on Our Schools. A Reprint of a Six-Part Series. Published as Special Report of Toronto Star. Copyright(c) 1987.

[2] - Paul Saffo ***"Sensors: The Next Wave of Innovation."*** Institute for the Future, (1997)

[3] – Homola Jiri, Sinclair S. Yee, Gunter Gauglitz, ***"Surface plasmon resonance sensors: review ."*** Sensors and Actuators B, **54**, (1999) 3 –15

[4] - Azedine Charef, Antoine Ghauch, Patrick Baussand and Michel Martin-Bouyer, ***"Water quality monitoring using a smart sensing system"***, Measurement, **28** (2000) 219-224

[5] - C. K. Y. Leung, ***"Fiber optic sensors in concrete: the future?"***, NDT & E International, **34** (2001) 85-94

[6] - Guido Tschulena, ***"Market Analysis for Microsystems 1996 – 2002"*** -

[7] - Azedine Charef, Antoine Ghauch, Patrick Baussand and Michel Martin-Bouyer, ***"Water quality monitoring using a smart sensing system"***, Measurement, **28** (2000) 219-224

[8] – Kathryn Brown, MAGNETORECEPTION:Animal Magnetism Guides Migration Science 2001 October 12; 294: 283-284

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# THE UNDERSTANDINGS OF ELEMENTARY SCHOOL TEACHERS ABOUT ENVIRONMENTAL EDUCATION, EDUCATION OF VALUES, AND STS RELATIONS

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**Abstract**

Considering that hidden questions concerning environmental problems involve the existing relationships between Science, Technology, and Society with nature, a discussion becomes necessary of the effects of these STS relations in the establishment and maintenance of the environmental crisis. This will make possible a process of revision of these relations, and the conceptions and values that support them. These considerations, when brought to environmental education, imply changes in the traditional pedagogical practices, since they refer to a process that does not have to be restricted to a simple offer of information, also involving the education of values. Admitting that any proposal of change and alteration to the curriculum for education also depends on the performance of the teachers, when thinking about the implementation of this proposal we need also to take into consideration the teacher education for this task.

From these considerations, since the beginning of 2001 the authors have been developing research with the objective of investigating the influence of an inservice teacher program concerning the understandings and practices of nine elementary school teachers of Rio Claro city ( São Paulo State, Brazil). The data of the research, still in progress, has been collected mainly from an intervention. The in-service teachers program occurred between March and October 2001 and was elaborated and developed by us. As we looked much more for the apprehension of the occurred process than to the product, this research had been conducted under a naturalistic-qualitative approach. In this work, we give a report of our research, identifying and analyzing the initial understandings of the teachers regarding the EE, the educative work with values and the STS relations with the environmental question (which were evidenced in the interviews carried out in the beginning of the year). We relate them to the work perspectives of our education program.

We perceived an apparent decrease in understanding by the teachers about the EE subjects, the education of values, and STS relations. The teachers were surprised by many of the presented and discussed considerations, which were unusual to them. They disclosed their doubts and frustrations about the complexity of the educative task, demonstrating moments of anxiety in terms of the changes proposed in their conceptions and practices.

## Introduction

Generally we perceive the products of science and technology in our lives but not their influences. In a fast look around us we will observe a great number of scientific and technological products. This is interpreted by many of us as an unquestionable sign of progress and well being in our society.

This causes ingenuous and optimistic conceptions about the exclusively beneficial influence of science and technology in our society, since the identification of such products does not imply either the broad understanding of their processes of production, the distribution and other aspects, nor a critical evaluation of the causes and consequences of the situation.

In our view, these products represent the visible part of one "iceberg" that if better observed displays a process of close relation between current science, technology, economy and intensive exploration of natural resources.

This process began during the industrial revolution with the development of new technologies, making possible more intensive ways of production of goods.

We focus on the environmental thematic of this perspective. Many of the questions behind environmental problems concern the existing inter-relations between science, technology, society and nature, from which it becomes necessary to discuss the effect of these inter-relations on the establishment and maintenance of the current environmental crisis.

Reflecting on the environmental question, we see it necessary to have these discussions so as not to reduce the "environmental" to merely management and behavioral aspects (LOUREIRO, 2000, p.13), unlinked to efforts to develop strategies for a better quality of life for all and the consolidation of a new relationship between society-nature. Facing the environmental problems, we consider that we are living in a civilization crisis, where the overcoming of the problems *"will involve a historically unprecedented revolution in institutions, systems, lifestyles and values."*(FIEN and TRAINER, 1993, p.39).

According to this perspective, we look at education, searching for the contribution that the education field can make towards the confrontation of this crisis.

SANTOS (1999) points out that the theoretical reflections on science, technology and society (STS), from the 1980s, had constituted an international movement that went to school, as a proposal of curricular reform of sciences for basic education, which resulted in several educative responses to STS problems. The author presents some "curricular responses," among them the Environmental Education (EE):

> *The conviction that the " environmental question " is mainly a "social question" and the verification that the current environmental fight is more than one alert for ecological questions (...) drive it in other way. The current fight must be directed in the direction to convince the people to modify its habits. It is therefore one fight much more difficult. It will not be easy to substitute a "catastrophes pedagogy " by the dismount of consumption habits, by the alteration of consumption standards (...) However it is basic that STS education learns to live with these difficulties to be able to help to solve them. (p.133)*

So, we consider the approach in the STS relations as essential for an appropriate education of the population, with the aim to provide conditions for everybody to understand how science, technology and society are mutually influenced and how they influence our relationships with nature. This will make possible a revision of our conceptions about these aspects which guide our actions. Agreeing with CARVALHO (1989) we recognize that it is necessary to have a deep and critical position concerning the current model of the relationship between science, technology and society, without being influenced by deformations of the ecological movement. The ecological movement believes, in an extreme way, that environmental problems will be solved by technology, whereas, in another extreme way, the movement disregards any possibility of technological development," *inclusive [of] the possibility to guide the technological model in order to guarantee a more healthful relation with nature."* (p.229)

However, we think that to deal with the conceptions and values that are behind these different views, in order to establish more appropriate changes, it is not enough to work only at the informative level. We consider that it is necessary to search for education proposals that also include, in an effective way, the specific work on values.

Really, since the First Intergovernmental Conference on Environmental Education, organized in 1977 for UNESCO, in Tbilisi, Geórgia, the recommendations of meetings and reflections regarding the EE have generally indicated that it does not have to reduce to a simple offer of knowledge, but also can involve aspects relative to ethical and aesthetic values.

Despite this, many studies have pointed out that aspects related to values are either disregarded or wrongly taught by the teachers. In our opinion it happens because, in spite of the discourse that characterizes our educational system and which presents as equally important the acquisition of knowledge and the formation of habits, attitudes and values, these last aspects have not been paid the same attention. The emphasis of the discussions pertaining to schoolwork concentrates on the content related to the information and concepts; the remaining aspects being little explored. The inclusion of an emphasis on values along with the other school content implies, therefore, a significant change in traditional pedagogical practices.

From these considerations, it appears necessary to focus on the figure of the teacher. When making any innovative proposal for education, we also have to reflect on the teacher, since the teacher is one of the essential elements in the effective implementation of any innovation. It is also necessary to think about the teacher's education: *"All educational change depends on the teacher and the teacher's education"*. (NÓVOA, 1992).

Knowing that working with the conceptions and values linked to the STS relationship is a perennial proposal for the EE, and recognizing that the deeper work *on* and *with* values in general is traditionally not part of education (neither professionally or personally for the teachers) there is a need to promote this approach in the programs of teaching education, looking for and constructing experiences that can support this educative proposal.

We do not conceive the teacher education program as a transmission of knowledge and skills. The teachers are not mere consumers of academic knowledge presented to them in pre- or inservice programs, they are active knowledge-makers: to learn to teach is a complex process that involves affective, cognitive and ethical factors, amongst others (MIZUKAMI, 1998). Following diverse approaches and perspectives, research on the professional education of teachers has grown in the last years, from the basic concern being to gain an improved understanding about the process of "learning to teach."

Thus, we consider that the education of teachers for a proposal - in this case, the value approach of the EE - cannot only be understood while thought for external specialists, but together the teachers who will live this "experience of learning", presenting their reflections, difficulties and possibilities of understanding and working about this innovation, that can subsidize the establishment of programs better directed to the teacher needs.

## The Research

The previously expressed view led us to the present research. We want to better understand the nature of the apprehension process by the teacher concerning a proposal of EE. It is considered by us to be complex, due to its inherent value content. Thus, our concerns had led us to the following research question: what is the influence of an inservice education program that looks to promote activities and reflections regarding the value approach of the EE on the understandings and practices of the participant teachers?

The data of the research, still being collected, has been collected mainly from a program, the in-service teacher program held between March and October 2001, which was elaborated and developed by us. As we looked much more to the apprehension of the occurred process than to the product, this research has been conducted under a naturalistic-qualitative approach (LÜDKE and ANDRÉ, 1986).

We worked at the municipal school network of Rio Claro city, with teachers interested in the program and that had a free schedule: 7 teaching at the elementary education, and 2 occupying other positions (one vice-director of a elementary school and one coordinator of the EE Section - Municipal Secretariat of Education). Among them, 8 were graduated (full or in progress) and all spontaneously looked for the course.

The course was organized in eight biweekly meetings during the 1st semester and two in the following semester, each one having a 3-hour duration. The first semester was dedicated to the exploration of some subjects related to the themes of the course, presented accompanied by various activities, like group dynamics and others, from which were raised aspects associated with them and the treated subjects. The last two meetings were devoted to the presentation and to the posterior evaluation of an educational plan elaborated and developed by the teachers in their work.

After each meeting, the participants had agreed to register their personal reflections in a diary. These are being collected for reading and deeper analysis. These will serve as a data source together with the interviews carried out with the teachers before the course. The notes are related to the facts of the meetings, the plans of teaching and the final evaluation of the course elaborated by the teachers.

In this work we will make a report of the research, identifying and analyzing the initial understandings of the teachers regarding the EE, the values education and the STS relationships with the environmental question (which were evidenced in the interviews carried out in the beginning of the year), relating them with the work perspectives of our education program.

The duration of the interviews (semi-structured) was about 30 minutes and was guided by a basic script containing the general items it was intended to contemplate: the EE, the educative work with values, the STS relationships, and the environmental question. With regards to the two initial items, we asked teachers about if and why they considered each one important; if she believed that her school currently carries out this work and, if yes, how it occurs. With regards to the last item, from our affirmation that it was one of the topics of the course contents, we asked if the interviewed teacher knew some relationship between them. The interviews were recorded on a tape cassette and later transcribed with each teacher identified using a capital letter.

## Results And General Discussion

Using the proper sequence of items proposed in the interviews, we will make the presentation and analysis of the data obtained in them: the thinking and ideas of the teachers regarding the EE, values education and STS relations with the environmental question.

### 1. Environmental Education

The teachers had spoken much about this aspect, explaining their ideas on the subject as well as their experiences: all already had had some practice, including one that just started to teach, i.e. had only 6 months of experience by the time of the interview.

In our view, this familiarity was due to the main fact that in the municipal school network the EE is part, as of some years ago, of the annual programming of the schools, because the municipality adhered to the EE Program "Water Week", that has been promoted in more than 30 cities of the state by the inter-municipal trust of Piracicaba and Capivari river basins.

Despite this, and perhaps exactly because they had already initiated their work with the thematic and perceived the challenges that it requires, 5 teachers explained in the interview the necessity to have a deeper knowledge about this topic and that this was reason why they had looked for the course.

When speaking about the importance of the EE, some ideas are reflected in the incidence of the use of specific terms or phrases: "the necessity of awareness" (term used by 5 of them), of "take care/preserve/conserve the nature or environment" (referred to by 4 teachers) and the references to a generic man, who "needs to be educated/aware" (referred to by 6 of them). Regarding this last idea, references had not been made concerning different social sectors or institutions involved with the environmental question, except for references made by 2 teachers of people living at the periphery city with which they had worked. They pointed out that the cause of the environmental problems in these places were the lack of awareness and notion of preservation of this community, which they had considered an education question.

According to the explanations, the general views of the teachers regarding the EE appear to be still linked to a traditional conservationist model whereby the basic aim is to change the individual behavior, and in which the structural causes of the environmental problems are presented as asocial or universal.

When looking for the characterization of work on the EE topic, we asked them if they recognize a school carrying through this work and two kinds of responses were made. Four teachers had noted the importance of the environment of the school as important in this process, as described below:

> *" I think about the school attitude: the attitude the school has. Sometimes one speaks: ' Ah, I discuss EE with my pupils, this is a very important subject in my school... ' But you see little of EE attitudes inside the school. You do not see trash recycling barrels, or plants in the school, and the environment is dirty and disorganized... Why do you work on EE if the proper school features do not help? (A)*

Three teachers had detected the subject or content that had been worked on in their schools - basically the subjects water and trash – and one of them added the necessity of working with the community to which the school belongs.

The perception of the necessity of the coherence between the school environment and the "speech" seemed to us to be a significant aspect, representing us to be an aperture to the reflection that restricted work with information is not enough for the broad purposes that we consider as the EE.

When we asked them if they carried out activities on EE (when they were teaching), the two teachers occupying other positions, had affirmed that when they were teaching (some years ago) they did not in fact carry out activities on this topic because information had not reached her ("S" speech) or the subject had not been considered ("V" speech).

The others had affirmed to work with the EE (always or sometimes), but when describing their work, the emphasis was in nonspecific actions, making use of situations, texts and talks to fit the subject into the lessons, as may be observed in the following example:

> *" I generally think, I always try to pay attention to these things and offer some texts, activities that I find and that I consider good for this subject." (P)*

If this characterization may point out to the understanding of the permanent and transversal characters of the subject - what we consider coherent with the EE proposals - we can question if this would not be occurring in detriment of the elaboration and development of more specific activities. If they were directly organized for this end they would allow us to take care more intently of the several aspects demanded by the work.

**2. Values education**

When requested about the work with values, the responses were generally more vague and uncertain than the previous ones. At some moments, some teachers had demonstrated clearly a disconnection of ideas. This we interpret as being due to a lesser familiarity with the subject.

From the general responses, it is inferred that all teachers had considered that work with values is important because the values serve as a basis for capacities diverse and always positive, despite not having explained how it would occur. This can be observed in the following examples:

> *" I think about how we will be able to live in a better world if people do not have this awareness about values? I think this: in order for everything to be alright, in order we will be able to make a good work, the main aspect is to develop values inside us, isn't it?"(R)*

> *" It is extremely important. To work with values... and I think it is important in any situation, do you know (...) If you do not work with values you will not have human being that... decides exactly, that has awareness about what is able to do and to help, did you understand me? (V)*

Following the interview with this last teacher, there is an example of an answer that shows a confusion of ideas. When we asked her to identify a school or teacher working with values, she answered in a circular way:

> *" Attitudinal values? What kind of values? (...) Ah, I think that it is to construct the day-by-day. I think that everything inlays values. Everything. Conceptual values, attitudinal values, I think*

*that... it is inside of the day-by-day. I think that when a teacher is teaching any kind of discipline in the classroom, he or she has to work with values." (V).*

When asking the teachers if and how a school would work with values, two of them had answered strongly that the school always does it. Together with another two teachers, they had mentioned the spontaneous work realized through the attitudes and daily examples.

Two other teachers had answered the question supporting them in an example of work carried through in their schools, i.e. about rules (teacher "Z") and water wastefulness (teacher "L").

Another three teachers considered that the school had not carried through this work, or had not been able to say how it would be:

*" Ah, I think it is difficult. I would not be able to give an example showing it to happen." (P)*

*" No. Because I think people are careful when involved with that ... it is a wound...; it is not a wound, as I told you, is an inner thing, and to you toil it ... It is a little monster inside you. If you toil it, you will have to manage it, and then? I think this thing of toiling with their values... Because you will know an unknown thing suddenly. People are afraid to toil with the unknown. So, this thing to toil with the values is... for instance, you toiled, then, you must support the consequences, right? I think our system never allowed it." (S)*

Beyond the previous explanation, another teacher showed the delicacy or "danger" of this work, disclosing the difficulties to deal with it:

*" Then I think that... is mainly by the example, ok, and always trying to discuss with the pupils, also trying to understand their values... trying to understand their values, because there are differences, ok, for example, from one suburb to another, from my life to them. Trying to understand this value and trying mildly to say that there exist other values that are not the ones that they have, ok. But here there is a danger. Here there is a problem.(B)*

Beyond this last teacher touching on the same aspect in another moment of her interview, another two ("S" and "P") also had made comments regarding the necessary care with the other people's values, demonstrating the consideration of these three teachers concerning this aspect.

At the same time, these considerations point out the need to consider the question of the universality vs. relativity of values. This is one conflict concerning the subject of the values education. For us, values education can and must be based on the rational and autonomous construction of principles. Thus, preventing extremist positions and considering that not everything is equally correct. That we have possibilities based on reason, dialogue, and desire of value, which can allow us to determine some valuable principles that, despite to be abstract and formal, may serve as guides of the judgement and human behavior (PUIG, 1998).

When asked if they had worked with values, no teacher denied it. For characterizing their work, six teachers (teachers "P", "Z", "S", "G", "A" and "V") had mentioned the spontaneous and nonspecific work occurring day-by-day, through inner attitudes. Another six teachers (teachers "P", "B", "A", "L", "Z" and "R") had mentioned the work were held through talks, allowing a dialogue with the pupils and explanations of subject/rules, as can be observed in the following examples:

*"I try to be talking with them about what happens: 'Ah, I threw the paper on the ground'. - ' Why? What is happening?'. I don't simply say 'You cannot throw'. Then, we stop and talk about the value related to throw there and not here; why not pulling out the notebook leaf... Then, I think that all these things have a subjacent value." (A)*

> *" I work... look, I work most of the time, ok (...) Including inside the room, by this way: a colleague to respect the other, to respect the teacher ... to conserve, ok, to help to conserve, to help to keep clean, ok; for example, we have a little garden there, then, I say to them: ' Look, everything is beautiful, let's keep it this way' (...) Come on, when you will have a snack, try to make... the waste place is in the litter'." (Z)*

Such speeches had demonstrated the existing lack in the school of better ways or procedures of working with values, and what must be explored in teacher education programs contemplating this subject.

**3. The STS relationships and the environmental question**

In our view, this was the less familiar subject to the teachers, as evidenced by the lower number of opinions and greater number of disconnected phrases. Four teachers ("P", "L", "B" and "G") had explicitly declared not to perceive - or only to perceive a little - the existing relation between these aspects.

Two teachers had tried to emit ideas about the subject from their previous experiences that had been anyway associated with the technology. One of them commented that the work carried out in her school about the World Olympiads, when the teachers had presented to the pupils *"(...) an example of the application of the joined technology-science relationship (...) So, we tried to bring to the school a thing that is very distant of them, despite not to be". (P).*

Following the same interview, when asked if the teacher "P" thought that the discussion involving science and technology could help in the EE works, she unconfidently answered:

> *" I think so, because I believe that from the moment we understand how it operates... I do not know if it is correct, that these relationships operate with the environment; I think that we can pay a little more attention to that I make, what I do not have to make, what will prejudice later... with relation to the environment itself, ok, degradation, everything more. Then, I think at least it supplies a little bit of conscience. At least the conscience... it supplies knowledge about the operation, ok."(P).*

From this and other responses, it was perceived that the maximum knowledge of the teachers relative to STS relationships was some prompt and particular aspect, in which the words science and/or technology appeared to be associated with some invention (i.e. television) or activity (in the case the World Olympiads).

Many confused phrases had been emitted, perhaps trying to give any response to the formulated questions. Two responses were more coherent, where the technology was the main or only detached aspect, involving its relation with the environment. Teacher "V" and "A" had pointed out that the technology could bring about either benefits or damages for the environment, but "A" expressed the idea that education would be the "key" to link the two: " *it is not enough for somebody to go 'there' [nature] and to improve it if other people do not conserve it".*

Teachers "G" and "S" articulated ideas better. The last pointed out significant elements with respect to the understanding of the subject, perhaps due to her experiences and studies in the EE Sector of the city, where she was engaged. But, in our view, she also presented an extreme position when considering exclusively the damages that the technology causes to the environment, as well as referring to a general "egoistic man," like perceived in the dialogue:

> *S - Ah, if you consider the EE history you will see that 'the thing' only had transformed after the industrial revolution, when the technology started to dominate the space, time... and to remove from nature what could be favoring human beings.*
>
> *I read in some place that man is very egoistic because he wishes things, more and more, without any utility. Then I thought to myself: 'Oh, my God, if I was living in a tent? With something, i.e. meat to eat, I would stay years there... How much do I actually need to consume? How much do I actually need from everything? Because today even to break eggs we will have a...*

*Researcher - A little machine?*

*S – Yes, a device! Then, to what degree is in fact necessary to have this device to break eggs? So, the people... like me have many household-electric machines in the house, but... I do not know, for example, if everything burns, am I going to die? I do not think so, I think that... we need to retreat... I think that... it is the only way.*

*Researcher – How to retreat?*

*S - Finishing with all this technology. It is too much technology. Then, they are inventing things without any necessity, it do not have... you know. I do not know...I think everything is linked: environment, technology, you know, each thing is linked with the other, ok.*

With respect to the considerations of teacher "G", probably enriched at the Geography graduation course she was attending, the relation between science and technology was clearer, as can be now observed:

*" (...) Let's suppose... science develops several theories, several... thus, let's suppose, as I could say, even several instruments of work, which would be more a technological task, that will have a consequence on nature, that can be either a beneficial or maleficent thing, ok. I am not sure. I think one-thing influences another, ok; but we do not have enough conscience about this influence, therefore sometimes prejudicing nature. We exert a force beyond the limit supported by nature and, then, you have responses to this too." (G)*

Although demonstrating a higher understanding of science-technology relations, teacher "G" presented a certain ingenuousness when mentioning the "damage" we cause to nature due to our little "*conscience*". Perhaps we have lacked a higher link with the economic aspects of our society, from which we can perceive that our interests generally do not consider the environment.

Anyway, despite the reasonable understanding of the subject, teacher "G" explains how difficult it is for her. Being a student of a Geography course, her explanation, allied to the comments of teacher "L", already graduated in the area of Biological Sciences (who affirmed that the subject was complicated and was not treated in her graduation course), only reinforced what the data revealed from the other teachers: the quasi total absence of this reflection among the teachers.

**Final Considerations: The Perspectives to Work with These Subjects in an Inservice Education Program**

Although our comments regarding the apparent higher understanding of the teachers relative to EE, our analysis demonstrate that the EE vision of the teachers was distant of the referential adopted by us, in which the discussions from the STS movement are essential for understanding the environmental question. Since they were unknown by most of the teachers, the same occurred with our EE perspective. Thus, the program presented, in several meetings, activities and discussions where these aspects were linked. Analogously, the educative work on values weakly carried out by the teachers was presented more specifically in other meetings.

During the program, some ideas of the teachers were strengthened and innovated, but also many concerns and frustrations appeared, due to the emergence of old ideas and the insecurity of the new ones. In many activities and discussions during the meetings, the teachers had referred to the frustration they felt in perceiving how much of our daily action - personal and pedagogical - is distant than considered more appropriate from the adopted referential.

We also perceive that many concerns and frustrations of the teachers were generally linked to a "dichotomist" vision of the process of change, considering both the inadequate/intended visions and practices, and wishing to move fast and completely from one side to the other.

Considering that the process of learning to teach is a complex and personal process which develops throughout the teacher's life (MIZUKAMI et al, 1998), it is not possible for only a single program to cause substantial changes in the conceptions and practices of the teachers. However, admitting that a program provides for a more effective chance for this construction, we think it can exert some influence when taking into account this procedural feature, by accompanying and supporting the discoveries, reflections and feelings of joy, anxiety and frustrations that appear to the teachers.

**References**

FIEN, J. & TRAINER, T., A vision of sustainability. (Chapter 2) *Environmental Education: a pathway to sustainability*, ed. J. FIEN, Deakin University: Geelong. pp.24-42, 1993.

CARVALHO, L.M. A temática ambiental e a escola pública de 1º grau. São Paulo, 1989, 282 p. *Tese* (Doutorado em Educação) – Faculdade de Educação, USP.

LOUREIRO, C.F.B. Teoria Social e questão ambiental: pressupostos para uma práxis crítica em educação ambiental. In: LOUREIRO, C.F.B; LAYRARGUES, P.P.; CASTRO, R.S.(orgs.) *Sociedade e meio ambiente: a educação ambiental em debate*. São Paulo, Cortez Editora, 2000, p.13-51.

LÜDKE, M., ANDRÉ, E.D.A. *Pesquisa em Educação: Abordagens qualitativas*. São Paulo, EPU, 1986, 99 p (Coleção Temas básicos de Educação e Ensino).

MIZUKAMI, M.G. et al. A reflexão sobre a ação pedagógica como estratégia de modificação da escola pública elementar numa perspectiva de formação continuada no local de trabalho. IX ENDIPE, *Anais,* p.490-509, 1998.

NÓVOA, A. Formação de professores e profissão doente. In: NÓVOA, A. *Os professores e sua formação*. Lisboa, Publicações Dom Quixote, p.15-33, 1992

PUIG, M.J. *Ética e valores: métodos para um ensino transversal*, Casa do Psicólogo: São Paulo, 1998.

SANTOS, M.E.V.M. *Desafios pedagógicos para o século XXI: suas raízes em forças de mudança de natureza científica, tecnológica e social*. Lisboa, Livros Horizonte, 1999, 275 p.

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# A GLOBAL VIEW OF THE CURRENT PLANETARY EMERGENCY TO MEET THE DEMANDS FOR FUTURE GENERATIONS

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**Summary**

A decade after the Rio Conference on Environment and Development, a serious effort is still necessary to make citizens *-and even educators-* aware of the gravity of the current situation of planetary emergency and of the necessity of studying and applying effective corrective measures to meet the demands for future generations before the degradation process becomes irreversible. The purpose of our contribution has been to construct a global picture of the state of the world, studying thoroughly the possible causes and remedies in order to avoid reductionist approaches to this essential component of citizens' education.

With this aim, we have made an effort to take into account the contributions of different studies elaborated with an explicit global point of view. We have also analysed papers published on the subject in science education and environmental education journals. Finally, we have undertaken a Delphi study implicating several dozens of science teachers of all levels and from different countries.

## Introduction: A decade after Rio

During the Conference on Environment and Development held in Rio in 1992, *educators of every subject* were asked to contribute to public awareness and understanding of the problems and challenges related to our planet's future, in order to make possible citizens' participation in well grounded decision-making (United Nations 1992).

Why should *all educators* incorporate *the state of the world* as an important dimension of their activity? And why *now*? Until the second half of the 20th Century, our planet seemed very large, practically without limits, and the effects of human activities remained locally compartmentalised. But these compartments have recently begun to dissolve, and many problems (greenhouse effect, ozone depletion, acid rain...) have acquired a global dimension (Bybee 1991; Fien 1995). This applies in particular, signalled the World Commission on Environment and Development (1987), "to the various global *crises* that have seized public concern, particularly over the last decade. These are not separate crises: an environmental crisis, a development crisis, an energy crisis. They are all one". We can, in short, speak of a *planetary crisis* (Bybee 1991). The "state of the world" has become, for this reason, an object of growing concern.

A decade after the Rio Conference, and in spite of such dramatic appeals, a serious effort is still necessary to make citizens *-and even educators-* aware of the gravity of the situation and of the necessity to study and apply effective corrective measures before the degradation process becomes irreversible.

The purpose of our contribution is, very precisely, to contribute to the construction of a holistic view of the state of the world and of the measures to be adopted.

### 1. Beyond the consideration of local environmental problems

If we want to understand correctly the current situation of planetary emergency and how to act upon it, it seems necessary to go beyond the consideration of some concrete or local environmental problems. We need to construct a global picture of the state of the world and to study thoroughly the possible causes and remedies. With this aim, we have made an effort to take into account the contributions of different studies elaborated with an explicit global point of view, as the Worldwatch annual dossiers on '*the state of the world*' (Brown et al. 1984-2001), '*Our Common Future*' (World Commission on Environment and Development 1987), '*Agenda 21*' (United Nations 1992) or "The World Ahead: Our Future in the Making (Mayor Zaragoza 2000).

We have also analysed papers published on the subject in science education and environmental education journals. Finally, we have undertaken a Delphi study implicating several dozens of science teachers of all levels and from different countries (Argentina, Brazil, Chile, Cuba, Mexico, Panama, Portugal, Spain). This Delphi study has been based on an open-ended question that we present in Table 1.

**Table 1.** An open-ended question aimed at constructing a global view of the state of the world

PROBLEMS AND CHALLENGES THAT HUMANITY HAS TO FACE NOWADAYS

We live in a time of accelerated changes and of growing concern about how these changes are affecting humanity and the whole of life on Earth. This concern about the "state of the world" must have a clear echo in science education and generate studies capable of helping to make well-founded decisions.

We invite you to participate in one of these studies, ***enumerating the problems and challenges that, in your opinion, humanity has to face nowadays and in the near future***. We intend, with your help, to collectively construct an image as complete and correct as possible of the current situation ***and of the measures to be adopted***.

What picture of the state of the world do we obtain with these convergent studies?

**2. Sustainability as a central unifying idea**

When thinking about problems and challenges concerning the future of humanity, the basic aim signalled by experts is to lay the bases of a *sustainable development* (World Commission on Environment and Development 1987; Folch 1998).

The World Commission on Environment and Development (1987) defines sustainable development as one which "meets the needs of the present without compromising the ability of future generations to meet their own needs". This definition seems to have obtained a wide consensus, but in many occasions this consensus is purely formal and hides serious misunderstandings as, for instance, interpreting 'sustainable *development*' as a 'sustained *growth*', which is, of course, the opposite. For this reason, the expression 'sustainable development' has begun to be critically analysed giving place to the use of other expressions such as *'construction of a sustainable society'*. Nevertheless, sustainability continues to be "*the central unifying idea society most needs at this point of human history*" (Bybee 1991).

But, how are we to move towards a sustainable society (or sustainable development)? Experts (United Nations 1992; Fien 1995; Tilbury 1995) refer to the necessity of putting an end to a series of facts, each one having particular importance and deserving particular attention, but completely linked to the rest: none of them can be understood or treated without taking into account the whole ensemble.

**3. A global view of the problems that affect our survival**

To make possible the sustainability of human life it is not enough to criticise –as is usually done- environmental pollution and its consequences (greenhouse effect, acid rain…) or depletion of natural resources. There are other problems to be taken into account:

First of all it is necessary to denounce economic growth guided by particular interests in the short term, as the foundation of the current degradation processes (World Commission on Environment and Development 1987;

Brown et al. 1984-2001). This economic growth produces, among other things, these particular problems:

*Multifaceted environmental pollution*, of air (due to heating, transport and industrial activities), superficial and subterraneous waters (due to polluting substances poured without purification into rivers and seas), and soils (particularly due to the storage of dangerous substances such as radioactive waste, heavy metals, oil...). Pollution which produce consequences such as acid rain, the green house effect, ozone layer destruction... and a global climatic change.

This pollution is associated with a growing, disordered and speculative urbanisation which in a few decades has multiplied the number and size of big cities.

It is necessary, on the other hand, not to forget other forms of pollution such as acoustic and light pollution (particularly damaging for living creatures) or spatial scrap, with thousands of fragments which encircle the Earth and menace the satellite communication network.

*Depletion of natural resources*, not only of fossil energy resources or minerals, but also of fertile soil layers, water resources...

*Ecosystem degradation and the destruction of biological diversity* (with serious consequences for the sustainability of human life) and, in particular, of *cultural* diversity which generates a sterile uniformity of cultures, landscapes and ways of life . As Folch (1998) signals, "why should we worry about cultural less than biological diversity?". **Table 2** summarises this ensemble of environmental problems which affect the survival of humanity:

**Table 2.** Ensemble of environmental problems which affect the survival of humanity

- Socio-economic growth, guided by particular interests in the short term, which seriously damages the environment and is particularly dangerous for living beings

This economic growth produces, among other things, these particular problems:

- A growing, disordered and speculative urbanisation
- Environmental pollution and its consequences (greenhouse effect, acid rain, global climatic change...)
- Depletion of natural resources (fossil energy resources, fertile soil, drinking water...)
- Ecosystem degradation and destruction of biological diversity (cause of illness, ravenous hunger...)
- Destruction, in particular, of cultural diversity

We must emphasise that the attention paid to these different problems in the answers given in the Delphi study (see table 1) is not homogeneous: while most of the answers include environmental pollution, depletion of natural resources and destruction of biological diversity among the main problems humanity has to face, there are few references to related problems such as growing and disorderly urbanisation or the destruction of *cultural* diversity. We find similar results in papers published in science education journals and in high school science textbooks.

These frequent omissions are a clear example of the reductionism that characterises the attention that we educators pay, in general, to our planet's problems (Fien 1995). In contrary to these reductionist views, we have to recognise that, as Tilbury (1995) states, "environmental and development problems are not solely caused by physical and biological factors" and that "an understanding of the parts played by aesthetic, social, economic, political, historical and cultural elements is required".

Reductionism must also be avoided in relation to the possible causes of the degradation of the Earth. We shall briefly discuss these causes in the next section.

### 4. Causes of an unsustainable socio-economic growth

Attending to the analyses of institutions such as the World Commission on Environment and Development (1987) or the Worldwatch Institute (Brown et al. 1984-2001), we have referred to economic growth, guided by particular interests in the short term, as the foundation of the current degradation processes.

But this economic growth is intimately related to other phenomena that should be considered as well. Firstly, experts draw attention to the over-consumption of so called "developed countries" and, we mustn't forget, of dominant groups in any society. A consumption that keeps growing as if the Earth's capacities were infinite is indefensible (Folch 1998).

Secondly, it is necessary to halt the demographic explosion on a planet which has limited resources. References to this problem are rare in most of the answers in our Delphi study and there is a frequent resistance to accepting that a growing population poses a serious problem today. The fact that most Europeans (including educators and politicians) see the current low birth rate in Europe as a problem, instead of a positive trend, is quite illustrative of the near absence of values related to sustainability. It seems appropriate, for this reason, to present some data about the influence of demography in relation to the present unsustainable rate of economic growth (World Commission on Environment and Development 1987; Folch 1998...):

- Since the second half of the 20th century, more human beings have been born than in the whole of humanity's history. As some authors have pointed out, soon there will be as many people alive as deceased in all history; half of all human beings that have ever existed will be alive (Folch 1998).
- The *present* population would need the resources of three Earths to generalise the standard of living of the developed countries (United Nations 1992).
- Although the rate of population growth has lately diminished, this population increases every year by about 80 million and will double again in a few decades.

Such data have led Ehlrich and Ehlrich (1990) to affirm emphatically that, without any doubt, the demographic explosion will soon stop. What we do not know is if the end will arrive in a gentle way, through a diminution of the birth rate, or tragically, through the growth of mortality. These authors add that demography is the most serious problem humanity has to face today, given the time gap between the start of an appropriated programme and the beginning of population decline. Population stabilisation appears then as a fundamental requirement to halt the destruction of natural resources and guarantee the fulfilment of everyone's basic needs.

In short, over-consumption and demographic explosion determine an economic growth which is extremely corrosive to the physical *and cultural* environment. On the other hand, over-consumption in developed countries and demographic explosion in others provokes grave inequalities. Billions of fellow humans are scarcely able to survive in non-developed countries and wide segments of the "first world" are excluded... while a fifth of the human population offers its high-consumption model (Mayor Zaragoza 2000).

Extreme poverty in undeveloped countries, which is a consequence of the demographic explosion and of the imposition of particular interests and values (through colonialism or the speculations of trans-national enterprises) leads inexorably to an unsustainable exploitation of natural resources, in a desperate attempt to pay back interest, satisfy external debts and gain some benefit.

Finally, we mustn't forget the conflicts and violence associated with these inequalities and values: wars, terrorism, Mafia activities... or the imposition of the interest of trans-national enterprises interests which escape any democratic control. **Table 3** summarises this ensemble of causes (and at the same time consequences) of an unsustainable economic growth and of the consequent degradation of the habitability of our planet.

**Table 3**. Ensemble of causes (and at the same time consequences) of an unsustainable economic growth

- Over-consumption of "developed" societies and dominant groups in any society
- Demographic explosion in a planet of limited resources
- Social inequalities between human groups
- Conflicts and violence associated with these inequalities (wars, terrorism, Mafia's activities... or the imposition of the interest of trans-national enterprises which escape any democratic control)

But a holistic approach to the state of the world demands more than diagnosing the problems; it is also necessary to study the possible solutions to the described planetary crisis, in order to help citizens explore alternative approaches and to participate in actions aiming to favour particular alternatives. To study just the problems provokes at best indignation and at worst despair (Tilbury 1995). It is necessary, then, to search for answers to the question: *What positive measures can be adopted?*

**5. What positive measures can be adopted?**
We can structure the different proposals made by researchers and institutions into the following three groups:

- *technological* measures to better satisfy human needs without damaging the environment;
- *educational* measures to make possible the necessary changes in personal values and life-style choices;
- *political* measures at a planetary level to avoid the imposition of particular interests and values harmful for other people or future generations.

We shall now discuss in certain detail each one of these measures.

*5.1. Technological measures*
There is general agreement about the need for technologies which favour sustainable development. The proposed measures extend to the search for new energy resources, the improvement of efficiency in food production, the prevention of illnesses and catastrophes, the diminution and recycling of waste... But, what are the criteria to distinguish when a technology favours sustainable development? Experts suggest two obvious principles:

- The gathering rates of resources must not surpass the regeneration rates (or, for resources that are not renewable, the creation of renewable substitutes).
- The waste production rates must be lower than the assimilation capacities of the ecosystems.

Additionally they insist on the fact that we are passing from an economy of an *empty world* (where technology was the limiting factor for taking profit from the exploitation of natural resources) to an economy of a *full world*, where the natural capital will be more and more the limiting factor. In other words, the aim of technology for sustainable development must be to increase the efficiency of the resources, rather than raise their extraction rate. This means, for instance, that we need to invent more efficient lamps instead of constructing more electrical power stations.

But, although technology has an important role to play, it is necessary to question the widespread and erroneous idea that the solution to the serious problems which humanity has to face today depends solely on a better knowledge and on more advanced technologies: options and dilemmas are essentially matters of ethics (Tilbury 1995). This conclusion directs us in part to the educational measures we have to consider.

*5.2. Educational measures*
The educational measures proposed to contribute to a sustainable society put the accent on global analyses and solidarity (Delors et al. 1996). Such measures overcome the usual tendency to attend to particular interests in the short term (or to follow habits that correspond to an 'empty' world of isolated compartments). We need an education that contributes to a correct perception of the state of the world and prepares citizens for decision-making, generating responsible attitudes and behaviours oriented to the attainment of a culturally plural and physically sustainable development (Bybee 1991; Fien 1995; Tilbury 1995; Mayor Zaragoza 2000).

Questions like "What energy policy should be promoted?" or "What role should be given to genetic engineering in the food industry?" and "What controls on GM food production should be introduced?" demand informed decision making and the adoption of suitable policies. We need an education that promotes responsible behaviours, not just favourable opinions and attitudes.

It is necessary for such an education to promote the questioning of conceptions that are presented as "obvious", without alternatives, thus obstructing the possibility of making choices. This is the case, very particularly, of the idea of *competitiveness*. Everybody speaks of competitiveness as something absolutely necessary, without realising that it is a type of behaviour which is incompatible with the aim of sustainable development. In fact, success by one person or group in a commercial battle implies the failure of others. This is contradictory, we insist, to the characteristics of a sustainable development, which has necessarily to be global and embrace the whole planet.

Instead of promoting competitiveness, we need an education that helps students and teachers to analyse the efficiency of our actions from a global viewpoint, taking into account their repercussions in the short, middle and long term, both for ourselves and for the whole of humanity. We need an education that helps to transform the current economic globalisation into a democratic and sustainable project (Delors et al. 1996) that enhances the richness of biological and cultural diversity. Nevertheless, it is quite frequent to hear some doubts about the effectiveness of such an education, "given that individual behaviours have a little influence on such big problems as, for instance, resource depletion or environment degradation" (ibid.). These problems, it is affirmed, are provoked, basically, by big industries. But it is easy to show (very simple calculations are needed) that although an individual can save a very small quantity of energy or materials, when these quantities are multiplied by millions of people, the totals that could be saved become quite large, with a consequent reduction of environmental pollution and degradation. In fact, appeals to individual responsibility are multiplying; they include detailed lists of possible concrete actions in different fields, from water and food supply to traffic, from cleaning, heating and lighting to family planning.

On the other hand, individual contributions can and must go beyond the private domain and extend to professional, social and political activities. Citizens can support, for instance, non-governmental-organisations and political parties which promote solidarity and environmental protection; they can also demand positive actions by public institutions (town councils, parliaments). It is necessary, in particular, that individual and collective actions avoid local or partial approaches and contemplate many-sided environmental questions (pollution, resource depletion...), and other related problems such as social inequalities and conflicts, from a planetary perspective. The ecologists' slogan "to think globally and to act locally" has its limitations; we now know that it is necessary to *act globally* as well, adopting *political measures at a planetary level*, capable of avoiding the imposition of particular interests and values harmful to other peoples or to future generations. We comment on this in the next section.

*5.3. Political measures*

The adopting of planetary political measures is contemplated by most citizens and educators with scepticism and with a certain reluctance. Scepticism because previous attempts have shown little effectiveness. Nevertheless, pollution that recognises no borders reminds us that we are living - for the first time in human history - in an interconnected civilisation which embraces the whole planet. We can understand then the absolute necessity, also for the first time in human history, for a political integration that puts environment, as the common substratum of life, above the economic interests of any country, region or trans-national enterprise.

We could think that the danger of exclusively local approaches is disappearing because of the present vertiginous process of economic *globalisation*. Paradoxically, this process is not global at all when it concerns the survival of life on our planet: in spite of so much talking about globalisation, our approaches continue to be partial. We do not consider, concretely, environmental destruction... or rather we take it into account, but not in order to avoid it. Economic globalisation irresistibly pushes to displace production centres towards countries where ecological norms are less restrictive.

Economic globalisation appears, thus, as something quite unidimensional. Because of this, planetary norms are necessary in order to avoid a general environmental degradation process. For this reason, political integration on a planetary scale is considered to be something absolutely *urgent*; an integration capable of promoting and controlling the necessary measures to protect our social and physical environments, before the degradation process becomes irreversible.

In short, a new world order is required, based on co-operation and solidarity, with institutions capable of avoiding the imposition of particular vested interests harmful to other people or to future generations (Folch 1998; Mayor Zaragoza 2000).

The ensemble of measures just discussed, appears nowadays to be associated with the need to universalise human rights. The next section is dedicated to clarifying this relationship.

*5.4. Sustainable development and human rights*

It may seem strange to establish such a direct relationship between human rights and sustainable development. In fact, very few of the answers to our Delphi study or of the papers related to environmental problems, consider that overcoming the current degradation processes and inequalities is a question of human rights. For this reason, it is necessary to clarify what is understood nowadays by *human rights* and how they are related to sustainability (Vercher 1998).

We can refer, firstly, to *democratic civil rights (opinion, association...) for everybody, without social, ethnic or gender limitations*. They constitute a condition *sine qua non* for citizens' decision-making about current and future environmental and social problems (Folch 1998). They are known nowadays as "first generation human rights", because they have been the first rights to be demanded and obtained (not without conflicts) in a growing number of countries. In this respect, we must not forget that the 'Droits de l'Homme' of the French Revolution (to mention a well known example) excluded women explicitly; they only achieved the right to vote in France after the Second World War. Neither must we forget that such basic rights are systematically violated every day in many countries.

We refer, secondly, to *economic, social and cultural rights* or "second generation human rights" (Vercher 1998) as:

- The universal right to a satisfying job, overcoming insecure situations to which hundreds of millions of human beings (including more than 250 million children) are submitted;
- The universal right to an adequate dwelling in an appropriate physical and cultural milieu;
- The universal right to appropriate nourishment, both quantitatively (avoiding under-nourishment of billions of fellow humans) and qualitatively (avoiding unbalanced diets);
- The universal right to health. This requires resources, research and education in order to fight infectious illnesses (cholera, malaria..., that are still ravaging many third-world countries) and the new 'industrial' and behavioural illnesses (such as tumours, depression, AIDS...). It is necessary, above all, to promote healthy milieus and habits as well as solidarity with handicapped people;
- The universal right to family planning and free enjoyment of sexuality (the only limitation being the freedom of others) overcoming the cultural and religious barriers which condemn millions of women to submission;
- The universal right to an education of quality, *throughout* one's life, without social, ethnic or gender limitations;
- The universal right to culture, in its widest sense, as a supporting axis for personal and collective enrichment and development;
- The universal right to investigate any kind of subject (the origin of life, genetic manipulation...) without ideological limitations (like, for instance, those which prohibited Galileo's works) but with a suitable degree of social control. This control must take into consideration social and environmental consequences and prevent the hasty application of insufficiently tested technologies.

Finally, we refer to third-generation human rights, known as *solidarity rights* "because they tend to preserve the integrity of the whole population" (Vercher 1998). They incorporate the right to life in a suitable environment, the right to peace and the right to a sustainable development for all people and future generations:

- *The right of all human beings to an environment appropriate to their health and welfare.* As Vercher (1998) states, the incorporation of this right as a fundamental human right derives from an unquestionable fact: "if degradation of environment goes on at the current rate, its maintenance soon will be the most fundamental question of survival for everybody, anywhere... The later we recognise this situation, the bigger will be the necessary sacrifices and difficulties which need to be overcome to achieve an appropriate recovery".
- *The right to peace,* which involves the prevention of particular or vested interests (economic, ethnic, cultural...) prevailing over general interests and values.
- *The right to a sustainable economic and cultural development* of all peoples. This involves, on the one hand, the questioning of the present extreme economic inequalities between different human groups and, on the other hand, the defence of cultural diversity and cultural crossbreeding (against racism and ethnic or social barriers).

The *ensemble* of these rights appears to be a requisite (and, at the same time, an objective) of a sustainable society; *they are all interconnected*. For instance, we cannot conceive of the interruption of the demographic explosion without the recognition of the right to family planning and free enjoyment of sexuality... and these are connected also to the right to education. In short, then, achieving sustainable development is synonymous with universalising human rights in their widest sense. **Table 4** summarises the positive measures contemplated.

**Table 4.** Positive measures to be adopted

- Political measures at the planetary level capable of promoting and controlling the necessary protection of the social and physical environment, before the current degradation processes become irreversible
- Educational measures to overcome the usual tendency to behave attending to particular interests in the short term, making possible changes in personal values and life style choices in order to promote solidarity
- Technological measures to better satisfy human needs without damaging the environment, capable of favouring a sustainable development. This includes, for instance, the search for new energy sources, the improvement of efficiency in food production, the prevention of illness and catastrophes or the diminution and recycling of waste)

**The precedent measures are associated with the need to universalise and widen human rights:**

- Democratic civil rights (opinion, association...) for everybody as a condition sine qua non for citizens' decision-making about current and future environmental and social problems
- Economic, social and cultural rights (to a satisfactory job and dwelling, to health, to family planning and free enjoyment of sexuality, to education and culture...)
- The right, in particular, to investigate any kind of subject (the origin of life, genetic manipulation...) without ideological limitations, but with a social control which takes into consideration the social and environmental consequences and prevents the hasty application of non sufficiently tested technologies.
- Solidarity rights (right to a healthy environment, right to peace and right to a sustainable development)

## Conclusions and perspectives

In **Figure 1** we have summarised the ensemble of *related* problems, challenges and positive measures discussed and, at the same time, highlighted their mutual dependence. Any attempt to face the current planetary crisis should contemplate this ensemble of aspects experts have pointed out.

If we wish to prepare citizens capable of participating in informed decision-making, we educators need to acquire a correct perception of the problems and measures to be adopted, overcoming the usual reductionism. This, of course, *demands specific formative actions*. We have already begun to implement workshops to facilitate the study of these problems by science teachers. The first results obtained are quite encouraging (Edwards et al. 2001).

## References

BROWN, L.R. et al. (1984-2001). The State of the World. (New York: W.W. Norton).

BYBEE, R.W. (1991). Planet Earth in Crisis: How Should Science Educators Respond? The American Biology Teacher, 53(3), 146-153.

DELORS, J. et al. (1996). L'Éducation: un Trésor Est Caché Dedans. UNESCO. Commission Internationale sur l'Education pour le vingt et unième siècle. (Paris : Jacob O.).

EDWARDS, M., GIL-PÉREZ, D., VILCHES, A., PRAIA, J., VALDÉS, P., VITAL, M.L., CAÑAL, P., DEL CARMEN, L., RUEDA, C. & TRICÁRICO, H. (2001). Una propuesta para la transformación de las percepciones docentes acerca de la situación del mundo. Primeros resultados. Didáctica de las Ciencias Experimentales y Sociales, 15, 37-67.

EHLRICH, P.R. & EHLRICH A.H. (1990). The Population Explosion. (London: Touchstone).

FIEN, J. (1995). Teaching for a Sustainable World: the Environmental and Development Education Project for Teacher Education. Environmental Education Research, 1(1), 21-33.

of the World 1999. (New York: W. W. Norton).

FOLCH, R. (1998) Ambiente, Emoción y Ética. (Barcelona: Ariel).

MAYOR ZARAGOZA, F. (2000). The World Ahead: Our Future in the Making. Published in French with the title 'Un Monde Nouveau' (Paris: Editions UNESCO).

TILBURY, D. (1995). Environmental Education for Sustainability: Defining the New Focus of Environmental Education in the 1990s. Environmental Education Research, 1(2), 195-212.

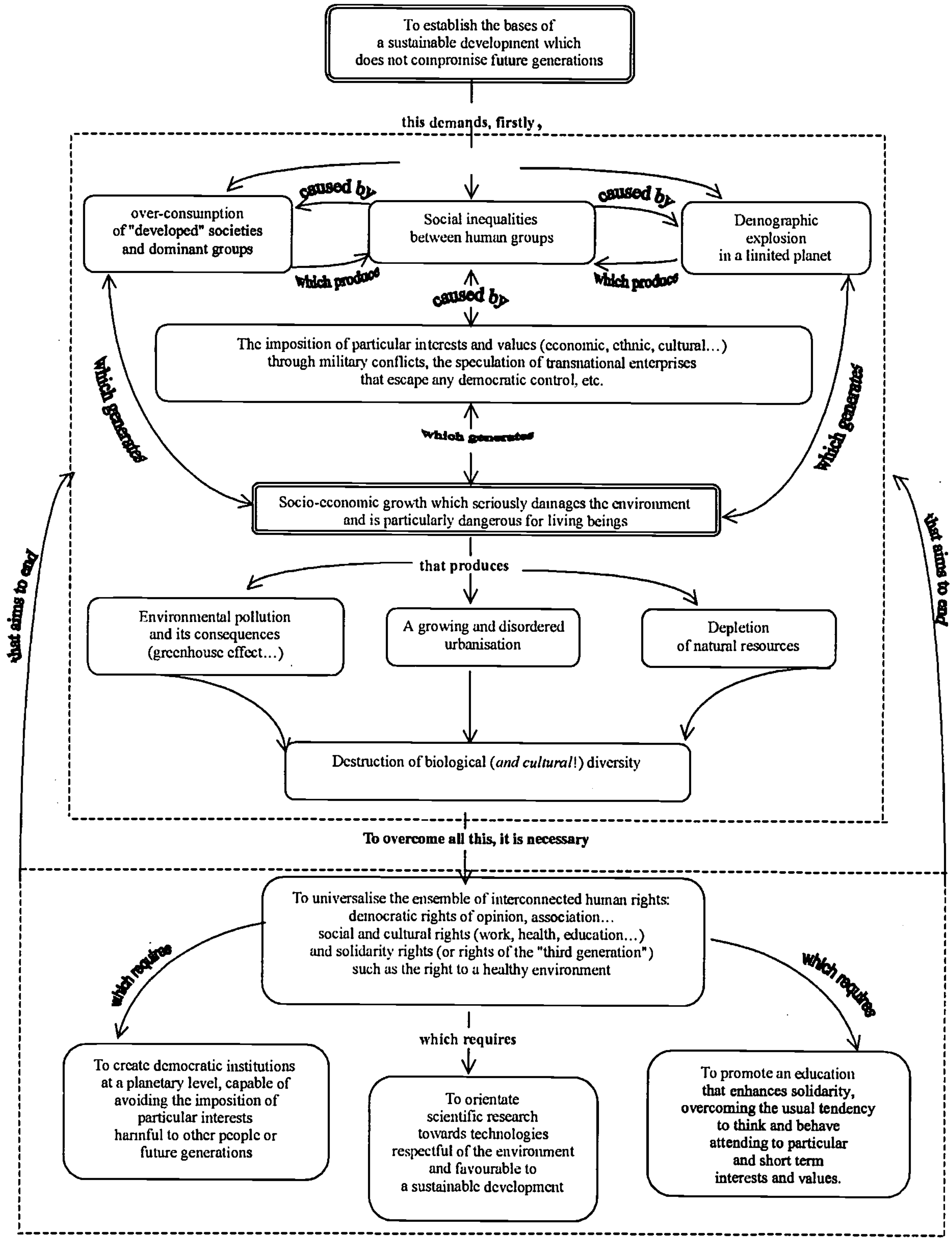
UNITED NATIONS (1992). UN Conference on Environmental and Development. Agenda 21 Rio Declaration, Forest Principles (Paris: UNESCO).

VERCHER, A. (1998) Derechos Humanos y Medio Ambiente. Claves de razón práctica, 84, pp.14-21.

WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT (1987). Our Common Future. (Oxford: Oxford University Press).

**Key words**: Environmental Education; Planetary Emergency; Challenge for the future; Sustainability; Human Rights.

**Figure 1.** Problems and challenges of the near future

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# SCIENTIFIC FORMATION WITH ENVIRONMENTAL RESPONSIBILITY

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**Resumo**

As *Diretrizes Curriculares para os Cursos de Química* no Brasil estabelecem que o químico deva saber atuar no controle ambiental, possuindo conhecimento sobre o tratamento de poluentes e/ou resíduos químicos, tendo em vista a preservação da qualidade do meio ambiente. Neste contexto, o principal objetivo deste trabalho foi conceber uma disciplina para um dos últimos anos da graduação em Química, que ao explorar os conhecimentos sobre a utilização de processos de descarte ou recuperação de resíduos químicos, os conceitos adquiridos nas disciplinas de química básica dos primeiros anos fossem aprofundados de forma integrada e interdisciplinar. Alëm da capacitação técnica, a disciplina propõe promover a responsabilidade ambiental, modificando valores e atitudes, enquanto cidadãos e principalmente futuros profissionais químicos. Desta forma, a disciplina Resíduos de Metais Pesados Gerados nos Laboratórios de Ensino: Descarte ou Recuperação (RMP) foi oferecida a alunos de graduação do curso de química da Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto (FFCLRP-USP) no segundo semestre de 2000 e 2001.

Conteúdos como por exemplo, transformações químicas, equilíbrio e solubilidade puderam ser explorados contemplando a dimensão ambiental. Partiu-se da análise de um ambiente conhecido dos alunos (o Departamento de Química) para ambientes mais gerais
(a sociedade). Assim, tratou-se resíduos líquidos sem identificação de alguns laboratórios de pesquisa e também resíduos sólidos de metais pesados gerados em algumas disciplinas de graduação. Os estudantes são preparados para analisar criticamente uma dada situação, tirar conclusões levando em conta o conhecimento científico disponível, além de apresentar soluções que minimizem o impacto ambiental.

## Introduction

The research and teaching laboratories of Chemistry and Pharmacy Schools have serious problems to manage their chemical wastes. The wastes generated in these institutions can have a different composition depending on each research project or experiment performed. The diversity of the chemicals, which are mixed, may generate new compounds of unknown toxicity. The waste produced in these institutions is constituted of a great variety of chemicals, making its management more complex than that of the wastes produced by industries. Although the industries generate a larger volume of waste, its composition is known [1]. As the Schools are responsible for the student education as professionals and citizens, they must be aware of the need of managing the chemical wastes generated by their activities properly. In fact, the research and teaching activities carried out in the laboratories can represent environmental and health risks if these institutions do not manage their own waste. In order to contribute to the solution of this problem, the Brazilian Chemical Society (SBQ) promoted two Workshops about waste treatment and management in their Annual Meeting (23rd e 24th). The Chemistry Department of the Faculty of Philosophy, Science and Humanities (FFCLRP/USP) is aware of the need of managing the wastes produced in its own laboratories and, therefore, has elaborated a project entitled Treatment of Chemical Wastes, which is in implantation. To elaborate this project, it was firstly necessary to identify the chemical wastes generated by each laboratory, which was done through the use of a questionnaire.

The Curriculum Guidelines for National Brazilian Education (law 9394/96) indicates the necessity of a curriculum flexibilization to enable an interdisciplinary formation, which is required for the formation of a good professional and citizen. In order to attend this recommendation, the discipline Qualitative Analytical Chemistry (QAC) has had the number of hours reduced from 8h per week in 1990, to 6h per week in 1999 in FFCLRP. In this way, a study was carried out to evaluate the possibility of reducing the number of reactions involving heavy metals to those considered more important in order to minimize the environmental impact of the waste generated. In this context, a new discipline was created: "Heavy Metal Wastes generated in the teaching and research laboratories: disposal or recuperation (HMW)".

In the traditional teaching, the undergraduate disciplines are presented in the segmented form, as for example Organic Chemistry, Inorganic Chemistry, Analytical Chemistry, Biochemistry, etc. In the integrated model, all the disciplines contribute to the study of complex themes that are chosen as an important process that the students must dominate. The objective of the integrated model is to obtain a global comprehension. In the traditional teaching, the discipline itself is the goal, while in the integrated model, the disciplines are the tools to reach a goal [2]. In this work, the main objective was to implement this new discipline, HMW, which has the specific goal of enabling the student to define the adequate strategy for disposal or recuperation of the chemical wastes for each case, through an interdisciplinary approaching. New experiments have been created and selected texts have been used to reach the objectives. In this way, the environmental responsibility desired for the professional and citizen can be promoted.

## Experimental Part

The discipline HMW was offered in the second semesters of 2000 and 2001 and had 30% of laboratories activities and 70% of classroom activities. The textbook "Environmental Chemistry" by C. Baird [3] was used **to discuss** the content related to the **heavy metals** Hg, Cd, As e Pb. Emphasis was given to the properties of these metals, their toxicity, the utilization of metals in industrial processes along the history and their environmental impacts, as can be seen in the box. The students had previously to read the text about a certain metal as homework. During the discussions, each student had some time (15 minutes) to review a specific part of the text from the book [3]. After that, the students had to present it to their colleagues. The **seminar** themes were selected from recent literature [4] on the photocatalytic degradation of organic pollutants. The laboratory activities were:

A. Toxicity of the heavy metals
B. Mercury
   - the free element
   - mercury amalgams
   - mercury and the chlor-alkali process
   - ionic mercury
   - methylmercury formation and toxicity
   - other sources of methylmercury
   - other forms of mercury
C. Lead
   - the free element
   - ionic 2+ lead
   - the solubilization of "insoluble"lead salts
   - ionic 4+ lead
   - tetravalent organic lead
   - lead in the environment
D. Cadmium
   - The free element
   - Environmental cadmium
E. Arsenic
F. Heavy metals in soils, sewage and sediments
   - Soil Chemistry
   - The analysis and remediation of contaminated sediments

1. **Characterization** of chemical wastes: liquid wastes without identification that was stored in some of the research laboratories of the Chemistry Department (FFCLRP). Some properties, such as air and water reactivity; flame test; water solubility; pH, cyanide, sulfide and halogen determination; oxidants and reductants were determined according to the reference [5]. The same methodology was used to characterize the wastes from the teaching laboratories (40 l). The experiments performed leaded to the labeling of the waste bottles.
2. The silver salts generated in the teaching laboratories were **recuperated** according to the modified method initially proposed by Faust [6];
3. The mercury salts waste was treated and **precipitated** as HgS insoluble salt [7];
4. Solutions containing $Cr_2O_7^{2-}$ were **treated,** considering the reduction of $Cr_2O_7^{2-}$ to $Cr^{3+}$, followed by precipitation as $Cr(OH)_3$ [8];

## Results and Discussion

The course started with basic principles of waste management [1]. The experiments were designed to present adequate final destination for some of the chemical wastes generated in the Department.

### Organic wastes treatment

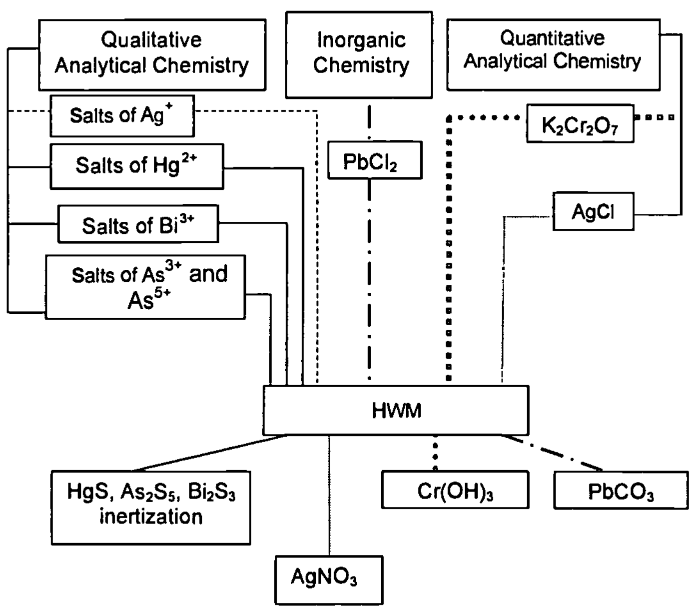
In order to identify some of the organic wastes obtained in the teaching and research laboratories, experiments were performed according to an article by Levine *et al* [5]. This article proposes experiments for a discipline on environmental analysis and was adequate, allowing the exploration of the concepts about the solubility of several kinds of substances. Nevertheless, some equivocated concepts about solubility were detected in the article during the discussion. For example, if a sample is soluble in water and insoluble in hexane, it can be classified as inorganic. However, there are polar organic substances such as methanol, which present this behavior.

From the previous survey in the Chemistry Department, there were 40 l of wastes from the teaching laboratory. These wastes were generated in the experimental classes of the second semester of 2000 and in the first semester of 2001. According to the survey, the probable waste composition was acetone, cyclohexene, cyclohexanone, diethyl ether, chloroform, buthyl chloride, benzene, hexane, dichloromethane, carbon tetrachloride, benzyl alcohol, methanol, ethyl acetate, ethanol. This waste presented two phases and was analyzed by the students attending the HMW discipline [5]. The students proposed solutions to the disposal problems. It was concluded that the waste collected at the end of semesters (~40 l) could not be disposed into the sink as it had always been, because it contained organo chlorides in both phases, and the final destination in this case should be incineration. From the survey, it was concluded that the aqueous phase (~20 l) contained acetone, methanol, ethanol and could be discarded in the sink if the students were adequately oriented during the experimental activities, preventing the generation of a large amount of wastes. The local legislation (National Council of Environment- Brazil, CONAMA 20/86) and handbooks about chemical safety [9] could be checked before deciding what could be disposed directly into the sink. This procedure could decrease by half the waste volume and consequently the cost of incineration.

***Inorganic Wastes Treatment***

The disposal of toxic inorganic waste can cause serious environmental problems and risks. In contrast with most of the organic wastes, inorganic waste cannot be eliminated by incineration, and its proper disposal can be expensive. As long as toxic substances remain in some soluble form they can eventually permeate into water supplies or otherwise pollute the surroundings. The alternative treatments of heavy metals are: a) precipitation in the form of an insoluble salt (inertization), or b) recuperation for later utilization [1,3].

The final destination was proposed for some of the generated wastes in the disciplines Qualitative and Quantitative Analytical Chemistry, and Inorganic Chemistry (Scheme 1).




**Scheme 1:** Fluxogram of the final destination proposed for some of the inorganic wastes generated in the teaching laboratories.

The silver recuperation is financially viable and adequate because the $AgNO_3$ salt is a reagent that can be used in other disciplines. The recuperation procedure [6] was discussed with the students. They were able to review principles of redox reactions such as the redox potential calculus learned in the first years of the undergraduate course. This experiment required some additional care to prevent $Ag^+$ splashing on the skin, such to wearing gloves and cleaning the working bench with a solution of **sodium hypochlorite** at the end of the class.

During the discussions, we tried to establish an ethical attitude about the final destination of the waste when the following questions were discussed:

- Do the laws permit the disposal of $Ag^+$, $Pb^{2+}$ e $Hg_2{}^{2+}$ in the sewerage?
- What is the best destination for these cations, recuperation or disposal? Does the cost/beneficial ratio recommend the recuperation or the inertization instead of disposal?

**Seminars**

A series of reports in a Brazilian newspaper in August 2001 (Folha de São Paulo) about i) pesticide contamination in Paulínia, SP, and ii) organic solvent contamination in Mauá, SP, was the starting point that helped the decision include the degradation processes of organic compounds in the program as seminars, attending to the society's needs. As a consequence of this change, we are suggesting that the discipline is renamed as "Chemical Wastes Treatment of Teaching and Research Laboratories" in the future.

**Interdisciplinarity**

It was possible to promote interdisciplinarity, as can be seen in the discussion about $Cr_2O_7{}^{2-}$ and $Cr^{3+}$, where several aspects can be explored [3,10]:

- comparison between the chemistry of iron and chromium, concepts about kinetic lability (Inorganic Chemistry);
- transport of ions through the cellular membrane, $Cr^{3+}$ binds to small molecules, protein and DNA, damaging these cellular components through oxidative processes (Biochemistry);
- hydrolysis of $Cr^{3+}$ and $Fe^{3+}$ in aqueous solution, formation and solubility of their respective metal hydroxides (Analytical Chemistry).

Another example of interdisciplinarity is given by the discussion about lead [3]:

- lead utilization since the Roman civilization (History);
- the deposit of $Pb^{2+}$ in the bones, the transport of ions through the cellular membranes (Biochemistry);
- formation of covalent compounds as tetraethyllead (Inorganic Chemistry);
- utilization of lead in cells and batteries (Electrochemistry)

**Evaluation of the learning process**

The method used to evaluate the learning process was based mainly on the answer to the two short questions at the end of each discussion session. The assessment also considered written reports of experimental activities and seminars. The continued evaluation of the students has the advantage of adjusting the discipline content depth according to the student profile.

## Conclusion

In the first approach, the Chemistry Department was explored as a known environment. Later, a holistic vision of the society and global environment was introduced to the students. The students were prepared to analyze an environmental issue critically, transferring the knowledge acquired in the first years of the undergraduate course to present solutions to minimize the environmental impact of the chemical wastes.

We can conclude that the goals of the discipline were reached and the better moment to offer this discipline is when the students have finished 50% of their credits. The students in the first and second years of the course would probably not have the necessary knowledge about chemical concepts and sufficient maturity to explore the environmental issues. Therefore, this discipline would be only informative and of a superficial character.

The efforts to reduce the large volumes of hazardous chemical wastes in the undergraduate laboratories have resulted in a unique, pedagogically useful experience for the students. Clearly, the students understand and accept the responsibility to reduce the environmental impact associated with the chemical waste generated in their laboratory experiments and seem genuinely satisfied upon accomplishing this task. In the final evaluation, the students expressed almost the same ideas, such as: *"Before, we simply disposed all the chemical wastes in the jars provided by the teacher for this purpose without asking any questions... We learned that the principles of chemistry can be applied to solve real – world problems, through the activities in this discipline".*

Besides the technical qualification, this discipline can promote ethical attitude and environmental responsibility, improving the profile of the future chemist both as a professional and as a citizen.

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**References**

[1] JARDIM, W. F., (1998). Chemical wastes management in the teaching and research laboratories. *Química Nova,* **21**: 671-673.

[2] MANSUR, O.C. & MORETTO, R. A, (2000). Aprendendo a Ensinar. São Paulo: Elevação.

[3] BAIRD, C., (1997). Heavy Metals and the chemical soils. Environmental Chemistry. USA: W.H. Freeman and Company, chap. 9.

[4] ZAMORA, P.P., ESPOSITO, E. & DURĂN, N (1997). Remediação de efluentes derivados da indústria de papel e celulose. Tratamento Biologico e fotocatalítico. *Química Nova*, **20**: 186-190.

[5] LEVINE , S.P., CHANG, J.C. & SIMMONS, M.S., (1986). A laboratory exercise for compatibility testing of hazardous wastes in an environmental analysis course. *Journal of Chemical Education,* **63:** 640-643.

[6] FAUST, D., (1984). Recovery of silver and cobalt from laboratory wastes. *Journal of Chemical Education*, **61** : 924.

[7] ARMOUR, M. A., (1996). Hazardous Laboratory Chemicals Disposal Guide. USA: Lewis Publishers.

[8] WALTON, W.A., (1987). Chemical Wastes in Academic Labs. *Journal of Chemical Education*, **64**: A69-A71.

[9] THOMPSON, G.R., (1990). Handbook of chemical and environmental safety in schools and colleges. USA:The Forum for Scientific Excellence, Inc.

[10] THEIL, E.C. & RAYMOND, K.N. (1994). Transition –Metal Storage, Transport and Biomineralization. In: GRAY, H.B., BERTINI, I., LIPPARD, S.J. & VALENTINE, J.S., (Eds). Bioinorganic Chemistry. USA: University Science Books.@bi =

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# SCIENCE LEARNING AS ARGUMENT BUILDING: AN INNOVATIVE COURSE FOR SECONDARY SCIENCE TEACHERS

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### Abstract

To have science learners engage in "science as argumentation" has become one of the most important goals of reform-oriented science education in the US. However, one of the major barriers to accomplish this goal has been that K-12 teachers frequently are not prepared to guide their students through that process. This paper describes a science course (*Technology Tools for Supporting Scientific Inquiry*, SCIED 410) designed to support prospective teachers (PTs) development toward this goal. The course was conceptualized with current understandings about learning and US reform goals for science education in mind. In SCIED 410, PTs engaged *as science learners* in three long-term problem-based science investigations. They built evidence-based arguments as they continuously interacted with their peers. These activities were supported with the use of specially designed technology tools. PTs were also asked to reflect on their experiences, focusing on various aspects of the course, such as understandings about teaching and learning science, the nature of science, the use of technology in science learning, and their developing subject matter knowledge. We argue that this course is not merely a setting in which we apply our current knowledge about science/teacher learning, but that it also serves as a context for empirical research that has the potential to inform our understanding of the processes involved in scientific knowledge construction within the context of school and, in particular, by future teachers.

### 1. Introduction

The notion of scientific inquiry is at the core of the view of science teaching and learning that US educational reform has sponsored (National Research Council, 1996, 2000). However, teachers do not have experiences learning this way (Putnam & Borko, 2000). Thus, there is an urgent need to address this issue in teacher preparation programs. The purpose of this paper is to describe and discuss the rationale for the development of an innovative, technology-rich, inquiry-based science course for prospective secondary science teachers taught at a large university in the Northeastern United States. In "Technology Tools for Supporting Scientific Inquiry" (SCIED 410), prospective secondary science teachers have the opportunity to learn science through inquiry and reflect on these experiences to reconsider their roles as teachers in the science classroom.

In this paper, we begin with a discussion of the rationale that framed the design of SCIED 410. Then, a description of the course is provided, establishing connections between each element/activity and the rationale previously described. We conclude the paper with a brief discussion of the significance of such a course for research in science education.

### 2. Science as Exploration versus Science as Argumentation

Despite its importance in the context of science education, like many fundamental ideas in education, 'scientific inquiry' has come to acquire multiple meanings and in this process is losing much of its significance; hence, the importance of making clear the meaning of scientific inquiry in the context of reform (Bybee, 2000). Mainly at the elementary level, science teachers too often equate 'scientific inquiry' with "hands-on activities" used to motivate children to learn science (Abell, Anderson, & Chezem, 2000; Wheeler, 2000). At the secondary level, on the other hand, science has been portrayed as a collection of facts or "stable truths to be verified" (Bybee, 2000). These understandings are limiting in the sense that they overlook the complexities of reform-oriented understandings of scientific inquiry that could be particularly valuable to the learner.

Two elements of scientific inquiry *for science learners* have been emphasized in the *National Science Education Standards* (National Research Council, 1996): abilities to do scientific inquiry and understandings about science and scientific inquiry. Doing scientific inquiry involves engaging in scientifically oriented questions, giving priority to evidence in responding to questions, formulating explanations from evidence, connecting explanations to scientific knowledge and communicating and justifying explanations (National Research Council, 2000, p. 29). 'Doing science' at school through these activities represents a shift in the focus of teaching: that is, less emphasis on "science as exploration and experiment", and increasing emphasis on "science as argument and explanation" (Abell et al., 2000; National Research Council, 1996).

The notion that *learning science* also means learning *a way of thinking* about nature underlies the other major dimension of scientific inquiry for learners, that is, that science learners should develop understandings *about* scientific inquiry. In other words, scientific inquiry from the reform-oriented perspective implies that through school science, students should learn *how* to "engage in a dialogue with the material world" (Wheeler, 2000). Moreover, in order to understand how scientific knowledge is constructed it is not enough to understand scientists' practices. Rather, it is fundamental that science is understood in a cultural and social context (Abd-El-Khalick & Lederman, 2000). Science educators have called this broader construct the nature of science (NOS). Unfortunately, these aspects of scientific inquiry, in particular, have been overlooked in school science (Bybee, 2000).

How do we achieve a more encompassing understanding of scientific inquiry (and NOS) in school science so science learners develop both understandings about and abilities to do scientific inquiry? Teachers would have to create opportunities in the classrooms for students not only to engage in inquiry-based investigations, but also to think about what is involved in doing scientific inquiry. To do so, teachers must know first what is meant by scientific inquiry (besides having robust understandings of subject matter and inquiry-oriented teaching strategies) (Bybee, 2000). Unfortunately, many prospective teachers have not learned science in this way and know little if anything about inquiry. How, then, can they realize the vision of reform in their classrooms? It is the responsibility of teacher educators to provide support to teachers in this area. SCIED 410 was a course conceived to address certain aspects of this task. In the following section, we will describe the rationale that guided its design.

## 3. Teacher Learning

In recent years, teacher development has been seen as teacher learning (Putnam & Borko, 2000). A major implication of such a perspective is that recommendations for teacher education must be informed by learning theory in the same manner that K-12 education is. At least three central ideas about learning have been identified as central to teacher education: (1) knowledge is situated in a physical and social context, thus, knowledge about science teaching should be situated in an appropriate context; (2) learning is seen as interpretation of experiences and the learner has an active role in that process, thus, teachers should be exposed to new experiences and should have the opportunity to reflect upon them, rethinking previous experiences; (3) knowledge is socially constructed, thus teacher educators should invest in building discursive communities of future teachers (Putnam & Borko, 2000). Unfortunately, still, the design of pre-service teacher educational programs, have not been impacted by such a perspective (Putnam & Borko, 2000). The creation of SCIED 410 represented part of an innovative effort to incorporate key ideas about learning into a teacher education program for prospective teachers.

One of the main difficulties in teacher learning is that, in spite of the extensive time spent in classrooms as learners, future teachers have rarely experienced the kind of learning that reform is promoting. If teachers need to develop subject matter knowledge and knowledge of subject-specific pedagogy for teaching science, how can science educators better situate and facilitate the development of this complex knowledge? From a situative perspective, the answer to this question is: It must be situated in the context of the classroom. However, prospective teachers cannot, like practicing teachers, refer back to past experiences in their own classrooms and try new ideas with their own students. The closest parallel to those experiences would be student teaching (ST). ST has been identified as potentially the most significant experience in pre-service education. Ideally, during ST, knowledge accumulated throughout college is applied to classroom contexts (Putnam & Borko, 2000). Nevertheless, little is known about how much future teachers learn during this late stage (Putnam & Borko, 2000), and PTs do not always have the opportunity to work in an appropriate context or even to teach through activities that are consonant with educational reform. More important, it appears that the gap between formal courses and school teaching is not necessarily challenged by the ST experience. There is evidence that future teachers hold structured knowledge and beliefs about teaching science that are built through their prior (and extensive) experiences as learners (Mellado, 1998). It is unlikely that such a complex knowledge structure will be changed during student teaching – even if that experience is exemplary. In other words, teacher educators should explore additional strategies to situate knowledge about teaching science in the classroom. Although student teaching is a valuable experience for future teachers, it is not sufficient to promote teacher development. Earlier in their education, PTs should be exposed to educational reform views, through experiences that take place in the context of classrooms, helping them to re-think their prior understandings. In sum, it is essential that throughout prospective teachers' education, educators - including science educators - provide diverse contexts to situate knowledge in the classroom, starting as early as possible.

The impetus to develop a new course for Secondary Science PTs, SCIED 410, derived from a funded project aimed at integrating technology for supporting scientific inquiry into the Secondary Science Education program at our university, during the period of 1999-2000. This experience led to the development of the *Learning to Teach with Technology Model* (Friedrichsen, Dana, Zembal-Saul, Munford, & Tsur, in press). Through the process of implementation, the instructional team reflected on how to support teachers' leaning about central ideas in science education. The model derived from the project was conceptualized around elements of the conceptual change model, implying that for learning to occur, new knowledge has to be intelligible, plausible and fruitful. Thus, the phases of the model were conceived to gradually promote these conditions. In Phase I, PTs, as science learners, use technology tools to engage in scientific inquiry. This phase supports students in making knowledge intelligible, that is, they come to understand how technology affects science learning. In Phase II, PTs focus explicitly on the technology tool, learning how to use the tool (e.g., set up, trouble shooting). In Phase III, PTs examine existing technology-enhanced science curricula and/or modify exemplary curricula. In Phase IV, PTs use technology to support students' scientific inquiry in a supportive small group setting. Finally, in Phase V, in a school setting, PTs use technology to support students' scientific inquiry, using lessons that they design and implement. Reflection is embedded throughout all phases of the model.

SCIED 410 was designed to provide science learning experiences to PTs earlier in the program to facilitate teacher development. Students majoring in Secondary Science Education are required to take a sequence of three SCIED courses before student teaching. The first course, SCIED 410, is characterized as a science content course. At this stage, which parallels Phase I in the model, PTs engage in scientific inquiry as learners, reflecting mainly about two aspects of science teaching and learning: the nature of science and the nature of science learning. As we will describe later in this chapter, activities were designed to emphasize these themes. As Putnam & Borko (1997) put it, "because teachers are being asked to make considerable changes in the nature and content of classroom instruction, it is essential that they themselves experience these new visions of education as learners and then reflect on them as learning teachers." (p. 1286)

The other two courses, SCIED 411 and SCIED 412, are Science Teaching and Learning courses (i.e. methods courses). Thus, in these courses the emphasis shifts to developing teaching strategies to teach science, although the two themes mentioned above still receive much attention. At the end of the advanced methods course, PTs spend time in the school setting, first making observations, and then teaching (last 5 weeks). These three courses are completed prior to student teaching.

## 4. Overview of the Course

***Description of the Course***

As we mentioned earlier, the course 'Technology Tools for Supporting Scientific Inquiry' (SCIED 410) is a science course developed specifically for secondary science education majors. PTs take the course prior to or concurrently with their first science methods course. In the first two semesters that the course was offered, however, it involved a more diverse group of education majors, including prospective elementary teachers.

**The Instructors**
SCIED 410 was designed and taught for two semesters by a team of 4 instructors: one professor and three doctoral students. The professor worked collaboratively with the graduate students in the design, implementation and revision of the course. As will be further described later, the course was composed of three modules, which focused on difference science disciplines (life, earth and physical sciences). Each of the modules had a lead instructor, one of the graduate students. The third author, who has background in Biology and extensive experience with both teaching high school science and science methods for PTs, was responsible for the Evolution Module. JT, who also has extensive experience with high school teaching, was responsible for the module on light, his area of expertise. Finally, the first author served as the instructor of the earth sciences module. Her background is in Biology and she has experience teaching high school and working with practicing teachers.

**Focus on multiple disciplines**
The course was structured around three modules (instructional units), focusing on life sciences (evolution), physical sciences (light) and earth sciences (global climate change). We purposefully chose to address different scientific fields for two major reasons.

First, we wanted to provide opportunities for PTs to experience at least one of the modules as learners. Given that prospective secondary science teachers major in a science discipline, we expected that they would be more knowledgeable about some modules (those most closely connected to their major) and less so about others. Many teachers do not have robust subject matter knowledge even in their areas of specialization; however, there may be strong resistance to engage as learners in experiences involving a content that you are supposed to know. Thus, learning content in other areas was intended to facilitate the process of being a learner of science.

Second, by having multiple disciplines represented in the course, we intended to address one particular aspect of the nature of science that is frequently neglected in school science: the common notion that there is a single 'scientific method'. This idea is rarely challenged in classrooms (e.g., Driver, Leach, Millar, & Scott, 1996), despite the extensive evidence derived from science studies research .

**Doing Science as Argumentation**
In each unit, PTs were confronted with guiding questions (e.g., Why so many finches died in Daphne Island in 1977? What happens to light after it leaves its source? Are global temperatures increasing?). It is not a new idea to adopt a question-driven or problem-based approach in science education. One of our major goals for using this approach in the course was to make the scientific concepts and practices part of an authentic context, meaning that learners would be engaged in ways that reflect what scientists do, as well as establish connections with their everyday lives.

As discussed earlier, knowledge tends to acquire 'inert' meanings when addressed in traditional ways in classrooms. It has been reported that situated experiences help teachers to develop more robust science subject matter knowledge (Putnam & Borko, 2000). Thus, PTs investigated scientific problems in a rich and complex context. They collected data and, working in pairs, they constructed evidence-based arguments. Through argumentation, our students were expected to explore multiple explanations for a problem, provide multiple and relevant pieces of evidence to support their conclusions, make explicit how evidence and conclusions are related to each other, and recognize limitations and strengths in explanations that they build. At the end of the unit, PTs presented their conclusions to their peers. In sum, PTs engaged in all basic activities involved in 'doing scientific inquiry' in accordance with reform documents, with an emphasis in "science as argumentation"

It is worth noting that "science as argumentation" is seen as a way to improve science *learning*, which had important implications for how argumentation was conceived in the context of the course. First, in spite of the great influence of Toulmin's work, we rejected the idea of argumentation as debate on ideas *already developed* (e.g. Toulmin, Rieke, & Janik, 1979); on the contrary, argumentation was seen as a continuous and dynamic process of knowledge construction as one (scientist or non-scientist) makes sense of his/her reality (Kuhn, 1991). This latter notion of argumentation also is particularly significant in light of the movement to make school science more authentic because argumentation is seen as an important part of scientific knowledge construction (Driver, Newton, & Osborne, 2000), as well as is considered a way of thinking that is fundamental for learners outside of school (Kuhn, 1991).

**Constructing Knowledge Collectively**

In SCIED 410, PTs worked in pairs or small groups when in class. Investigations were conducted in pairs, with data collection occasionally involving bigger groups (4-6 students). Whole class discussions were a common practice to make sense of what happened in class, as well as to process homework assignments (e.g., readings). More important, argument construction and evaluation was also a collective process. As mentioned before PTs initially built written arguments in pairs. Later in each module, they joined another pair to peer review and refined their arguments. Finally, at the end of the module, they presented their arguments to larger groups of colleagues (8 PTs) and the instructors.

The notion of knowledge as socially constructed that has became increasingly prevalent in science education and teacher education literature (e.g., Putnam & Borko, 2000) was used to inform the design of course tasks. Although our current conceptions of knowledge, in general, and scientific knowledge, in particular, imply that it cannot be constructed in a social vacuum, school science normally portrays the process of knowledge generation as if it takes place in each individual's mind in an isolated manner (Driver, Leach, Millar, & Scott, 1996). The image that emerges from these experiences not only is inaccurate in terms of how knowledge is constructed in "professional science" (e.g., Hess, 1997), but also fails to promote learning (Putnam & Borko, 2000). In fact, in those settings, scientific knowledge does not cease to be socially constructed, it just is constructed through a "social process" in which learners do not have a voice, and authority defines what counts as scientific knowledge. In SCIED 410, we attempted to create opportunities for science learners to collaborate with each other to construct scientific knowledge, with instructors' support.

Moreover, these collective tasks reflected the authors' understandings of argumentation in the context of SCIED 410. Our work was guided by the view of argumentation as "dialogic reasoning", meaning that "Whereas problem solving, in the usual sense of the word, compels one to coordinate internal reasoning structures with some aspect of the physical world, ... (argument) compels one individual to coordinate his or her reasoning structures with those of another individual." (Zeidler, 1997, p. 485). This perspective, taken in conjunction with Kuhn's perspective discussed previously, emphasizes the role of the social context in knowledge construction.

**Technology-Rich Environment**

In SCIED 410, technology tools were used to assist PTs as they engaged in long-term investigations. These tools, specially designed to support scientific inquiry, provided access to complex databases, powerful analytical tools, tools for organizing data and constructing arguments, and access to complex scientific representations through visualization (Reiser, Tabak, & Sandoval, 2001). One fundamental aspect of the "situative perspective" is the distributed nature of cognition (Putnam & Borko, 2000). This notion implies that thinking does not occur in the mind of a single individual, but is distributed among other persons, as well as, tools that are part of the physical environment (Putnam & Borko, 2000). In this context, technological tools become pedagogical tools that have the potential to not only enhance cognition, but also transform it quantitatively (Putnam & Borko, 2000).

Most of the technology tools in the course were developed by Northwestern University. In the Evolution unit, PTs used the software The Galapagos Finches, a rich scientific environment that provides scaffolding in the process of subject matter knowledge acquisition, and the development of domain-specific strategies for constructing scientific explanations in the field of evolutionary biology (Reiser et al., 2001). In the Light module (adapted from KIE; see Bell & Linn, 2000), probeware and the software Data Studio from Pasco were used for data collection; and the software Progress Portfolio was used for argument construction. Progress Portfolio is a flexible environment designed to promote and support reflective inquiry, allowing students to record, annotate and organize products of an investigative project (Edelson, 2001). Finally, in the Climate Change unit, PTs used World Watcher, "a scientific visualization and data analysis program designed for learners" (Edelson, 2001, p. 362); and Progress Portfolio to construct their arguments.

**Learning about the Nature of Science**
Following each unit, there were lessons in which PTs reflected on their experiences in the unit and made connections with fundamental concepts associated with the nature of science (e.g., what is theory and its role in science). To facilitate discussions, PTs did readings and engaged in activities that explicitly addressed the NOS. Those lessons were designed to support PTs in articulating their conceptions about nature of science and scientific inquiry in their philosophies. The focus was on the following aspects of NOS: role of theory, science as tentative, science cannot prove but can only disprove, and the influence of values and perspectives on scientific knowledge construction.

There is a consensus in the science education community that science teachers possess inadequate conceptions of the nature of science (Abd-El-Khalick & Lederman, 2000). PTs in particular, "showed themselves to be insecure and contradictory in answering questions on the epistemology of science, and recognized that they had not reflected before about these topics" (Mellado, 1998). Underlying the goal of helping PTs to develop better understandings of NOS is the assumption that such conceptions would influence their classroom practices. However, research has indicated that there is a complex relationship between teachers' conceptions of the nature of science and teaching practices (Abd-El-Khalick & Lederman, 2000; Mellado, 1998). The major implication of these findings is that initiatives in the context of teacher education can be considered 'successful' only if teachers are able "to convey appropriate conceptions of the scientific enterprise to pre-college students" (Abd-El-Khalick & Lederman, 2000). In that sense, initiatives that were oriented by an *explicit* approach to NOS – in which inquiry-based activities are combined with activities that explicitly discuss aspects of NOS and support reflection – appears to be more effective than those that had addressed the issue implicitly. The explicit approach guided the design of the course.

**Philosophy of Science Teaching and Learning**
The other major task PTs had in SCIED 410 was to develop a web-based philosophy of science teaching and learning, in which they discussed their understandings of the nature of science and scientific inquiry, science learning, and the use of technology in science education. These ideas should be presented with supporting evidence derived from their experiences in the course. Their philosophy was revised after each of the modules, and at the end of the course PTs were asked to write a reflection on the changes their ideas underwent during the semester.

To see the learner as the one who actively constructs knowledge, instead of a passive receptor of information implies that learners must have opportunities to reflect and construct new meanings based on their experiences in the course. Moreover, it is important for learners to be able to recognize and make sense of the changes in their thinking throughout the course. The philosophy of science teaching and learning was designed to support learners in this process of reflection.

**Reflections on Subject Matter Learning**
In SCIED 410, PTs also reflected on their own learning. In each module, PTs were asked to comment on articles that discussed common alternative conceptions on the topics addressed in class. As part of the assignment, PTs had to identify their own misconceptions, and discuss possible sources of alternative conceptions. In other words, in the same way we expected PTs to construct new understandings about teaching and learning science, we expected them to develop new understandings about subject matter knowledge in different disciplines. Again, we argue that as active learners PTs need to reflect about their own learning process. In this case, we focused on the recognition of limitations in their own subject matter knowledge, and the tenacity of misconceptions. These aspects should help teachers to see themselves as life-long learners with respect to scientific knowledge.

**Implications for Practice**
Finally, PTs were required to reflect on the implications of their experiences for teaching practice. They had to comment on articles that described experiences associated with teaching the topics being addressed in SCIED 410 to K-12 students, discussing how it would inform their own teaching and establishing connections between the article and class activities. This task, contrary to the others, was explicitly connected to the development of

teaching strategies. The reasoning underlying it was that although PTs engaged in the course to experience a different way of learning science, it was important that they, as future teacher, reflect about how their experiences as learners would inform strategies for teaching science. Again, reflection is a key aspect in the process of developing new understandings, thus it was an essential part of the task.

## 5. Final Comments/Conclusion

K-12 science teachers are not the only ones to experience the challenges involved in engaging their students in "science as argumentation". Teacher educators also struggle with the difficulties of trying to reduce the gap that has separated theories and goals in science learning and our practices as science educators. This course represents an attempt to make these practices more coherent with our ideas and understandings about science teaching and learning. Nevertheless, the design of such a course goes beyond an effort to reflect those theories and goals, meaning that research in the context of SCIED 410 involved not only evaluating the extent to which goals were accomplished and teaching strategies "fit" our theoretical framework. Empirical research in this course has the potential to contribute to a better understanding of the very process discussed in learning theories, as well as to help us clarify aspects related to working in the specific context of *science* learning and with *future teachers*, in particular. In sum, we see the course as a setting that will permit us, as researchers, to refine our current knowledge about science learning and teacher learning (or teacher development).

Through qualitative research, various aspects have been explored so far in the context of SCIED 410. First, we are trying to learn more about how teachers engage in science learning and construct scientific knowledge through argumentation. Our approach to this issue involves interviewing participants, as well as observing and recording their interactions in class. Thus, we can better understand how PTs perceive and make meaning of these experiences in learning science. Second, we have been investigating how science learners use technology tools and how educators can better support them in the learning process. Finally, we have been able to identify limitations in PTs subject matter knowledge (both scientific concepts and understandings about scientific knowledge construction) and what activities/approaches/strategies appear to be particularly significant for conceptual development.

## 6. References

Abd-El-Khalick, F., & Lederman, N. (2000). Improving science teachers' conceptions of nature of science: a critical review of the literature. International Journal of Science Education, 22(7), 665-701.

Abell, S. K., Anderson, G., & Chezem, J. (2000). Science as argument and explanation: Exploring concepts of sound in third grade. In J. Minstrell & E. H. van Zee (Eds.), Inquiry into Inquiry Learning and Teaching in Science (pp. 100-119). Washington: American Association for the Advancement of Science.

Bell, P., & Linn, M. C. (2000). Scientific arguments as learning artifacts: designing for learning from the web with KIE. International Journal of Science Education, 22, 797-817.

Bybee, R. W. (2000). Teaching science as inquiry. In J. Minstrell & E. H. van Zee (Eds.), Inquiry into Inquiry learning and teaching in science (pp. 20-46). Washington: American Association for the Advancement of Science.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). Young's people's images of science. Buckingham: Open University Press.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. Science Education, 20, 1059-1073.

Edelson, D. C. (2001). Learning-for-Use: A framework for the design of technology-supported inquiry activities. Journal of Research in Science Teaching, 38(3), 355-385.

Friedrichsen, P., Dana, T., Zembal-Saul, C., Munford, D., & Tsur, C. (in press). A Conceptual Change-based Model for Technology Integration in Secondary Science Teacher Education. Journal of Computers in Mathematics and Science Teaching.

Hess, D. J. (1997). Science studies: An advanced introduction. New York: New York University Press.

Kuhn, D. (1991). The skills of argument. Cambridge: Cambridge University Press.

Mellado, V. (1998). Preservice teachers' classroom practice and their conceptions of the nature of science. In B. Fraser & K. Tobin (Eds.), International Handbook of Science Education (Vol. 2, pp. 1093-1110). Hingham: Kluwer Academic Publishers.

National Research Council. (1996). National Science Education Standards. Washington: National Academy Press.

National Research Council. (2000). Inquiry and the National Science Standards: A guide for teaching and learning. New York: National Academy Press.

Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? Educational Researcher, 29(1), 4-15.

Reiser, B. J., Tabak, I., & Sandoval, W. A. (2001). BGuILE: Strategic and conceptual scaffolds for scientific inquiry. In S. M. Carver & D. Klahr (Eds.), Cognition and instruction: Twenty-five years of progress. Mahwah: Erlbaum.

Toulmin, S., Rieke, R., & Janik, A. (1979). An introduction to reasoning. New York: Macmillan Publishing Co., Inc.

Wheeler, G. F. (2000). The three faces of inquiry. In J. Minstrell & E. H. van Zee (Eds.), Inquiry into Inquiry learning and teaching in science (pp. 14-19). Washington: American Association for the Advancement of Science.

Zeidler, D. L. (1997). The central role of fallacious thinking in science education,. Science Education, 81, 483-496

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**020**

# TEACHING CHEMISTRY IN CONTEXT: THE RISKS AND REALITIES

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## Abstract

This paper reports on two studies to highlight the risks and realities associated with teaching chemistry in context. The first study looks at the consequences for teaching and learning of the introduction of Science-Technology-Society (STS) perspectives into a senior high school chemistry curriculum through providing two exemplary case studies The second study is one in which students were trying to make sense of new information when presented in two different types of concrete situations. Situations that were embedded in a range of suggested student relevant out-of-school-science everyday concrete contexts and other situations that involved in-school-science concrete contexts. The nature of the behaviour, language and understanding that was perceived to evolve was recorded and is compared. The data presented is deliberately positive in terms of the possible learning outcomes for adopting this approach to teaching chemistry is order to provide some insights to the gains that can be made from adopting such approaches.

## Introduction

There has been debate for some time about what it means to teach in context. The stance in this paper is where the context that students experience should be meaningful to them and not just their teachers. Teaching in context is not about teaching the chemistry content and then providing real world applications of this content. It is about using real situations that can be explained through the use of chemical concepts,

This paper reports on two studies. The first study looks at the consequences for teaching and learning of the introduction of Science-Technology-Society (STS) perspectives into a senior high school chemistry curriculum The second study is one in which students were trying to make sense of new information when presented in two different types of concrete situations. Situations that were embedded in a range of suggested student relevant out-of-school-science everyday concrete contexts and other situations that involved in-school-science concrete contexts. The nature of the behaviour, language and understanding that was perceived to evolve was recorded and is compared.

## Background and Experience

Until recently, the experience of many teachers of chemistry has not involved experience of chemistry in a setting outside an educational one. A common route for the preparation of teachers of Chemistry in high school is for them to undertake a Science or related degree in conjunction with an Education Degree or a one year add on Graduate Diploma in Education. This can mean that Chemistry teachers can return to the high school setting within five years of leaving as students. Recent trends in teacher education programs in Australia and in other Western cultures are slowly changing, with the Graduate Diploma in Education programs largely being used by more mature students are an avenue for changing their careers. Such changes in student profiles have been helped by the current shortages in teachers, particularly Chemistry, Physics and Mathematics teachers and consequently, many opportunities for employment.

There is little opportunity for teachers to enter Chemistry teaching in any other pathway than an academic one. Vocational pathways are not well-developed in many countries as the focus in many Western cultures requires Chemistry teachers to have a sound academic discipline knowledge on which they build their teaching expertise This is reflected in the structure of many high school Chemistry curricula, which will be discussed below.

## Science Curriculum

In this discussion, science curriculum has been highlighted. The arguments for chemistry curriculum are synonymous with science curriculum in most instances and so no distinction has been made here.

At any time, Layton (1994) suggests that science curricula are subjected to four pressures. These pressures are political, economic, cultural transmission and subject maintenance. Since the 1950s, society has demanded two things of science education, the demand for future scientists and the demand for a scientific literate citizenry. The demand for specialist workers in science has been important for the maintenance and development of social, economic and defence needs of countries. This demand has tended to dominate science education, and there has been a price paid by society for this dominance. The priority of producing future scientists has generated a "knowledge of worth" according to Fensham (1985, p417), which consists of the consolidation of specific conceptual content in each of the science. The learning of such knowledge can take so much time that the more exciting, contemporary and socially useful aspects of science are omitted or overlooked.

Fensham (1985) in his articled titled "Science for all: A reflective essay" suggests that the two demands of providing future scientists and a scientifically literate citizenry have been " conflicting and not complementary as was almost universally assumed in the first wave of the science curriculum movement" (p417) in the 1960s.

He goes on to argue that:

> *...the supply of technological and scientific manpower is important to the maintenance and development of the social, economic and defence needs of all countries. The educational system must meet this supply need...[but] it is important to assess some of the prices that educational systems have paid in giving priority to meeting this national need and to consider these in relation to the associated gains. ...The main price of these solutions to the manpower demand is that the majority of the school population learns that it is unable to learn science. ...Science to the majority of students becomes a subject that is mysterious.* (p417)

Fensham (1985) argues that, for the characteristics of science curriculum for all students to be met, there are 10 major components of learning science that represent the total learning in science. These components are: knowledge, applications of knowledge, skills, practical skills, problem-solving, science traits and attitudes, applications of science and technology, personal and social needs, the evolution of scientific knowledge and the boundaries and limitations of science.

The two purposes of science education, as outlined above, will produce different curriculum emphases as outlined by Roberts (1982) for each of the different stakeholders, in curriculum development. Each of these stakeholders make choices based on different values and so the emphases selected are likely to be different. For teachers, it is difficult to shift to a new curriculum emphasis since their experience of science (Chemistry) has been in a particular set of curriculum emphases such as the " correct explanations" and "solid foundations" or in more recent times a "structure of science" emphasis.

Rejection of particular curriculum emphases, according to Roberts (1988), can be for two main reasons. One may be that stakeholders do not value an emphasis enough to allow it to detract from other curriculum emphases, and secondly, that the amount of time and effort required to interpret and understand new emphases is too great.

An example of such rejection was highlighted by research undertaken by Fensham and Corrigan (1994) on the introduction of the Victorian Certificate of Education (VCE) Chemistry Study Design in Victoria, Australia. In this research, teachers who found difficulty in interpreting and understanding the Science-Technology-Society (STS) emphasis adopted in this curriculum reverted to fitting their current curriculum to the new course requirements.

The introduction of the VCE Chemistry curriculum reflected a worldwide trend in curriculum reform. Science curricula were developed with an STS emphasis as opposed to the more "traditional" science curricula that had existed previously. STS perspectives were introduced into many science curricula worldwide to:

> ...emphasise the basic facts, skills and concepts of traditional science, but to do so by integrating science content into social and technological contexts meaningful for students. (Aikenhead, 1994, p59)

Generally, Aikenhead as has summarized the goals of an STS curriculum:

1. The characteristics of science; including its aims and values, its human character, and its strategies for decision making and extending knowledge,
2. The limitations of scientific knowledge, values, strategies and techniques; including the recognition that science is but one knowledge system among many in society, and an examination of boundaries between science and politics, economics, religion, technology and ethics,
3. The characteristics of science and its place in society; including case studies of science-related problems, personal interpretation of one's community by making decisions as a consumer, voter, in career planning and so on. (Aikenhead, 1980, p13)

The function of traditional science curriculum has been to prepare students for the next level of education as well as teaching correct answers (Roberts, 1988). STS science curriculum on the other hand intends to address the needs of both the future scientists and citizens (science for all).

In a recent research report into *The Status and Quality of Teaching and Learning of Science in Australian Schools* (Goodrum et al, 2001), a view of the ideal picture of quality in science teaching and learning included the fundamental belief that

> "scientific literacy is a high priority for all citizens, helping them to be interested in, and understand the world around them, to engage in the discourses of and about science, to be skeptical and questioning of claims made by others about scientific matters, to be able to make informed decisions about the environment and their own health and well-being." (Goodrum et al., 2001, pvii)

This report also sought to present "the actual picture" of science teaching and learning. This picture is one of great variability and generally disappointing. While the curriculum is outcomes-based with the intention of providing a framework for developing scientific literacy, the implemented curriculum is very different from the intended one. In primary school, sometimes science is not taught at all, and when it is taught on a regular basis, the approach is generally student-centred and activity-based, with students highly satisfied with this approach.

In high school, students are often disappointed as the science taught may not be relevant nor engaging and does not connect with their experiences and interests. Traditional teaching methods, such as chalk-and-talk, copying notes and "recipe-style" practicals offer little challenge or excitement to students. Such disenchantment with science is reflected in decreasing numbers of students participating in science subjects in post-compulsory years of schooling.

Many science students conduct experiments, make observations and are asked to infer from these observations. The 'knowledge' they acquire is considered self sufficient and independent of situations where it is used. Under these conditions these bits of knowledge become discrete, supposedly independent structures and are stored in a specific internalised context pertaining to classroom chemistry. Classroom science teaching is commonly thought of as the transmission of concepts which then become part of a internalised context (Greeno, 1989). This is problematic, for as Korthagen and Lagerwerf (1995) suggest, schematization requires the schema to be filled with details and concrete experiences and during schematization students need to express things and explain their work.

## Study 1: Two case studies of site visits

While there were a number of opportunities to explore technology and industry links with chemistry in the post-compulsory years of studying Chemistry in Victoria, Australia, the investigation of a chemical in everyday use was a task specifically introduced to focus on these contexts. Presented here are two case studies of teachers and their students undertaking this task through the use of industrial sites. The two case studies demonstrate diversity in approaches that can be adopted by groups. The approaches here are an issues-based approach and a community-based approach.

### Case Study 1: An Issues-Based Approach

Adrian (teacher: a pseudonym) approached the investigation of a chemical in everyday use with an issue-based approach. His choice in this approach was deliberate as he was teaching chemistry to a group of girls and felt such an approach would engage his students more actively in this investigation.

Adrian directed his students to identify an area of interest to them in order to investigate a chemical in everyday use. Some of the student choices were chemicals used in firefighting, the dangers of fluoride overdose and benzene and its role in the Coode Island fires. All of these issues had particular interest for the students as in each case the students brought some personal experience to the topic. For example, the investigation of the chemicals used in firefighting was selected by a students who lived in an area of fire danger and the local community had been devastated by fire ten years before (when the student was eight). Her father was also a volunteer firefighter. Similarly, the student investigating the dangers of fluoride overdose was concerned on a personal level as she had fluoride staining on her teeth resulting from the doses of fluoride her mother had taken during her pregnancy with the student. The Coode Island example result from a huge chemical fire in the Coode Island chemical facility located in close proximity to the centre of Melbourne, Australia, which had occurred in the previous year. The Coode Island facility stored a number of chemicals, but primarily benzene. As a result of this chemical fire, large areas of Melbourne were covered with black smoke and areas of the central business district were evacuated. Each student was expected to organize their own investigations, including site visits, with Adrian acting as a resource for the students.

After interviewing Adrian it became clear that he found the role of being a resource for the students quite demanding as it required knowledge of a variety of issues and associated chemistry, as well as a sound knowledge of industry practices. For example, students needed to write to appropriate industry sites with well-defined requests and questions in order to be able to visit the site and obtain information. Adrian readily admitted that his experience as an industrial chemist had been invaluable in this instance. It gave him not only the appropriate skills to help his students approach the necessary industries, but had also given him a broader understanding of chemistry by forcing him to use his knowledge in a variety of settings. Such skills enables Adrian to cope with the wide ranging issues that interested his students.

Both Adrian and his students commented on the advantage of this approach to this investigation. While the approach had taken huge amounts of time for all concerned, the students not only completed the task, but remained interested and enthusiastic about their investigation throughout. Adrian comments:

> *...it was a lot of work, but it was worth it to see them [the students] actually engaged in investigating a chemical in such an enthusiastic way. A number of students have said that they felt like real scientists, really investigating something.* (Adrian)

Adrian's students echoed his thoughts with their comments such as:

> *...it was really important to thoroughly investigate my topic, but it was interesting as I thought I was really investigating it and organizing everything myself. Seeing the industry setting helped me clarify the research I was doing and made me understand better.* (Adrian's student)

In questionnaire responses, Adrian's students made positive comments about what they had learnt and the experience generally. They could articulate their ideas and understanding very well in response to questions and while they recognized the extra effort required by this approach, felt it was well worth it.

**Case Study 2: A Community-Based Approach**
Paul (teacher: a pseudonym) was a chemistry teacher in a country high school in a town in the far north-west of Victoria, Australia, some 5.5 hours drive from the capital, Melbourne. Paul had lived in this country town for the last 20 years, the last 10 years teaching chemistry at the local high school. The previous 10 years he had worked as a winemaker in a local winery.

In order to undertake an investigation of a chemical in everyday use, Paul looked at the local community for an industry that was an integral part of the community and consequently would be known to his students. His choice of industry was the local winery. While Paul had worked in this winery, it was not the only factor in his decision. The winery was the largest industry in the community and also one in which his students would most likely be involved with in some was as many of the local families grew grapes for the winery or had been employed at grape harvesting time as pickers. Paul felt that by using the winery on which to base the investigation, his students would have a greater sense of ownership of the investigative enterprise.

Paul was very positive about the success of the investigation. When interviewed, he commented on the high standard of work produced by his students and the motivation they maintained throughout the investigation as illustrated by:

> *...it was a fantastic experience for any teacher to see his students attack a piece of work with such enthusiasm and maintain it all the way through. They [the students] deserve a lot of credit for what they learnt and the way they approached the investigation. They produced a first rate product at the end too.* (Paul)

Paul's' students also expressed their positive feelings about the investigation with comments such as:

> *...I learnt about pH levels, organic chemistry, decomposition and fermentation, and acidity involved in the winemaking process. I never thought I'd use any of this stuff, but I did and its right here, almost in my own backyard.* (Paul's student 1)

> *The best part was when the winemaker let us use our own judgement and chemistry to blend some wines. It was fantastic to realize that I did know something and could use it.* (Paul's student 2)

Throughout the whole investigation, Paul reported that the willingness of the students to question and organize their information was a highlight for him.

*LEARNING CHEMISTRY IN INDUSTRY SETTINGS*
The above case studies can be used to illustrate the possibilities for learning chemistry through the inclusion of technology and industry links. However, such possibilities were only apparent when individual teachers and their students were considered. Earlier data from this study on teachers and students collectively did not provide such a healthy perspective. There are a number of examples where the approaches adopted by teachers can positively influence the learning of their students through the use of industry and technology links.

Aikenhead (1994) suggested that "STS science teaching's student-orientated approach emphasizes the basic facts, skills and concepts of traditional, but does so by integrating the science content into social and technological contexts meaningful to students" (p. 59). Industry can provide a meaningful social and technological context for students but this cannot be assumed as a given. Some industrial settings may not represent meaningful contexts for students studying chemistry, but this does not need to be the case.

For an industry setting to be meaningful for students, the establishment of a need to know more about the industry is important. This may be achieved through an issues-type approach or a community-based approach, as outlined in the case studies. These are to name only two such successful approaches, others that may be considered are outline by Ziman (1994). Teachers need to develop in their students ( and themselves) working concepts of chemistry that cross settings such as school, home and industry.

### Study 2: Teaching Oxidation and Reduction

This research was conducted over three phases. Units on oxidation and reduction topics in a range of external societal and industrial contexts were written, trialled and modified based on student and teacher responses to these units. The starting point for each unit was out of school occurrences of oxidation and reduction explained processes. The units were still expected to deliver the oxidation and reduction concepts prescribed in the final year of high school chemistry (16-17 year old students) curriculum. The units ranged from hair perming to sewage treatment, from breathalysers to siting new smelters. The learning activities involved in each task situation varied and included role plays, problem solving, whole class and small group discussions and semi-open investigations.

The units were intensively monitored through completing pre- and post- questionnaires, responding to a mid-intervention letter asking for feedback, and drawing pre-, middle and post- intervention concept maps within one class of twenty female students over a 10 lesson period . In addition some students were interviewed informally after each lesson. Two lessons were taught in the teacher's traditional way using teaching practices, experiments and styles that she had used in the past.

The research provided detailed insight into the role and effect of context on students learning oxidation and reduction concepts in a classroom setting. This detail enables the illustration of some of the characteristics of a unit driven lesson and a traditional lesson. Throughout the text below , these terms, unit driven and traditional lesson will be used to identify the lesson type.

**Students as learners of oxidation and reduction concepts**

In unit driven lessons, data analysis indicated several features of the students as learners of oxidation and reduction concepts such as:

- students asked questions,
- abstracted and applied chemistry concepts promoted in previous unit driven lessons to make sense of other unit driven lessons,
- provided information that had a 'domino' effect,
- volunteered information, and
- were assertive during discussions with peers and the teacher.

There was a notable change in the classroom interaction between the teacher and students. This was not always a comfortable feeling, as the students' questions were often demanding and challenging. When being taught in the traditional lesson, these same students were reticent. They waited to be questioned by the teacher, did not challenge the teachers' reasoning, there was no domino effect, and the direction of the lessons were governed by the teacher rather than the students' questions. Furthermore they expected to be 'fed' information.

During unit-driven lessons, students were engaged and motivated. They were on task, working through complicated tasks rather than simply looking busy. For example, the excerpt below highlights this enthusiasm and motivation. The students had been given 45 minutes in which to design a breathalyser. In essence they were being asked to apply the information in a semi-open investigation to produce a breathalyser.

| Lesson Commentary | Lesson Explanation |
|---|---|
| Bell rings<br>Zoe. 2.41 g of dichromate.<br>Yve. Well I'll work out the molar mass and then we can do it from the-<br>Una. Will it be done ready for tomorrow?<br>Zoe. Yes.<br>Una Coolest!<br>Teacher . Do you want to continue that little problem solving activity next week?<br>All. Yeah, yeah.<br>Una. Because we did, we did a big equation and worked it all out...<br>Yve. We are just going to use n equal m over m<br>Una. So it's getting exciting because we ...<br>Teacher. All right, all right.<br>Zoe. I'll take, the bag, the breath bag.<br>Yve. OK.<br>(G CO9 29/5/92) | The school bell goes, indicating the end of the lesson. They continue to work. They are interested and want to know if it will be ready for the next lesson.<br>The teacher notices this activity and asks if they wish to carry on in the next lesson. Excitedly they say yes and then carry on with their work, even though the bell had gone some time ago.<br>The teacher tries to hurry them on and out! They volunteer themselves to undertake tasks in anticipation of the next lesson. |

Students also talked to their parents about the work they did in unit-driven lessons. Their enthusiasm was not just confined to the classroom. In a mid-intervention letter . Toni and Alison explained;

| | |
|---|---|
| Toni. | You should see me round at home, I'm going, - that's a redox reaction. |
| Ali. | I suppose it's obvious. |
| Toni. | And I'm going -oh my God, why have I said that? |
| Researcher . | You were saying that at home? |
| Toni. | I did that, I did that to my mum and dad. And they are going what's a redox reaction and I spend about ten minutes explaining it to them. |
| (G Ai/T I.6 29/5/92) | |

Another noticeable facet of the unit-driven lessons was the number of questions asked by students and the nature and delivery of these questions. The questions were characterised in terms of being indicative of students' :

- interests;
- ways of challenging;
- seeking clarification;
- seeking directions.

Students challenged the teacher during unit-driven lessons. The following excerpt taken from a lesson involving the bacteria *thiobaccilus*. illustrates this. The essence of the unit was the contention that *thiobaccilus* bacteria had an ability to convert sulphur into sulphates and due to the fact that it was already in soils it was a better fertilization process in comparison with the current practice of adding sulphates and phosphates to the soil. The latter being thought to result in water pollution due to excess chemical run-off. The student (from a farming family) chose to challenge the teacher's tacit acceptance that the bacteria method was environmentally better than the existing method.

| **Lesson Commentary** | | **Lesson Explanation** |
|---|---|---|
| Mira. | Wouldn't you have to put something else on, to be able to get the pH normal, neutral or anything? | The student perceives a flaw in the bacteria method |
| Nina. | Put lime on it. | Instead of the teacher responding another student intercedes |
| T. | Yeah, you have. Probably have to lime it. To get it back up to neutral. | The teacher concurs hesitantly |
| Mira. | Yeah, so you're still going to have to use other fertilisers as well. | The student who initiated the discussion moves on doggedly. |
| Nina. | So you, you'd have to phosphate the lime. | |
| Mira. | No, but they are saying they are putting sulphur on it, straight on to it. | |
| Ivy. | Yeah but.. | Another student enters the fray. |
| Teacher. | Umm. So what's, so what's the advantage of throwing sulphur on rather than putting super phosphate? (c.o.4 30/4, 9) | The teacher's tone is unsure and she asks for further clarification. She is now working as part of the team rather than a deliverer of knowledge. |

Apart from challenging the teacher, students questioned each other. For example, in the following excerpt

taken from their problem solving unit on designing a breathalyser, the students had completed an experiment in which they added potassium dichromate to alcohols, from which they deduced that acidic conditions were required. The following excerpt begins at a stage where they were trying to design their breathalyser to take into account the reaction findings. Ali kept challenging the other members of her group, because she wanted a reason for including the acid in the breathalyser.

| **Lesson Commentary** | | **Lesson Explanation** |
|---|---|---|
| Ali | There must have been a reason for putting it in there. It can't be completely irrelevant. When we put sulphuric acid in, did it change colour? | Alison (St Ai), did not accept the need to use acid in a breathalyzer. She kept challenging her group to explain why they needed to consider the acid in their design. |
| Jo. | No. | |
| Ai. | So maybe we were just testing it? To see that it didn't react with other things as well. | |
| Toni. | I suppose so. | |
| Ai. | Right OK.. That's the theory! | |
| Jo. | Coloured in for..(inaudible) | This forced Joanne and Toni to revisit the notes they had made. |
| Ai. | Oh did it? Oh darn! There goes that theory. Oh, hang on. | |
| To. | Hang on, and that stayed the same and then when we heated it | |
| Ali | There was no change when we put in sulphuric acid. | This led to an agreement that acid and heat were both needed for a breathalyzer to work. |
| Toni. | So it didn't have anything to do with it until it was heated?(G CO9 29/5/92) | |

*THE 'DOMINO' EFFECT.*

The students' questions and challenges promoted a 'domino' effect, which was common during the unit-driven lessons. During a group interview, students commented on this effect, they said;

| | |
|---|---|
| Abby . | Yeah, well, things got remembered and I remembered them. |
| Toni . | Everything kept on leading to another - |
| Abby. | Yeah. |
| Toni. | -and you are going 'Oh! that's right!' |
| Researcher. | What kind of things were leading on to another, give me an example. |
| Abby. | Things like corrosion leading on to oxidation reduction and then the other things that prevent corrosion and stuff like that. |
| Toni. | Like galvanising, like paint and metals and metals on the reactivity series. (G Ab/T I.1 22/4/92) |

This type of behaviour is indicative of the unit-driven lessons helping students to make links to existing internalised contexts. As Abby explains the difference between her lessons last year and the unit-driven lessons this year:

| | |
|---|---|
| Researcher | Now, why is it that it is going a lot better, what's the difference? |
| Abby. | Well last year all we did was stuff about metals. And changing iron to iron ore and I don't even know if you can do that, if that is some such thing, but yeah...That's all we did. And formulas and equations and that and I just got completely confused and I lost it very early on. |
| ...Later she went on to try and explain why it was better for her this time. | |
| Abby. | I don't know, it's just better because it's more things you can relate to better and that. So it's easier to understand. |
| Researcher. | What do you mean by relate to? |
| Abby. | Well, I mean, like with real life and that. Like with the hair perming and the meat and stuff like that. You can, put it alongside your life and see where it turns up. |
| Researcher. | Why do you find that useful? |
| Abby. | Cause it's, it makes more sense and you can understand it.(G Ab I.3 4//92) |

These students were not taught the theory first and then asked to apply what they were taught, (a common practice in science lessons). The chemical concepts being promoted were embedded in various contexts, but it wasn't a discovery exercise either. When butter goes rancid, we observe the phenomena, but it is not oxidation and reduction, it is a process that can be explained by oxidation and reduction concepts. Oxidation and reduction, like energy and other concepts, is a human construct, a means of making sense of phenomena. Stumbling upon these constructs would be difficult. Hence the unit-driven lessons were not discovery lessons in the sense that students would stumble upon the oxidation and reduction concepts, instead the unit-driven lessons were lessons in which the students would encounter and reflect on experiences which promoted oxidation and reduction concepts in external to school concrete contexts.

The questions, the domino effect, the challenging, were behaviours that demonstrated that these students were reflecting on their past experiences, the new oxidation and reduction ideas they were encountering and then trying to reconstruct their ideas so as to reap fruitful dividends.

*CONFIDENCE.*

The previous excerpts are also indicative of the confidence exhibited by students learning oxidation and reduction concepts. In the unit-driven lessons students demonstrated assertive behaviour and volunteered information. The following excerpt from a response to the mid-intervention letter confirms the evidence provided by classroom observation (the underlining is the students own);

> I feel I understand them better than I usually do when in chemistry- still not 100% confident but not totally confused or at a loss to know why you do something/ what the point behind learning some of these things is. I can relate (sic) these to me, so it is easier to understand why & how you learn these things. As I can understand I find it easier to remember, so feel more confident, so I am able to learn the next step with more ease. I am actually feeling relatively happy in chemistry due to this method of teaching. The steps are simple and I can link them together.(G 1 L 1992)

*STUDENTS USE THEIR EVERYDAY EXPERIENCES TO VALIDATE THEIR OPINIONS*

Students used many of their everyday experiences to support their ideas and viewpoints, and often these were beliefs, and affective related viewpoints. Pairs of students were asked to argue the case for a bridge to be built from either copper, aluminium or iron in their town in order to cope with increased traffic demands. The following excerpt, provides the case being made to support a bridge being built from iron rather than aluminium or copper. Notice their use of everyday experiences to validate their opinions. Notice also that these everyday experiences may not concur with accepted scientific reasoning or understanding.

*STUDENTS ABSTRACT AND APPLY THE CONCEPTS*

| | | |
|---|---|---|
| Ali. | ...You can't put oil and grease over it! Cause they are going to slip off the road! That would be fun wouldn't it? Painting, that wears off. | They were discussing how to protect the iron. There was a suggestion that oil or grease coating could prevent rusting. The idea was discarded |
| Jo | Plate it. | |
| Ali. | Plate it, yeah, plating it would be , that's better eh? | |
| Jo | Or sacrificial | |
| Ali. | No, I don't think. Plating. It's better. | |
| ...... (A few minutes later)...... | | |
| Ali. | Can you imagine a bridge of aluminium anyway? | Baking foil is associated with aluminum, therefore the bridge cannot be built from aluminum, it would not be strong enough. |
| Jo | It would be, it would be... | |
| Ali. | It just doesn't seem.. | |
| Jo. | It would be , you'd need too much of it. It wouldn't be dense enough, it would bend too easily. | |
| Ali. | A bridge of tin foil! | |
| Jo | Aluminium isn't nearly as strong as steel or copper is it? So if you had a bridge of it , it would probably bend eventually and then break! So we can write that down. | |
| Ali. | O.k. (c.o.10 2/6, 5-6) | |

The students were also seen to abstract the essence of the concepts encountered in one unit-driven lesson and apply them in others. Students themselves noted this process, as the following interview transcript illustrates;

| | |
|---|---|
| Ali. | ...basically all we've done is we've sort of learnt about oxidation reduction and we have just sort of branched out to talk about electrons and balancing all these equation things. But we are using the same things we've learnt every unit. ..., it's like, you are sort of building it up but you are using all the things you've built up. ...(G Ai/T I.6 29/5/92) |

However the notion of context in teaching and learning science is not simply to equate it with external themes, topics or scenarios. The student's links to existing ideas have to be taken on board and this is demanding.

**Summary**

There are inherent risks in teaching chemistry in context. The context must be meaningful for students if it is to engage, motivate and challenge students. Teaching in context must also enable students to link their existing ideas with new ideas they encounter, if their learning is to be meaningful. There is a certain amount of risk in this as many chemistry teachers have not had these experiences in their own background that will enable them to embrace this approach with high levels of success. The data presented here has deliberately focused on positive outcomes of teaching chemistry in context, to highlight the real gains that can be made in student learning by adopting such approaches.

The reality in many countries is similar to the picture painted in the Goodrum et al (2001) report in terms of the meaningful learning that students can undertake in Chemistry. The learning experiences in science and chemistry for students around the world does not have to fit this reality and can indeed come much closer to the ideal picture this report also described in terms of educating scientifically literate citizens. The challenge will be to provide teachers of chemistry with experiences that will enable them to rely less on their own background and more on teaching from meaningful contexts for their students.

## References

Aikenhead, G.S., 1980. Science in Social Issues: Implications for Teaching. A Discussion Paper. Science Council of Canada, Ottowa.

Aikenhead, G., 1994. What is STS science teaching? In Solomon, J. & Aikenhead, G. (Eds). *STS Education: International Perspectives on Reform*, Teachers College Press, New York,47-59.

Fensham, P.J., 1985. Science for All: A reflective essay. *Journal of Curriculum Studies, 17*(4), 415-435

Fensham, P.J. and Corrigan, D.J., 1994. The implementation of an STS chemistry course in Australia: A research perspective In Solomon, J. & Aikenhead, G. (Eds). STS Education International Perspectives on *Reform*, Teachers College Press, New York, 194-204.

Goodrum, D., Hackling, M. & Rennie, L., 2001. *The status and quality of teaching and learning of science in Australian schools.* DEETYA. Report available at http:://www.detya.gov.au/schools/publications/index.htm

Greeno, J. G. (1989) A perspective on thinking. *American Psychologist*, 44, p 134 -141.

Korthagen, F and Lagerwerf, B (1995) Levels in Learning. *Journal of Research in Science Teaching*, *32*, 10 p 1011-1038

Layton, D., 1972. Science as general education. *Trends in Education, 25*, 11-14

Roberts, D.A., 1982. Developing the concept of curriculum emphases in science education, *Science Education, 66*(2), 243-260.

Roberts, D.A., 1988. What counts as Science Education in Fensham, P.J. (Ed) *Development and Dilemmas in Science Education*, Falmer Press, 27-54.

Ziman, J., 1994. The rational of STS education is in the approach. In Solomon, J. & Aikenhead, G. (Eds). *STS Education: International Perspectives on Reform*, Teachers College Press, New York, 21-31.

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021

# A NEW METAPHOR FOR TEACHING: SCIENCE TEACHER AS ANTHROPOLOGIST

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**Abstract**

This article addresses problems inherent in traditional science teaching and argues that the pitfalls of assimilation and exclusion can be avoided by adopting an anthropological approach: regarding scientists as a subcultural group with its own language and ways of thinking about, investigating and explaining phenomena and events, its distinctive methods for generating new knowledge and solving problems, its tradition, history, set of conventions and underlying values. Students learn why scientists think and act in these ways, and how they differ from or resemble the practices and traditions of other subcultural groups.

The other element in this approach to science education is the self-conscious *metacognitive* dimension: students knowing that this is what they are doing. More crucially, knowing which aspects to access for particular kinds of activities and encounters, when to use science and how to use it, when to use some other way of knowing.

## Border Crossings and Exclusion from Science

Every individual has membership of a number of social groupings, some of which are long-term associations, others of which are merely temporary. Effective participation in these social groups is, of course, dependent on possession of the appropriate cultural knowledge - that is, the shared understandings, beliefs and language, codes of behaviour, values and expectations of the group. Just as each student's personal framework of understanding is unique, so also is each student's complex of social group membership, their perceptions of what that membership entails and requires and, in consequence, their profile of cultural knowledge. When students, each with a distinctive personal and cultural framework of understanding, are presented with a particular learning task set within a distinctive educational context (involving a particular class or learning group), a unique learning context is created for each individual. Appreciation of the uniqueness of personal learning contexts helps to explain why some students learn successfully, while others of supposed equal ability do not, even in apparently very similar circumstances. It helps to explain why particular students may learn on some occasions, but not on others, despite circumstances that to others may seem identical.

Factors that impact on learning include the student's views of school, science and the activities associated with learning science, relationships with peers, teachers and family, learning preferences and other aspects of metacognitive awareness, self-image, aspirations and values. Some are wide-ranging and stable over time; they govern the student's overall attitude and commitment to learning science. Others are topic-specific, even lesson-specific, and influence short-term decision-making about learning behaviour.

For school-age students, the major social groupings of the family, the peer group and the school create distinctive 'social worlds' which may or may not have common cultural knowledge. Phelan et al (1991) suggest that points of similarity and difference between these three social worlds lead to four types of transition into the culture of the school, a transition that is crucial to students' prospects of using the education system to further their life chances and career prospects. Their conclusions are that:

- Congruent worlds facilitate smooth transitions
- Different worlds require transitions to be managed
- Diverse worlds lead to hazardous transitions
- Highly discordant worlds result in transitions being resisted or proving impossible

For science students there is an additional border to cross: transition into the culture of science, or the particular school version of it. School science has its own set of beliefs, values and codes of behaviour. It has its distinctive linguistic code. There are many students for whom the rules about the conduct of lessons, the conventions concerning who can speak and what can be spoken about (including what can be challenged), and the particular form of school talk and science talk, constitute a set of conventions and restrictions that are so formidable they are dissuaded even from seeking access to science education. Many students do not see themselves or their experiences, interests, aspirations, values and attitudes reflected in the science curriculum and are uncomfortable with the way it is presented. It is little wonder they decide that science is not for them.

## The Culture of Certainty and Compliance

Sadly, some of those students who do succeed in entering the subculture of school science are not so much enculturated into the community of science as autonomous individuals as assimilated into a culture of schooling that emphasizes certainty and compliance. Many school science curricula continue to promote the view that science provides a body of fixed, authoritative knowledge about the world arrived at via an all-powerful and all-purpose scientific method. These impressions are reinforced by a heavy reliance on didactic teaching styles and by a style of laboratory work in which students spend considerable time on 'cookbook exercises' designed to reach particular, pre-determined outcomes. As a consequence, students are socialized to see their task as memorizing a series of definitions and reproducing them on demand, mastering a set of algorithms for solving standard problems, and carrying out the teacher's instructions for obtaining a particular set of results. They do not see their role as thinking about or questioning the source, relevance, validity and reliability of the views and ideas presented to them. Nor are they given opportunities to design, conduct and interpret scientific inquiries for themselves and by themselves; they merely carry out the teacher's instructions. Thus, students may succeed in the sense of being able to say and do the 'right things', and can gain the marks available for such conformity, but they fail in the sense of gaining a robust and usable set of meanings to incorporate into a personal framework of understanding. What many students learn is how to do classroom tasks, how to be neat, how to finish on time, how to look busy and to fill up the available time, how to avoid attracting the teacher's attention and, in practical lessons, how to tidy away and write things up in the approved form. What they do *not* learn is how to employ their knowledge in novel situations and how to use it to develop a deeper and richer understanding. Such students have not been enculturated into science, rather they have been assimilated into *school*. They have learned to be compliant students, rather than good scientists and effective learners.

Furthermore, when the curriculum is monitored by the kind of rigid, analytical, objectives-oriented approaches to assessment that are currently in vogue in many places, it becomes an ideal vehicle for those who seek to shape people towards pre-determined goals. It is disempowering because it rules out a concern with critical thinking. Goals are taken on trust; emphasis is on obedience and efficiency in effecting someone else's plans; there is no concern with valuing, criticizing, challenging and changing the goals. By inculcating a willingness to accept prescriptions for behaviour and an acceptance of external control and management, a culture of compliance is created, which impacts adversely on both students and teachers. Education becomes a means of social reproduction, with all its existing inequalities, rather than a means of social reconstruction. When the reward of marks is restricted to the uncritical execution of carefully specified tasks, critique becomes de-valued in the eyes of students, critical faculties atrophy through lack of use and, eventually, students lose all trust and confidence in their capacity to make judgements. Thereafter, decisions on all matters of importance are left to so-called experts.

## Avoiding the Pitfalls of Assimilation and Exclusion

The notion of science education as enculturation necessitates students crossing cultural boundaries from other sub-cultures into the sub-cultures of school, science and school science. The chances of smooth border crossings are greater when everyone is clear about the nature of the boundaries and the nature of the likely obstacles, and make concerted efforts to overcome them. Thus, it is important that both teachers and students recognize that science itself is a sub-culture, with its own distinctive knowledge, language, methods, rationality, criteria of validity and reliability, traditions and values.

Perhaps the major problem in science education is not that students sometimes have conceptions of phenomena and events that are incompatible with scientific views. Nor that these alternative conceptions are resistant to change. Rather, the problem is that students have not recognized that they are able to incorporate different aspects of meaning, additional connotations and new relationships into their personal framework of understanding, in order to extend the usefulness and range of applicability of their knowledge, without necessarily giving up their previous, trusted understanding. Not only do we need to ensure that students develop the ability to add to their understanding, we need to ensure that they acquire the second order understanding that includes:

(i) recognizing that alternative conceptions and explanations exist (and alternative methods, too);
(ii) appreciating that the appropriateness and usefulness of knowledge are determined by context;
(iii) knowing what knowledge to access and how to use it in a variety of problem situations and social contexts.

Scientific understanding that cucumbers and tomatoes are fruit, for example, does not preclude the commonsense understanding that they are located in the vegetable section of the grocery store, together with plant roots, tubers and leaves. What is important is recognizing when particular meanings are appropriate and being able to use them properly in the appropriate discourse. There are situations in which the scientific approach has very obvious utility; for certain types of question it can provide a well-tested and powerful answer. In other situations, everyday knowledge is far more useful and appropriate. A central goal of science education is to show students when their own needs and purposes are best served by scientific knowledge and scientific ways of proceeding, and when they are better served by other ways of knowing and acting.

What I am advocating is an approach that recognizes, acknowledges and promotes multiple meanings and multiple perspectives, but ensures that students know which meanings and understandings to access for use in particular circumstances. It is summed up by the phrases "finding one's way around one's repertoire of knowledge" and "having confidence in making an appropriate selection to fit the circumstances". This self-knowledge may be the key to smooth and comfortable border crossings into and out of the culture of school science. Crucial, also, is the capacity to reflect on one's own understanding of these matters and to understand and control one's own learning.

The fundamental point is that one's way of thinking is relative to context and, sometimes, even unique to context - where 'context' includes the physical context, the immediate social context and the wider cultural context, as well as the specific problem context. Since we all move between and among a multiplicity of contexts, we are all capable of holding multiple views about the world. These different perspectives create, for each individual, a complex web of understanding around any given phenomenon or event, which throughout this article I have referred to as a *personal framework of understanding* (Hodson, 1998) and within which students can hold a multitude of diverse and sometimes contradictory views - among them, of course, some entirely erroneous views. Moreover, these personal frameworks of understanding include substantial elements of personal experience, feelings, emotions, attitudes and socioculturally-determined knowledge, beliefs, values and customs.

Extending Giroux's (1992) notion of the teacher as "cultural worker", Medvitz (1997) argues that science can be learned in much the same way as an anthropologist learns another culture. The concepts, procedures and language of science are recognized as cultural artefacts, susceptible to systematic study. They are valid and robust within the cultural context in which they were developed, but sometimes have little relevance or meaning outside it. This 'anthropological curriculum' might usefully be extended to include critical scrutiny of the culture of the school: that is, being explicit about the ground rules of school (codes of behaviour, language use and social norms) and the rationale that underpins them.

## Science Teacher as Anthropologist

The literature of teacher education abounds with metaphors: teacher as broadcaster, teacher as gardener, teacher as tour guide, teacher as police officer, entertainer, and so on. Perhaps there is room for another: *teacher as anthropologist*, or "teacher as culture broker" as Aikenhead (2000) expresses it. It is part of the teacher's job to help students gain an understanding of what, for many, are alien cultures (the subcultures of science, school and school science) and assist them in moving freely and painlessly within and between them (Pomeroy 1994, Aikenhead 1996, 1997; Aikenhead & Jegede, 1999). What is needed is a way of entering the subculture of science, using its knowledge and procedures to engage in interesting and important tasks, and leaving again with one's sense of self intact. Better still, with one's sense of self enriched by the experience. It seems almost superfluous to say that it is crucial that the science education we provide does not require students to give up or compromise their cultural identity, aesthetic sensibilities or moral/ethical values. When presented with such a choice, many students do not choose science.

> When... students' language and cultural experiences are in conflict with scientific practices, when they are forced to choose between the two worlds, or when they are told to ignore their cultural values... [they] may avoid learning science (Lee, 1997, p.221).

My argument is that students can only understand science properly (that is, at a personal level) if they understand 'where it is coming from' - that is, what its fundamental beliefs and assumptions are. Teaching for personal understanding is not just a matter of providing discrepant events and a clear argument for the validity of a new idea. Students also need to understand the fundamental metaphysical considerations and value positions that underpin scientific knowledge and scientific inquiry - for this, they need explicit teaching about science.

Tyson et al (1997) suggest something similar when they make a case for conceptual change to be viewed through three lenses: an ontological lens (students are looking out at the world), an epistemological lens (students are looking in at their own knowledge) and a social/affective lens. As they say, all three aspects impact on learning and can impede or facilitate border crossings. However, their model is too static and too logical for my purposes. Above all, it is too impatient of culturally-determined differences in worldview: "students have to *stop* thinking of concepts like heat, light, force, and current as material substances" (p400, emphasis added). The approach I am seeking does not equate understanding with belief, nor does it seek to displace other worldviews with the approved scientific view. Rather, it seeks to equip students with the knowledge, self-knowledge and confidence to move freely between different worldviews, accepting each on its own terms and for its own purposes. Ogawa (1995) expresses similar views in his notion of "multiscience teaching": helping students to move comfortably and effectively among personal science (including all forms of idiosyncratic beliefs and explanations for phenomena), indigenous science (the communal beliefs of the specific cultural group to which one belongs) and Western modern science (as promoted through the curriculum). Aikenhead (1996, p.41) develops this idea further.

> Border crossings may be facilitated in classrooms by studying the subcultures of students' life-worlds and by contrasting them with a critical analysis of the sub-culture of science (its norms, values, beliefs, expectations, and convention actions), *consciously* moving back and forth between life-worlds and the science-world, switching language conventions explicitly, switching conceptualizations explicitly, switching values explicitly, switching epistemologies explicitly.

Particularly helpful in this regard, despite being more than thirty years old, is the approach of King and Brownell (1966), who describe the disciplines (including science) in terms of eight characteristics.

- As a community - a corps of competent people with a common intellectual commitment to building understanding.
- As a particular expression of human imagination - an idea that has much in common with Gardner's (1984) currently fashionable notion of multiple intelligences.
- As a domain - each discipline defines and develops its particular sphere of concern and interest.
- As a tradition - a history, comprising the activities, experiences and discourse of earlier practitioners.
- As a syntactical structure - a distinctive mode of inquiry and collection of methods for generating and validating new knowledge.
- As a substantive structure - a complex framework of concepts, laws, models and theories.
- As a specialized language - a form of intellectual shorthand for conveying meaning quickly and accurately, as well as a distinctive form of argument.
- As a valuative and affective stance - an array of fundamental beliefs about the nature of being and a complex of emotional dynamism and aesthetics.

Studying these matters and making them explicit to students involves confronting and dispelling the many distortions and falsehoods about science that are commonly projected by school science curricula. Prominent in this distortion of science are the following ten myths (Hodson, 1999a).

- Observation provides direct and reliable access to secure knowledge.
- Science starts with observation.
- Science proceeds via induction.
- Experiments are decisive.
- Science comprises discrete, generic processes.
- Scientific inquiry is a simple, algorithmic procedure.
- Science is a value-free activity
- Science is an exclusively Western, post-Renaissance activity.
- The so-called scientific attitudes are essential to the effective practice of science.
- All scientists possess these attitudes.

In general, female students and members of ethnic minority groups experience the greatest barriers to successful border crossing into the community of science. Consequently, de-mythologizing science should pay particular attention to dispelling the notion that science is an exclusively European or North American (ie white ethnocentred) and masculine practice, and should address questions about the rationality of science and its correspondence (or not) with other ways of knowing and other 'sciences' (African science, Feminist science, etc) (Hodson, 1999b). The explicit comparison of science with other ways of knowing (philosophy, religion, etc) and with everyday knowing and indigenous science (what Ogawa (1995) calls "multiscience teaching") is likely to prove the principal means of achieving the goal that Jegede (1995) calls "secured collateral learning" – the capacity to pass freely and confidently between different knowledge stores and worldviews as the need arises.

**Becoming More Self-conscious**

As individuals learn more science and more of other things, too, their personal frameworks of understanding become more complex by addition of concepts and ideas (what Hewson (1981) calls "conceptual capture") and by reorganization and restructuring (what Ausubel et al (1978) call "progressive differentiation"). These concepts and ideas can be arranged in a number of different ways, rather like a series of maps can be organized to represent rainfall, population or geographical features. Not only do these maps differ somewhat from person to person, but each of us has an idiosyncratic selection of maps available to us. These maps constitute our personal framework of understanding. Learning which map to choose and how to deploy it effectively in particular circumstances is the passport to smoother border crossings.

Of course, these maps are predominantly linguistic maps. Hence, education in science is, in large part, a matter of (i) acquiring familiarity with the specialized language of science and (ii) using it appropriately, in both its spoken and written forms, for a variety of purposes and in a variety of contexts. Learning the language of science is not just a matter of acquiring a few specialist terms and purpose-built vocabulary items. It involves introduction to, and gaining familiarity with, what Lemke (1990) calls the "thematic patterns" of science: the ways in which concepts and ideas are related within a much broader network of inter-dependent meanings. It also entails getting used to some of the other distinctive features of scientific language: the tendency to utilize universal rather than particularistic meanings; the use of technical terms and symbols in preference to colloquial terms; and the use of familiar everyday words in restricted and specialized ways. A science curriculum can be regarded as successful by the extent to which students can use this language appropriately and can present ideas and findings in the distinctive genres of science, particularly the scientific paper and the laboratory or fieldwork report.

Students will learn the language of science properly only through interaction with someone who is already an expert, and by using it themselves in carrying out authentic scientific tasks. Thus, teachers should model appropriate language use, make explicit reference to its distinctive features, provide language-based activities that focus on them, create opportunities for students to act as autonomous users of the language, and provide critical feedback on their success in doing so. There also needs to be much more *metatalk* (talk about talk), with teachers explaining why they are adopting a particular linguistic form. Students need to know that while everyday language will suffice on some occasions, a specialized language of science is necessary on others. They need to know the circumstances in which different codes are applicable and they need lots of practice in switching between them. This is one key aspect of what Aikenhead (1996) calls autonomous acculturation: "a process of intercultural borrowing or adaptation in which one is free to borrow or adapt attractive content or aspects of another culture."

Strike and Posner (1992) found that students' epistemological views and attitudes affect and are affected by their learning of science. In particular, "students who did well in physics were more inclined to be realists about physics, to demand consistency in their beliefs, to be empiricists in their views of scientific method" (p.165). They also found that confidence in one's ability to learn physics, approaching learning as a task of understanding rather than just remembering, and valuing learning for its own sake, facilitate and are facilitated by growth in physics competence. Of course, it begs the question of what counts as "doing well in physics" and leaves unanswered the question of what "physics competence" means. Nevertheless, it does point to the importance of studies in the history, philosophy and sociology of science in bringing about better learning of scientific content and attitudes more favourable to successful learning in science. And it does point to the significance of self-awareness in achieving what Munby (1980) calls *intellectual independence*: the capacity of an individual to judge the truth of a knowledge claim independently of other people, and to exercise similar independent judgement with respect to views about science and scientific practice. Kuhn (1989) summarizes such views when she describes those enculturated into science as capable of consciously articulating the theories they hold, knowing what evidence supports them or would refute them, and justifying why they hold those views rather than some other views that might also explain the evidence. In a sense, she says, the scientific expertise that enculturation bestows is rooted in metacognitive awareness of epistemological issues: "thinking about theories, rather than merely with them, and thinking about evidence, rather than merely being influenced by it" (p.688).

What I am arguing is that border crossings are eased by helping students to become more conscious of what is involved in border crossing, by promoting a kind of cultural awareness that involves students understanding the social location of beliefs and practices, acknowledging the context-dependence of most of what they think and do, and recognizing the existence of different modes of discourse, each having a distinctive sociocultural origin. Part of this cultural awareness entails recognizing that science itself is a subculture, with its own distinctive knowledge, language, methods, rationality, criteria of validity and reliability, traditions and values; part entails students reflecting on their personal frameworks of understanding and considering carefully the circumstances in which they came to hold particular views and develop particular skills. The capacity to reflect on one's own understanding and to understand and control one's own learning are further elements in the struggle against assimilation and exclusion. However, the capacity to engage in such critical reflection and the attitudinal commitment that drives it also have to be taught.

### Learning About Learning

With appropriate teacher support, students can construct an understanding of their own learning processes, just as they construct (or co-construct, with teacher support) their own views of the world and their views about themselves. Indeed, Gunstone (1994) reports that even students as young as eight years old can be made "learning conscious". It is widely acknowledged that students who understand their own learning and know how to monitor and regulate it are far more effective and successful learners than those who do not. In general, students who learn to reason about their own knowledge, and to question how and why it fits in with other ideas, are more successful in learning (Linn, 1987). This understanding also influences how students perceive errors in their work - as evidence of failure or as a source of useful information for modifying future actions. Learning how to learn more successfully is also an important key to feelings of control and competence, factors that are essential to good motivation and are at the heart of intellectual independence.

Two points should be noted. First, teachers should employ a wide variety of metacognitive activities, because students quickly routinize any task and may fake good learning behaviour in order to win teacher approval (White & Mitchell, 1994). Second, teacher development must precede that of students. Significant changes in the metacognitive skills of students can only be achieved by teachers who, themselves, possess appropriate understanding, attitudes and abilities (Baird et al. 1991). Similar demands on teachers accrue from the several other aspects of the approach to science education described in this paper. In adopting this approach, teachers are more than facilitators, organizers, managers and discussion leaders, they also have to be skilled practitioners of science. In order to introduce students to the cultural tools and conventions of the community of scientists, devise learning experiences that are scientifically significant as well as meaningful and interesting for students, and in order to guide, criticize and advise students, and ask and answer critical questions, teachers must have a deep understanding of both scientific knowledge and scientific methods. Moreover, they must have a thorough knowledge of the historical development of science, its social, economic and environmental impact, and the social, moral and ethical issues it raises for individuals and for society. This is a pretty daunting set of specifications, but one that holds out the prospect of a much more professional role for science teachers than many other models of teaching and learning, and one that points to clear targets for both pre-service and in-service teacher education .

**References**

AIKENHEAD, G.S. (1996) Science education: border crossing into the subculture of science. *Studies in Science Education*, 27, 1-52.

AIKENHEAD, G.S. (1997) Toward a First nations cross-cultural science and technology curriculum. *Science Education*, 81, 217-238.

AIKENHEAD, G.S. (2000) Renegotiating the culture of school science. In R. Millar, J. Leach & J. Osborne (Eds), *Improving Science Education: The Contribution of Research*. Buckingham: Open University Press.

AIKENHEAD, G.S. & Jegede, O.J. (1999) Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching*, 36, 269-287.

AUSUBEL, D.P., Novak, J.D. & Hanesian, H. (1978) *Educational Psychology: A Cognitive View*, 2nd edn. New York: Holt, Rinehart & Winston.

BAIRD, J.R., Fensham, P.J., Gunstone, R.F. & White, R.T. (1991) The importance of reflection in improving science teaching and learning. *Journal of Research in Science Teaching*, 28, 163-182.

GARDNER, H. (1984) *Frames of Mind: The Theory of Multiple Intelligences*. London: Heinemann.

GIROUX, H. (1992) *Border Crossings: Cultural Workers and the Politics of Education*. New York: Routledge.

GUNSTONE, R.F. (1994) The importance of specific science content in the enhancement of metacognition. In P.J. Fensham, R.F. Gunstone & R.T. White (Eds), *The Content of Science: A Constructivist Approach to its Teaching and Learning*. London: Falmer Press.

HEWSON, P.W. (1981) A conceptual change approach to learning science. *European Journal of Science Education*, 3, 383-396.

HODSON, D. (1999a) Science fiction: the continuing misrepresentation of science in the school curriculum. *Curriculum Studies*, 6, 191-216.

HODSON, D. (1999b) Critical multiculturalism in science and technology education. In S. May (Ed), *Critical Multiculturalism: Rethinking Multicultural and Antiracist Education*. Lewes: Falmer Press, pp.216-244.

HODSON, D. (1998) *Teaching and Learning Science: Towards a Personalized Approach*. Buckingham: Open University Press.

JEGEDE, O. (1995) Collateral learning and the eco-cultural paradigm in science and mathematics education in Africa. *Studies in Science Education*, 25, 97-137.

KING, A.R. & Brownell, J.A. (1966) *The Curriculum and the Disciplines of Knowledge: A Theory of Curriculum Practice*. New York: John Wiley.

KUHN, D. (1989) Children and adults as intuitive scientists. *Psychological Review*, 56, 674-689.

LEE, O. (1997) Scientific literacy for all: What is it, and how can we achieve it? *Journal of Research in Science Teaching*, 34, 219-222.

LEMKE, J.L. (1990) *Talking Science: Language, Learning and Values*. Norwood, NJ: Ablex.

LINN, M.C. (1987) Establishing a research base for science education: challenges, trends, and recommendations. *Journal of Research on Science Teaching*, 24, 191-216.

MEDVITZ, A.G. (1997) Science, schools and culture: the complexity of reform in science education. In K. Calhoun, R. Panwarm & S. Shrum (Eds), *International Organization for Science and Technology Education (IOSTE) 8th Symposium Proceedings: Vol 2 - Policy*. Edmonton: University of Alberta.

MUNBY, H. (1980) Analyzing teaching for intellectual independence. In H. Munby, G. Orpwood & T. Russell (Eds), *Seeing Curriculum in a New Light: Essays from Science Education*. Toronto: OISE Press.

OGAWA, M. (1995) Science education in a multi-science perspective. *Science Education*, 79, 583-593.

PHELAN, P., Davidson, A.L. & Cao, H.T. (1991) Students' multiple worlds: Negotiating the boundaries of family, peer, and school cultures. *Anthropology and Education Quarterly*, 22, 224-250.

POMEROY, D. (1994) Science education and cultural diversity: Mapping the field. *Studies in Science Education*, 24, 49-73.

STRIKE, K.A. & Posner, G.J. (1992) A revisionist theory of conceptual change. In R.A. Duschl & R.J. Hamilton (Eds), *Philosophy of Science, Cognitive Psychology, and Educational Theory and Practice*, Albany, NY: State University of New York Press, pp.147-176.

TYSON, L.M., Venville, G.J., Harrison, A.G. & Treagust, D.F. (1997) A multidimensional framework for interpreting conceptual change events in the classroom. *Science Education*, 81, 387-404.

WHITE, R.T. & Mitchell, I.J. (1994) Metacognition and the quality of learning. *Studies in Science Education*, 23, 21-37.

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022

# SCIENCE AND SCIENTISTS: A COMPLEMENTARY STUDY

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## Abstract

Are children's acceptance of science learning and their attitudes toward practitioners shaped in the classroom by means of the priorities of the attentions of the teacher or by the demands for attention by males in co-educational environments? If they are significantly affected by the educational environment, would the attitudes of children toward science and scientists be altered if the children were taught in gender-specific schools? An interest in the correlation between gender-specific educational environments and learners' attitudes in science education has piqued the curiosity of the present researchers. This question, therefore, has served as the major focus for the present research.

The researchers, with full permission and approval of the original author, used a slightly altered questionnaire originally developed to determine, on a broad international scale, the attitudes of children toward science and scientists. The questionnaire in the present study was distributed to 180 eighth-grade students in six private schools in a single geographic area in one state in the United States.

Findings were interesting and indicated that attitudes among upper middle-class children in the southern United States are much more influenced by cultural factors, including television, than they are by the absence or presence of students of the opposite sex or the attentions of the science teacher. The findings would appear to negate the claim that the reason girls frequently do not choose a science career is because their elementary school teachers favor males with more attention. In this particular study, although there were noticeable variations in attitudes of female students in gender-segregated schools as well as in co-educational schools, single sex educational environment does not appear to make a significant difference in general attitudes. There is a need for more and different types of research into children's attitudes toward science and scientists.

## Introduction

There has been much written and a number of research studies done indicating that single-sex schooling could be beneficial for girls, especially in those curricular areas generally thought to be "male oriented" (science and mathematics). In an article by Thomas Lyles in *The National Elementary Principal* (1966), the author told how teachers used more science materials and experiements with boys' classes. He stated, "Mold can be studied from a medical standpoint by boys and in terms of cooking by girls" (39). In the 1990s, Sadker and Sadker (1993), found arguments in favor of single-sex schooling persuasive. They wrote in *Failing at Fairness,* "Girls in single-sex schools have higher self-esteem, are more interested in nontraditional subjects such as science and math and are less likely to stereotype jobs and careers" (233).

The present researchers got their inspiration and a great deal of assistance from the Science and Scientists (SAS) international study of Dr. Svein Søjberg, whose preliminary findings were published in *Acta Didactica* by the Department of Teacher Education and School Development at the University of Oslo in January, 2000. It is a great method of finding out about children's attitudes, despite the fact that some of the questions - those designed for children in less highly developed societies - gave pause and perhaps a smile or two to some of the respondents!

In his pilot study report, Dr. Søjberg (2000) stated that, "The intention of the SAS study is to shed light on some of the issues that may be important for an informed discussion of priorities in science education that is sensitive toward the background of children, with emphasis on culture and gender" (7). * Having seen several interim presentations (GASAT, 1996; IOSTE, 1996 and 1999) and carefully studied the publication of the results of *the SCIENCE AND SCIENTISTS* twenty-six nation study, the present researchers were curious about the ramifications of the research if it had other parameters. They thereafter embarked upon a further investigation as a complement to and expansion of the original SAS project.

This is not intended to be a replication of the SAS study, although permission to use their questionnaire and to slightly modify it to suit present circumstances were secured from Dr. Søjberg. What this study is presenting, along with the collected data, is the researchers' interpretation of those data and their own speculation about the motivations driving the responses received. The present researchers are endeavoring to determine how cultural factors and parental attitudes have affected students' perceptions of science as a career choice and scientists as persons, as well as the impact of school type on attitudes of students in a selected socio-economic and educational setting.

Since some researchers' responses to other gender based science education studies (i. e. Lockheed, 1986) have suggested the strong possibility that gender bias would not be present in science instruction provided by teachers in gender specific schools, one of the prime motivations for the present study was to attempt to either give credence to this theory or to prove it false. The schools used in the present study: two all male sectarian (religious), two all-female sectarian, one co-educational non-sectarian and one co-educational sectarian, all catered to upper middle-class students and teachers were of both genders in all schools. Students' ages varied from thirteen to fourteen and they were all in eighth grade. The results indicate that there is no appreciable difference in the attitudes toward science and scientists in single-gender schools and, for the most part, responses follow a cultural rather than a gender trend.

## Procedure

With the full permission and approval of the director of the primary study, and using a slightly altered SAS questionnaire, present research was designed to complement the original investigation, to determine if attitudes toward Science and Scientists are in any way influenced by gender-segregated schooling. Because the gender-segregated schools to be used were religious one question was omitted (having to do with birth control); and, due to the difficulty already encountered by the primary researchers in evaluating the writing and drawing samples, both were omitted from the present study.

The questionnaire, a five-part instrument after the above-mentioned alterations, was distributed to eighth-grade, thirteen and fourteen-year-old students in two male-only, two female-only, and two co-educational schools. All schools are privately run and charge tuition. Only one of the schools (co-educational) was secular in orientation. Ninety-nine percent of the students come from upper-middle-class homes; fewer than one-half of one percent of the students receive tuition relief. There were thirty-five completed responses from each school. Completed questionnaires were coded, using an eight-digit number to indicate student, gender, age, co-educational or gender-segregated school, and country. Results were interpreted using SPSS, and produced in graph format. Responses were interesting and generally mirrored those of respondents in developed countries in the pilot study. There were noticeable variations in attitudes of female students in gender-segregated schools as well as co-educational schools..

There is no doubt that the data greatly reflect the fact that all questionnaires were distributed to students enrolled in private (tuition-charging) schools in a single state of the southern United States (Louisiana). All respondents are products of their upper middle-class environment - children from a socio-economic status which adopts much of its thinking, attitudes and opinions from televison, movies and social peers. The responses also reflect the more conservative position of parents who are anxious for their children to conform to the social and cultural norms of their own class.

This is an extremely long survey, having some two hundred and two items; and, to save time, the researchers have elected to discuss some of the questions whose answers indicate strong differences of opinion. Only those responses will be discussed, although all responses have been graphed and are available in another part of this paper.

The data collected were coded for gender, age, school type, and country. The questionnaire was divided into five sections and the data analyzed accordingly. The data were analyzed using the Statistical Package for the Social Sciences (SPSS, 2000). Two graphs were produced per question showing percentages by school type and gender. One graph shows results of female-only school and female-coed school views of the items from the questionnaire. A second graph shows the same for the males.

A one-way multivariate analysis of variance (MANOVA) was conducted to determine the effect of school types and gender (All female school only vs. females in a coed school; all male school only vs. males in a coed school) on the dependent variable (Questionnaire items.). Significant differences were found among some of the dependent variables.

## Discussion of Results

The responses to questions 21 (caring for others) and 25 (interesting and exciting person) indicate that the children feel that the biologist and the medical doctor are very caring and interesting; girls in co-ed. (CE) schools to a greater extent than girls in single-sex (SS) schools; while responses to 12 (selfish) and 15 (boring) - ss girls saw the physicist as more caring than did those in CE schools, which does not fit the general pattern - indicate that they see the physicist or engineer as boring and selfish; a reflection of the fact that most children have, at some time in their lives, met a physician and been either positively or negatively impressed by the person. They have seen doctors depicted in movies as suave, wealthy, intelligent individuals who do exciting things. The work of physicists and engineers is usually behind-the-scenes, no matter how impressive the project, and relatively unexciting, so they are not seen as interesting to the casual observer.

Male responses to questions in section A, especially 9, 12, 16, and 19, indicate that boys in SS schools believe that scientists in general are intelligent, hardworking, kinder and more humane than do males in CE schools, indicating a more consistent trend among boys in SS schools toward a favorable view of science and scientists.

Answers to questions 17 (authoritarian/domineering) and 26 reflect that the respondents in both SS and CE schools see the medical doctor/biologist as more authoritarian than the physicist/engineer . The researchers believe the key here is that engineering is known as a consultative profession, dealing with more abstract ideas (if bridges can be thought of as abstract!), and the opinions of these individuals may or may not be accepted; whereas, doctors are consulted when one needs their opinion; when one has a personal stake in that opinion. People in developed countries tend to have a great deal of respect for their doctors and their opinions. In addition, much respect is given in the United States to those in high-paying positions and the medical profession tops the list.

In questions 40 (used a radio), 41 (recorded with a tape recorder) 42 (recorded on a VCR), 43 (played video or computer games) , 44 (used a calculator), all dealing to some extent with technology, girls in both SS and CE schools indicated "often" while boys more frequently used a personal computer (question 45). These responses indicate that girls are more attuned to personal, passive, "inside" activities and less to the active, participatory. Girls, although they mature earlier than boys, frequently don't like to be seen as smarter or more "grown up" than their male peers; African-American girls are often seen as "selling out" to the white over-culture if they display their intelligence or appear to be smarter than the African-American males.

All girls indicated that they "played with light and mirrors" (# 46) more than boys did. This was interpreted to reflect their use of makeup and their greater concern with their appearance, probably a reflection of the American culture's obsession with youth, good looks and the traditional role of women as decorative objects. There was almost no difference between responses from SS and CE respondents.

Items 29, 30, 45, 73, 75, 77, 79, 82, all directed toward children in a non-industrialized society, and taking into consideration the large size of the sample, elicited generally negative responses, most respondents in both school types indicating "Never". In number 99 (made anything from clay) both sexes in CE schools indicated that they had done it more often that any respondents in SS schools.

In questions 108 (pollution and dangers of traffic), 113 (plants and animals in other parts of the world, I15 (bacteria, virus and disease), girls indicated a slightly higher concern than boys, which is probably attributable to their increased concern for the environment and, by extension, the general awareness of problems of family health.

Responses to questions 115 (bacteria, virus, disease) and 116 (vaccination and prevention) showed that both SS girls and boys have a greater interest in these topics than CE girls and boys. Traditionally in both undeveloped and in industrialized societies, food gathering (here and now known as supermarket shopping), family care and child rearing are the provinces of women; and, among the upper middle class until the last century, was almost their only occupation. It is to be expected, therefore, that questions 119 (how to heat and cook food), 120 (what to eat to be healthy), and 121 (how babies are made, how they grow and mature) would reflect that tradition; girls, especially those in SS schools, being more anxious to learn about such things than boys. As all respondents were children of the city, in a highly industrialized society, they showed very little interest in anything related to food gathering and processing.

Girls, and this was consistent in both SS and CE schools, were much more enthusiastic about learning about colors and how we see them than boys (question 129), probably because they are trained almost from birth to be concerned about their appearance. Other gender based studies have indicated that the most frequent comment to girls by their science teachers have to do with the students' appearance. More girls rated number 138 (the rainbow) as interesting than did boys. As they did with number 141 (why the sky is blue and the stars twinkle). These responses could reflect both girls' concern with the environment and their interest in color. In general, boys showed more interest in pure science, in both categories of gender and school type. Boys indicated more interest in computers and how they work than girls.

Females showed more interest in questions 160 (how to get clean and safe drinking water)and 161 (how we can protect air, water, etc.) because of their heightened concern for the environment. However, they tend to take such things for granted in their society. Question 163 (test-tube babies) reflects girls' interest in the traditional female role of child bearing and rearing. Responses to numbers 164 (how children in other parts of the world live and think), 165 (why people in different parts of the world look different...) and 166 (how science and technology may help the disabled) all indicated a higher interest level of girls than of boys in both types of schools. Society assigns the "sensitive and caring" role to females and these responses indicate that the respondents probably subscribe to that prescription.

All male respondents indicated a high level of interest in question numbers 170 (how a nuclear power plant functions) and 171 (what an atomic bomb consists of ...), which may reflect boys' greater interest in war and weapons.

Forty-five percent of girls in SSs schools and 33 percent of girls in CE schools indicated that work with people rather than things is important to them (questions 175 and 187), reflecting the overall pattern of female concern with and caring for people. In item number 186 (time for own interests) girls again demonstrated their concern for others. Males in CE schools had a higher mean than males in SS schools in their responses to questions 175 and 187. Males' responses to question 183 (control other people) fits the cultural pattern of male leadership - males lead, females follow - and their interest in leadership training.

Question 178 (earn lots of money) was considered very important by boys in SS schools (65 % ), while 43% of girls in SS schools considered it of some importance. Getting a secure job (item 185) was very important to both boys and girls and there was little statistical difference between the two, indicating that, in today's society, secure female employment, even among those of the moneyed class, is of high importance, while males, too, feel the pressing need to be assured of a lucrative career. Question 189 asked for respondents' opinions about developing new knowledge and skills. Over 80% in the SS boys' schools considered it very important, while only

45 % of SS girls agreed that it was important. Both boys and girls fell somewhere between in the CE schools. There were many blanks on question number 196 (most suitable for boys), probably indicating a basic career indecision on the part of respondents.

Girls found science boring (191), which fits into the cultural pattern of science as a male career. However, the positive responses by both boys and girls to items 192 (science creates problems for society), 193 (science creates pollution) and 194 (science is useful for everyday life) indicate that children in our society do not think too badly of science in general and they think that science professionals are useful members of society.

In item 201 (science is difficult to understand) 55% in SS girls schools and 45% of SS boys and 50% in CE schools responded positively. Question 202 produced 48% yes and 52% blank responses from SS boys, and 32% yes and 54% blank from SS girls. Forty-five percent in the CE schools said yes. What is interesting is the number of items which were left blank.

## Conclusions

Conclusions to be drawn from this study:

1. Girls are generally more imaginative, creative and caring in SS schools than girls in CE schools. This could be a factor of the cultural vision of the female as possessing these attributes.
2. Single-sex educational environment does not seem to make a significant difference in the altitudes toward science and scientist in either males or females.
3. Pure science seems to be of greater interest to boys than to girls, regardless of educational environment.
4. Science content which interests children appears to be more a factor of enculturation in girls more than in boys.
5. Although there are women in the biological, life and environmental sciences, for the most part, the physical sciences are still male-dominated in the United States. This vision is reinforced by television, peers and parents.
6. Nothing in this study gave any indication of the influence of either male or female science teachers in the schools used.

The only trend evident in the collected data is that no change in attitude is apparent or prevalent and there is no indication that change is likely to take place in the present or even in the next generation. There is a need for more and different kinds of research into children's attitudes toward Science and Scientists.

## References

Green, S. B., Salkino, N. J., & Akey, T. M. (2000) *Using SPSS for Windows.* NJ: Prentice-Hall.

Lockheed, Marlaine. (1986) "Reshaping the Social Order: The Case of Gender Segregation." *Sex Roles* 14:17, pp. 617-128.

Lyles, Thomas (Nov. 1966). "Grouping by sex." *National Elementary Principal* 46:2, pp. 38-41.

Sadker, M. & Sadker, D. (1993). *Failing at Fairness.* NY: Charles Scribner's Sons.

Sjøberg, Svein. (2000) *Science and Scientists: The SAS Study.* Oslo, Norway: Department of Teacher Education and School Development.

023

# DINOSAUR FORESTS AND GLACIAL TERRAINS: NEW ZEALAND PRESERVICE AND UNITED STATES INSERVICE TEACHERS DEVELOPING A VISION OF ENVIRONMENTAL SUSTAINABILITY

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## Abstract

This paper describes how preservice primary and inservice middle schools teachers received a practical introduction in their course work to the key features of environmental education, by being immersed in local environmental case studies where crucial decisions about the future were being decided. In Hamilton city, New Zealand, a remnant of the ancient podocarp forests – the so-called dinosaur forests - was under threat by neglect; in Durham, New Hampshire, city planners were considering developing a glacial forest terrain. In the absence of formal, compulsory environmental education curricula in both countries, the teachers voluntarily enrolled in these two courses (only sixty hours duration) because they sensed that environmental education could be very important in their future teaching. The two researchers therefore adopted a framework for environmental education at large, using these two cases studies as an early way of immersing students in the richness and complexity of environmental decision-making. The model's objective is to provide a preliminary definition of environmental education by integrating learning "about", "in" and "for" the environment on a time-line which perpetually holds out the goal of sustainability. The model is under-pinned by carefully selecting (from science, technology, etc.) concepts, skills and values – described fully in the paper - which ultimately drive socially responsible action.

Both courses, based on experiential learning, therefore adopted a case-based, inquiry-orientated pedagogy incorporating social action on a local issue. The New Zealand students, fortified with an understanding that a huge forest of these podocarp trees (called kahikatea) had once thrived in large cool, silty local river beds, were able to investigate the result of human actions: tree-felling, wetland draining, dairy farming and urbanisation. In one patch, a civic decision was imminent: either to enhance the trees' sustainability by incorporating them into a new artificial wetland and park, or to turn the whole area into a sports facility. In New Hampshire, the students explored the local university forest with the knowledge that this piece of land was under intense pressure by the university officials and the city council to be used for sports fields, parking and a loop road. Teams of students investigated facets of the problem and this knowledge was incorporated into decision-making process.

In summary, the case studies served as frequently revisited contexts in which the model of environmental education could be understood. Consequently, this *early* highlighting of decision-making ensued that social action was *always* recognised as the central feature throughout, not merely at the end.

## Introduction

Even when they were emerging as significant phenomena in human social history, science and technology could be seen to have enormous environmental consequences. For example, Francis Bacon's catalogue of twenty-four 'improvements' in scientific knowledge, as outlined in his supposedly utopian *New Atlantis* of 1621, now seems to clearly anticipate such contemporary issues as genetic modification, drug trials on animals, nuclear armaments, and so on (MacDonald, 2001). Goethe's 1829 prophetic anxiety (Riordin, 2001) about rampant technology – "the alarming increase in machines torments and frightens me" – has found its fulfilment in Rachel Carson's indictment of the pervasive and insidious consequences of technology: "Only within the moment of time represented by the present century has one species - man – acquired significant power to alter the nature of his world ... The most alarming of all man's assaults upon the environment is the contamination of air, earth, rivers and sea with dangerous and even lethal chemicals" (Carson, 1963, p.6).

Encouraging people to actively engage with local issues about the past, present and future consequences of this "significant power" is a central goal of most environmental education. A basic concept underpinning issues-based approaches is that of 'sustainable development', which is often defined as "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). It is hoped that through this approach, people are more mindful about how decisions impact human and non-human populations.

Although the need for environmental education might seem to be self-evident to many educators (van Matre, 1990), and despite the often-expressed views of pupils and parents (Osborne and Collins, 2000), environmental education frequently still struggles to find a place in national and regional curricula (Yencken, Fien & Sykes, 2000). Given the origins of many environmental problems described above, it is nevertheless encouraging that - as this conference calls for - "rethinking" is occurring in science education (Gough, 1999; O'Donoghue & McNaught, 1991; Nicholas, Oulton & Scott, 1993) and in technology education (Dillon, 1993) as these two established curriculum areas seek "... to meet the demands of future generations in a changing world". The present paper describes a contribution by two tertiary science educators, who have adopted a framework for environmental education at large and have sought to epitomise its essential features in a case study approach.

## The Framework and the Pedagogical Strategy

The framework (Figure 1) provides a preliminary definition of environmental education as an integration of *three dimensions* - learning "about", "in' and "for" the environment - on a *timeline* which perpetually holds out the concept of *sustainability* as a key goal. Three other concepts underpin this goal: *maintaining biodiversity, understanding interdependence*, and *accepting personal and social responsibility for action*. It is the latter, which drives the process forward, but it needs to be coupled with a social context where problem solving and decision-making are currently required.

The framework was applied in the design of a course for preservice primary in New Zealand and inservice middle schools teachers in the United States in situations where science education and technology education, but not environmental education, were accepted components of the curriculum. Both courses faced the same dilemma: how, in a very limited time frame, to introduce the essential, distinguishing character of environmental education. The pedagogical strategy adopted to achieve this was to select a *local* context (as opposed to a *school*, *national* or *global* context) where contestation and decision-making was currently an issue, and to identify and be part of the decision-making throughout the course.

## The New Zealand Case Study

For the 25 students taking the fifty hour, twelve-week New Zealand course, a remnant of the ancient podocarp lowland forests of Gondwanaland (the so-called dinosaur forests) within Hamilton City (population 110,000, 100 kilometres from Auckland) was chosen as the local issue. A Hamilton City Council decision crucial to the future of this 5 hectare block of mainly kahikatea trees (*Podocarpus dacrydioides*), known as Jubilee Park (formerly called Claudelands Bush), was currently being made, and public submissions were being encouraged. The issue was: What will happen to the Jubilee Park forest as it becomes amalgamated with an adjacent lot of 25 hectare (previously an agricultural showground) in the setting up of the new Claudelands Park?

The issue was raised very early in the course when students viewed a videotape which summarised the history of Jubilee Park until about 1990. Then they became aware that, taking into account an assessment carried out seven years previously (Hamilton City Council, 1993), the Council had proposed a draft plan (Hamilton City Council, 2000a) for the new Claudelands Park which had received favourable submissions (Hamilton City Council, 2000b). However, these had been set aside when Council decided to call for further submissions based on two zoning possibilities for the new Park. Should it be zoned as a 'passive recreation area' (basically as in the draft plan), comprising lawns, walkways and an extended pond area which encompassed Jubilee Park? Or should it be zoned as an 'active recreation area', which would permit the construction of sports facilities and playing fields, with no special provisions for Jubilee Park?

The students' issue-based learning then developed, simultaneously, along the three dimensions of environmental education:

**Education 'about' the environment:** Students researched and discussed the *timeline* for kahikatea. They discovered that

- These tall, straight conifers, unbranched for much of their immense height, were present 160-180 million years ago in the birdless, flowerless world of the super-continent of Gondwanaland; pterosaurs, no doubt, "... perched in the branches of kahikatea overhanging tidal rivers, drying (their) clumsy wings" (Park, 1995, p.36).
- When New Zealand began to raft away from Gondwanaland about 80 million years ago, terrestrial dinosaurs continued to digest the little fleshy red lumps (feet) under the black seeds, which would be "... planted out, each in its supply of slow release fertiliser, somewhere in the forest" (Bellamy, 1990, p.72).
- Perhaps 15,000 years ago the present site of Hamilton City was near the centre of a huge basin (McCraw, 1967; Soons & Selby, 1992, p.243; Stephenson, 1986, p.40) where forests of kahikatea grew densely "... in deep peaty ooze or even over flowing water" (Smith, 1987).
- Over the 1,000 years or so of human habitation, Maori have climbed these 60 metre trees (New Zealand's tallest) to gather the fleshy 'feet' for food, and they have snared the birds which come for the same purpose (Orbell, 1996, p.27).
- Jubilee Park represents one of the many kahikatea forest fragments (Environment Waikato, 2001) which remain from the huge forests which existed when Europeans first arrived in the Hamilton basin in 1840s (Norris, 1963, p.1) but which – with the need for land for dairy farming - had largely disappeared by the 1940s (Park, 1995, p.69).
- Like many New Zealand native plants, kahikatea comprise a gene pool with considerable medicinal and therapeutic potential (Brooker, Cambie & Cooper, 1981, p.32).

**Education 'in' the environment:** Formally and informally, the students visited Jubilee Park on a number of occasions. They

- Explored the concept of *biodiversity* by comparing the species present now with those of fifteen (Boase, 1985) and fifty (Gudex, 1955) years ago.
- Came to a deeper *understanding about interdependence* by discussing how forest 'islandisation' creates damage by wind exposure and reduces bird habitats. In particular, they reflected on the near absence of seedlings and pole kahikatea, and how lowering of the urban water table makes regeneration of swamp trees nearly impossible.
- They strolled around three other local kahikatea remnants – Masters' Avenue Bush, Whewell's Bush and Yarndley's Bush (Evans, 1982; Edmond, 1984) – comparing them with Jubilee Park, and also trying out interpretativist activities (Cornell, 1989) in experiential learning mode (Fien, Heck & Ferreira, 1997, p.37).

**Education 'for' the environment:** The students

- Worked for a day replanting a former kahikatea wetland, Lake Rotomanuka.
- Held a concluding class debate, where they surveyed all their perceptions of the 'active' versus 'passive' recreation choices for Jubilee Park, and were encouraged to make individual submissions. Later, but before the course concluded, they learned that the second round of submissions (Hamilton City Council, 2001a) had resulted in the adoption of a plan (Hamilton City Council, 2001b) based on the 'passive' recreation option and which included specific provisions for the management of the Jubilee Park kahikatea forest, and that sports interests (like rugby football) were willing to co-operate with the plan (Taylor, 2001).

Concerning the remainder of the course, this early highlighting of local decision-making ensued that social action was always recognised as the central feature. Decision-making remained the central focus when the students explored a school context (Mardon & Jones, 1999), a national context (conservation of endangered species), and an international context (greenhouse emissions, ozone depletion, and human populations).

## The United States Case Study

Fifteen graduate students, most of them experienced middle school teachers, enrolled in an institute on environmental education. This summer course consisted of students attending class for four weeks, four days a week, eight hours a day. The goal was to immerse students into the complexities of the learning about and the teaching of environmental education. Three university faculty members (a scientist, a science/environmental educator, and a philosopher) worked to provide a coherent model on how to unpack and learn about local environmental issues. During the first two weeks of the course, the students investigated a small piece of forest comprised of 250 acres of woods, streams and small fields called College Woods. College Woods is not a unique forest, in fact, the eastern deciduous forest is most common type in New Hampshire where the thin soil and cold climate.

The instructors of the course selected this forest as the focal issue in their case-based approach. They thought that the College Woods case made an exemplary example of how decisions are made about small pieces of undeveloped land. Smaller and unnoticed decisions about development is typical of what every community is facing in this part of the United States (Kaufman, 1992).

In our example, College Woods is under heavy pressure to be developed in several ways. The university wants to expand and would like to see playing fields and buildings where there are presently trees. The town and surrounding areas are growing and the main thoroughfare is congested with traffic. The town leaders see the forest as a perfect place to construct a loop road diverting traffic around the town. Both the town and the university see this piece of land as "being unused." However, people from New Hampshire are proud of their rural heritage and development is changing the landscape subtlety into a suburban environment. The students were faced with the following questions: is the land unused, is it unique enough to be protected, and who should decide if and how to alter it?

The faculty members and students investigated the composition and biodiversity of the forest, examined university documents, and interviewed people who use the forest as a way to frame their answers to the questions. The pedagogical intent was to use this case study as a way to learn about issue-based environmental education and to serve as a springboard for groups of students to then select their own issue to study for the next two weeks of the summer institute.

The instructors developed issue-based case along the three integrated dimensions of environmental education. For the purpose of the paper, the three strands are examined separately.

**Education 'in' the environment:** Students explored the College Woods as a typical forest habitat. They walked through the forest several times noting the different forest types and gained some understanding on what caused the local variation. Qualitatively, the students looked for evidence of disturbance (Watts, 1957; Wessels, 1997, 1999; Leslie, 1999). The students also studied the forest quantitatively. They ran some transects through portions of forest to gain an understanding of the species composition of the vegetation, dug soil pits to categorising the type of soils that existed, and monitored the quality of water in the river that ran through the forest. They discovered that:

- The soil is thin and the Precambian granite (6 to 12 inches) base lies just under the soil.
- The river affected the type of forest near the water.
- Human disturbance was a major cause of what types of plants and animals lived there now. Examples include:
  - Farming in the 1800s is still affecting the soil composition.
  - A tree farm planted by students in the 1930s that was soon abandoned after the planting has a lower diversity of plants and animals than the surrounding forest.
  - A dam that was constructed in the 1940s on the river now supplies the water to the town. Students found differences in water quality and the biodiversity of macroinvertebrates above and below the dam.
  - Old stone fences run through the woods as reminders that the forest was a farm.
  - Large spreading maples, used as shade trees, indicate some of the original farm was used for livestock and now is forest.

  - Walking and running trails bisect the woods and are heavily used by the students and town's citizens.
- Biodiversity of the forest was affected by soil characteristics, past use, and current human impacts.

**Education 'about' the environment:**
To support their observational findings the students also read the history of the development from a large farm in the mid-1800s to the university that exists today. To triangulate the information, several people (ecologists, townspeople, and social scientists) talked about the development of this area. The students discovered that:
- The glaciers receded around from this area 10,000 years ago scraping away much of the topsoil.
- The colonists cleared most of the land in the 1700s for farming but as the more productive western lands opened up in the 1800s New Hampshire turned away from agriculture to industry.
- The man who donated his land to build the university was a farmer.
- The river that runs through the forest can not meet the demand for water by the townspeople so the town is building a canal from another river to this river to divert water to the reservoir.
- The town and university does not have plans to keep or maintain any natural areas, except 60 acres of College Woods set aside as a multi-use area, in its mission statement.

**Education 'for' the environment:**
The students started to understand that to maintain natural areas at a local scale within a community, understanding the appropriate scientific knowledge and applying the latest technology developments alone would not change the path of development. Their conclusion was that certain values needed to be in place along with the knowledge if wild areas were to be preserved (Snyder, 1990).
- People can make a difference. Because of many concerned citizens, including the students, the development in College Woods has been stopped for the moment.
- The students realised without a change of values by the university and town communities from growth to diverse natural and human communities (Berry, 1996) there will be continued pressure to develop College Woods
- The students summarised the information about College Woods and sent to the town administrators and the university planning committee.
- This example served as a springboard into explorations by the students into environmental issues in their own state or community. Groups of students spent the next two weeks on issues of their own choice.

## Conclusions

An issue-based model of environmental education that integrates "in", "about", and "for" the environment serves as a rich and appropriate curriculum in which students can learn and apply key concepts in science and explore the possibilities and the limitations of technology. In addition, students grapple with higher-order thinking skills such as problem solving and decision-making in the same contexts in which they will have to make decisions when they reach adulthood. In fact, the decision-making core of environmental education can provide potentially liberating feedback to help shape a science education which is more attractive to a diverse population of students and less elitist; more willing to engage in genuine action; and more capable of empowering young people as future citizens (Gough, 1999).

Through this case-based approach students became aware of a more comprehensive world of meaning. Trying to solve environmental problems awoken both a sense of grandeur about the world and a sense of responsibility in them (Hutchinson, 1998). That paradoxical nature of awe and the disposition to care set the foundation for solving problems. It also bought to bear the need to critically analyse the latest scientific information, to think of a variety of solutions and to discuss the development and application of appropriate technologies to solve problems now and in the future (Millar & Osborne, 1998). Applying science, technology, and values to environmental problems in the classroom and beyond might help us grow beyond the Australasia notion of humans as "the future eaters" (Flannery, 1994).

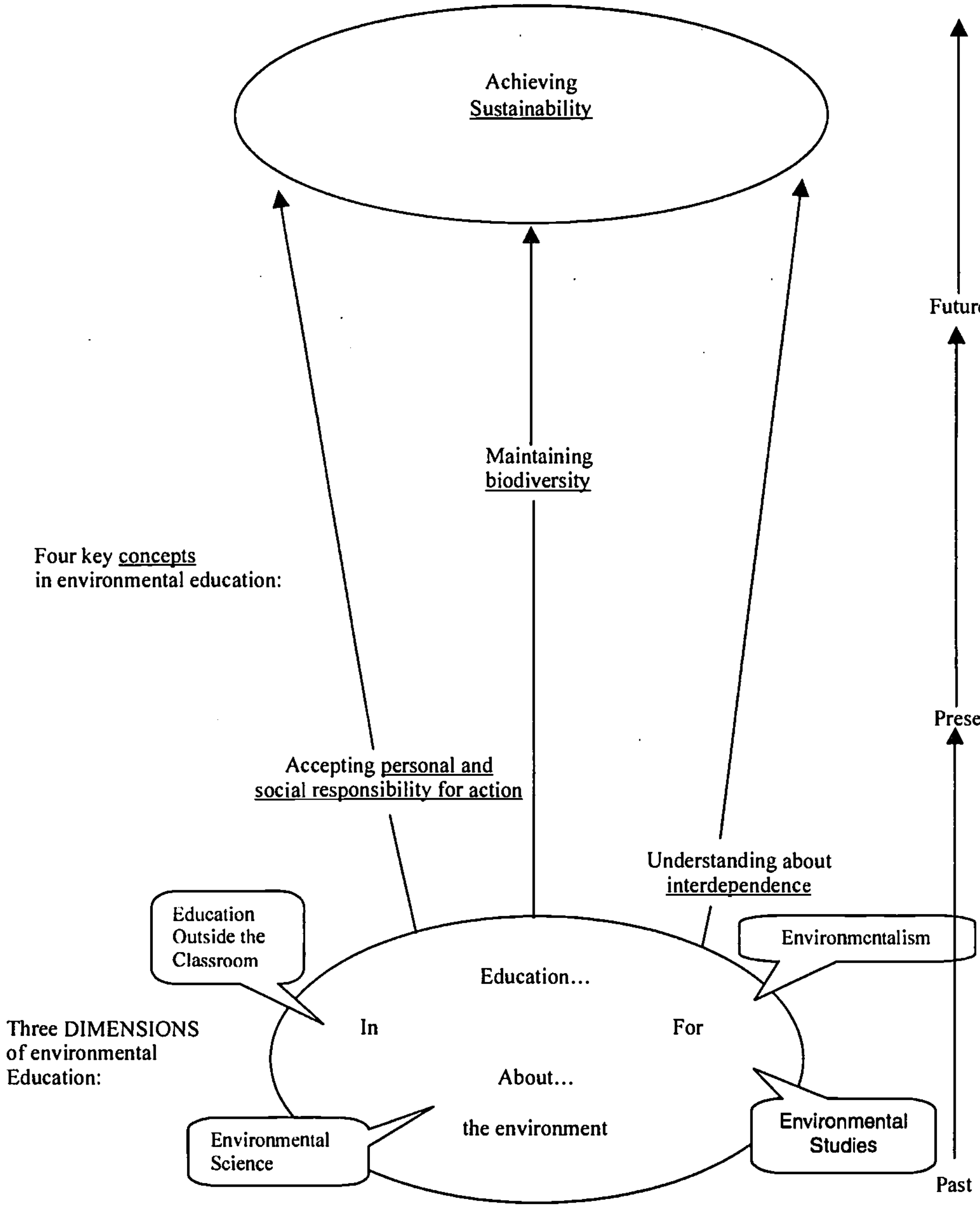


**Fig 1:** The framework suggested in this paper: Environmental education has three DIMENSIONS which operate together under the guidance of four key concepts with the aims of maintaining and improving the quality of the environment. This whole process of informed participation in decision-making is meaningful only in a time frame, but it can be conceived in any one of four contexts: school, local, national or global. An appropriate dimensional balance needs to be maintained: for example, teachers of science need to be wary that data gathering (environmental science) does not subsume the process at large.

## References

ABRAM, D. (1996). *The Spell of the Sensuous.* New York; Vintage Books.

BELLAMY, D., (1990). *Moa's Ark.* Auckland : Viking.

BERRY, W., (1996). Conserving Communities, In Vitek, W. & Jackson, W. (eds.) *Rooted in the Land*, Princeton; Yale University.

BOASE, M. R. (1985). The Flora and Vegetation of Jubilee Park (Claudelands Bush), Hamilton. Rotorua Botanical Society Newsletter No.4, April 1985: 10-19.

BROOKER, S. G., Cambie, R. C., & Cooper, R. C. (1981). *New Zealand Medicinal Plants*. Auckland : Heinemann.

CARSON, R., (1963). *Silent Spring*. London : Hamish Hamilton.

CORNELL, J., (1989). *Sharing the Joy of Nature*. Nevada City, CA : Sharing Nature Foundation.

DILLON, P., (1993). Technological education and the environment. *International Journal of Science Education*, 15(5): 575-589.

EDMOND, A. S., (1984). *The Waipa County Landscape: Vegetation and Wildlife*. Wellington : Queen Elizabeth National Trust.

ENVIRONMENT WAIKATO (2001). *Forest Fragment Management Series Factsheets 1-4*. Hamilton : Environment Waikato.

EVANS, B., (1982). *The Waipa County Landscape: An Introduction*. Wellington : Queen Elizabeth National Trust.

FIEN, J., Heck, D., & Ferreira, J. (1997). *Learning for a Sustainable Environment: A Professional Development Guide for Teacher Educators*. Bangkok : UNESCO Principal Regional Office for Asia and the Pacific.

FLANNERY, T., (1994). *The Future Eaters – an ecological history of the Australasian lands and people*. Chatswood, NSW : Reed Books

GOUGH, A., (1999). Science: an appropriate vehicle for environmental education? Proceedings of the 9th Symposium of the International Organisation for Science and Technology Education (IOSTE), Durban, June: 250-259.

GUDEX, M. C., (1955). The native flora of Claudelands Bush. *Transactions of the Royal Society of New Zealand*, 83(2): 313-319.

HAMILTON CITY COUNCIL (1993). Jubilee Park Management Plan, August 1993. Hamilton : Hamilton City Council.

HAMILTON CITY COUNCIL (2000a)*. Claudeland's Park Draft Management Plan, 28 February 2000. Hamilton : Hamilton City Council.

HAMILTON CITY COUNCIL (2000b)*. First Report on Submissions to the Claudelands Park Draft Management Plan, 2000. Hamilton : Hamilton City Council.

HAMILTON CITY COUNCIL (2001a)*. Second Report on Submissions to the Claudelands Park Draft Management Plan, January, 2001. Hamilton : Hamilton City Council.

HAMILTON CITY COUNCIL (2001b)*. Claudelands Park Operative Management Plan, February 2001. Hamilton : Hamilton City Council.

HUTCHINSON, D., (1998). *Growing Up Green: Education for ecological renewal*. New York; Teacher's College Press.

KAUFMAN, D., (1992). Confessions of a developer. In Sauer, P. (ed.) *Finding Home*, Boston: Beacon Press, 38-54.

LESLIE, C. W., (1999). Teaching nature journaling and observation. In Orion Society's Nature Literacy Series 3, Barrington, MA; The Orion Society, 35-58.

MacDONALD, M., (2001). Francis Bacon, 1561-1626. In Palmer, J. (ed.)* *Fifty Key Thinkers on the Environment*, London : Routledge, 38-43.

MARDON, H., & Jones, P., (1999). *Enviroschools Handbook – Agenda 21 in Action*. Hamilton : Hamilton City Council.

McCRAW, J. D., (1967). The surface features and soil pattern of the Hamilton basin. *Earth Science Journal*, 1(1): 59-74.

MILLAR, R., & Osborne, J., (1998). *Beyond 2000 – Science Education for the Future*. London : King's College London School of Education.

MINISTRY OF EDUCATION (1995). *Technology in the New Zealand Curriculum*. Wellington : Learning Media.

NICHOLAS, J.,, Oulton, C., & Scott, W., (1993). Teacher education for the environment: a comparative view from Australia and the UK. *International Journal of Science Education*, 15(5): 567-574.

NORRIS, H. C. M., (1963). *Armed Settlers*. Hamilton : Paul's Book Arcade.

O'DONOHUE, R., & McNaught, C., (1991). Environmental education: the development of a curriculum through 'grass-roots' reconstructive action. *International Journal of Science Education*, 13(4): 391-404.

ORBELL, M., (1996). *The Natural World of the Maori* (2nd ed.). Auckland : David Bateman.

OSBORNE, J., & Collins, S., (2000). Pupils' and parents' views of the school science curriculum. *School Science Review*, 82(298): 23-31.

PARK, G., (1995). *Ngaa Uruora – The Groves of Life*. Wellington : Victoria University Press.

RIORDIN, C., (2001). Johann Wolfgang von Goethe, 1749-1832. In Palmer, J. (ed.)* *Fifty Key Thinkers on the Environment*. London : Routledge, 63-69.

SMITH, K. (1987). Kahikatea – the feathers of tawhaitari. *Forest and Bird*, 18(2): 4-9.

SOONS, J. M., & Selby, M. J., (eds.) (1992). *Landforms of New Zealand* (2nd ed.). Auckland : Longman Paul.

STEPHENSON, G., (1986). *Wetlands – Discovering New Zealand's Shy Places*. Wellington : Government Printing Office.

SNYDER, G., (1990). *The Practice of the Wild*. New York; North Point Press.

TAYLOR, G., (2001). Marist to move to new park. *Waikato Times*, April 11th 2001.

VAN MATRE, S., (1990). *Earth Education: A New Beginning*. Greenville, WVA : Institute for Earth Education.

WATTS, M.T., (1957). *Reading the Landscape of America*. Rochester, New York; Nature Study Guild Publishers.

WESSELS, T., (1997). *Reading the Forested Landscape: A natural history of New England*, Woodstock, Vermont; The Countryman Press.

WESSELS, T., (1999). Reading the landscape's history, In *Into the Field: A guide to locally focused teaching*, Orion Nature Literacy Series Number 3, Barrington, MA; Orion Society, 59-81.

WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT (1987). *Our Common Future*. Oxford : Oxford University Press.

YENCKEN, D., Fien, J., & Sykes, H. (eds.) (2000). *Environment, Education and Society in the Asia-Pacific: Local Traditions and Global Discourses*. London : Routledge.

**Keywords:** Sustainability; science knowledge, skills and values; teaching practice; environmental decision-making; case studies.

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# AIDS AND REPRODUCTIVE HEALTH: AN ANALYSIS OF THE PRODUCTION OF EDUCATIONAL TECHNOLOGY

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**Abstract**

Grande parte das ações de Informação, Educação e Comunicação (IEC), centram-se na produção dos chamados materiais educativos, sendo um dos componentes primordiais das políticas de prevenção do HIV/Aids. Observa-se no âmbito das ações governamentais e não-governamentais a existência de um expressivo conjunto de materiais educativos (folhetos/*folders*, manuais, cartilhas, vídeos, etc. (MS, 1999). No entanto, com base em revisão bibliográfica constatou-se uma reduzida problematização do uso e da produção de tecnologia educacional no campo da saúde, sendo necessário um maior aprofundamento teórico capaz de dar suporte ao desenvolvimento e avaliação desses recursos. Este trabalho analisa a produção de materiais sobre DST/Aids e temas afins (década de 90), estabelecendo interfaces entre os campos da educação, saúde, comunicação e tecnologia educacional.

O levantamento da produção de materiais resultou no Banco de Materiais do LEAS (Biologia/IOC, Fiocruz) que reúne publicações diversificadas (livros, *folder*/folheto, manual e vídeos) editadas no âmbito governamental e não-governamental. Seu objetivo é oferecer aos profissionais da educação e saúde acesso a uma fonte de recursos e pesquisas, em geral dispersas, capaz de auxiliar o planejamento e reflexão de suas ações. O Banco visa também subsidiar o desenvolvimento e avaliação de tecnologias educacionais relacionados ao temas abordados. O desenvolvimento do Banco de Materiais foi norteado por duas fases: 1- Levantamento dos materiais existentes e organização do acervo (catalogação e indexação dos assuntos, temas e público alvo); 2- Ampliação do Banco através da incorporação de informações oriundas de outros acervos: Secretaria Municipal de Saúde/RJ, Centro de Documentação/ABIA, Catálogo Prisma (Núcleo de Estudos de Saúde do Adolescente/UERJ) e Odebrecht.

A análise dos dados do Banco indicou um total de 807 *folders*/folhetos cujos temas mais recorrentes foram Aids (41,0%), DSTs/Aids (23,3%), Saúde Reprodutiva (9,5%) e em termos de público alvo predominou: população geral (39,4%), adolescente (12,5%), mulher (12,0%). Quanto aos 334 manuais os temas prevalentes: Aids (40,1%), DST/Aids (15,9%) e Saúde Reprodutiva (11,7%), sendo estes dirigidos principalmente a profissional de saúde (21,3%), população geral (19,5%) e adolescente (15,9%). Os dados sobre temas e públicos alvos predominantes no Banco contribuem para a identificação das tendências da produção nesse campo. Permite ainda refletir sobre a existência de lacunas nas abordagens educativas preventivas, como a necessidade de ações de saúde mais integradas em relação à AIDS e saúde reprodutiva. Ademais indica a importância de se refletir sobre as definições da categoria público alvo, visando a análise das concepções de identidade sociocultural, sexual e de gênero, a ela associada.

## Introduction

One of the major characteristics of Brazilian policies designed to prevent HIV/AIDS has been their component of Information, Education and Communication (IEC). This component implies, among other things, the production of educational materials. A substantial expression of this is the widespread production of such materials as a part of the activities of governmental and non-governmental organizations and programs (MS, 1999). However, our bibliographical search revealed that only scant attention has been given so far to the use and production of educational technology for health programs. This indicates that there is a need for theoretical discussions to support the development and evaluation of these resources. This means that the scopes and the results of the use of these materials remain largely unknown, both by their producers and their users. According to the analysis made by the National Coordination of Sexually Transmitted Disease (STD)/AIDS, these materials are produced, distributed used and/or publicized without an organized and systematic monitoring, be it quantitative, be it qualitative.

This text proposes to contribute to the advancement of the reflections about educational technologies developed for health programs. It will do so by presenting a preliminary study about the productions found in the Educational Materials Collection of the Environmental and Health Education Laboratory (LEAS), linked to the Department of Biology of the Fundação Oswaldo Cruz (Rio de Janeiro, Brazil). It will present a partial overview of the production of materials about STD/AIDS and associated topics put out during the 1990s. We intend our analysis to establish interfaces between the fields of education, health, communication and educational technology.

## Universe of the investigation

The Educational Materials Collection assembled at LEAS results from an ample inventory of the Brazilian production of the so-called educational materials about HIV/AIDS, sexuality, reproductive health and the illegal use of drugs. It pulled together a large variety of publications (books, folders, leaflets, manuals, catalogues, videos, etc.) put out by governmental and non-governmental organizations. The Collection was conceived to support the development and evaluation of educational technologies related to those topics, besides aiding in the access of those resources. It helps professionals linked to education and health assistance to gain easy access to a wide variety of resources that are usually filed in different institutions, therefore supporting the efforts of all those engaged in conceiving and planning health programs.

The Collection is linked to several investigative programs undertaken by the team of researchers working at LEAS concerning the production and evaluation of educational technologies about STD/AIDS and related topics, and the formation of human resources. It allows the dissemination of scientific knowledge and supports continuing projects in environmental education and health. It is worth mentioning that the team of researchers at LEAS has experience in the production of educational games about the prevention of HIV/AIDS, the illegal use of drugs and scientific information (Rebello et al, 2001). These resources are based on critical evaluations of the dominant preventive models. They give high priority to interactivity, exchanges of ideas among participants, and reflections about the topics in debate. Therefore, they incite players to exchange ideas about the social, economic and symbolic dimensions of the phenomena in the scope of pedagogical practice. Besides producing these materials, LEAS researchers propose a methodology by which they should be created and have studied the effects of the use of these games (Schall et al, 1999; Vargas et al, 1999, Rebello et al, 2001).

In order to propose more effective preventive measures, LEAS also develops other complementary lines of research, such as: analyses of the theoretical foundations and of the repercussions of preventive policies, associated with the control of the HIV/AIDS epidemic and to sexual and reproductive health; development and dissemination of educational approaches linked to the topics of STD/AIDS, sexuality, gender relations, human rights and drugs; research about representations and practices of different social groups (based on a socio-historical approach and on qualitative methodologies).

Assembling the Collection is a more recent LEAS activity, of which this article is a part. As mentioned, the Collection pulls together educational resources produced about sexual and reproductive health by many governmental and non-governmental organizations (Monteiro et al, 2001). The technical treatment of these publications (to be described below) allows research about current materials and the formulation of guidelines for future policies in the area of IEC.

## Methodology

The process of developing the Educational Materials Collection at LEAS was divided into two phases. The first one was a search for published materials, in order to establish and organize the collection and allow its further expansion. The research team wrote letters to 45 Brazilian publishing houses and 49 Brazilian NGOs, besides a large number of government agencies involved in relevant programs. The second phase included the organization of an electronic data base and the technical treatment of all collected materials. The purpose was to set up an access system that would allow the quick retrieval of information and easy access to empirical data.

The construction of this data base required four procedures: (1) development of a form allowing detailed classification according to the following indicators: type of publication[1], target audience, topics and content; (2) filing of materials, based on the Filing Code adopted in libraries, known as AACR2; (3) indexation by subject, using a two-step method of pre-coordinated indexation[2] and post-coordinated indexation[3]; (4) the development of a subject index, a Controlled Vocabulary extracted from the publications themselves, allowing combinations for searches and the indexation of newly added materials. The technical treatment of the materials implies their thematic and descriptive analysis. The thematic analysis is defined by indexation (of major topics and target audiences) and by classification (according to the nature of the source – leaflet, folder, manual, book, periodical or thesis). The descriptive analysis includes a physical description of the materials (author, title, publisher, publication history, place, date and number of pages).

Following these two phases, the Collection was reviewed for the sake of attaining a uniform pattern of information that would allow the proper delimitation of searches and its adequate expansion. This time the goal was to incorporate information about the educational resources filed in other collections, such as Rio's Municipal Health Department, the Documentation Center of the Brazilian Interdisciplinary Association for the Study of Aids (ABIA, 1998), and the Prisma and Odebrecht catalogues (Barros et al, 1999; Odebrecht, 1994).

In this phase, general and specific topics were unified and the target audiences were adequately defined in order to allow the adoption of indicators (quantitative and qualitative). These procedures were preceded by the reading of all materials. The creation of these lists organized by topics and by target audiences demanded a level of detail that adequately described the content of all materials, as explained below.

**List of terms used for classification by TOPICS**

The methodology allowed the description of each publication according to three terms: a generic term, a specific term, and a further detailing of the specific term. This allows the inclusion of the largest possible number of pieces of information about each resource, as shown in Table 1:

[1] The following categories were used: books (more than 42 pages); leaflets (up to 42 pages); folders (folded paper); manuals; catalogues; videos; theses; booklets/periodicals and bulletins.

[2] The method for combining terms for the search is established previously.

[3] The method for combining terms is defined when the search is in progress.

**Table 1**

| Generic Term | Specific Term | Detailing of the Specific Term |
|---|---|---|
| **Column 1** | **Column 2** | **Column 3** |
| AIDS | Accidents | Abortion |
| Citizenship | Counseling | Adherence to Medication |
| Drugs | Breast feeding | Teenager |
| STD | Psychological Aspects | Community Agent |
| Education | Religious Aspects | Uterus |
| Youth | Economic Aspects | Community |
| Environment | Epidemiological Aspects | Child |
| Social Movements | Social Aspects | Physically Handicapped |
| Health | Harassment | Development of Materials |
| Reproductive Health | Clinical Assistance | Opportunistic Diseases |
| Sexuality | Bio-ethics | Physiological Effects |
| Tuberculosis | Cancer | Businesses |
| Violence | Basic Sciences | Schools |
| | Technological Development | Family |
| | Rights | Flux of Patients |
| | Discrimination | Armed Forces |
| | Domestic | Man |
| | History | Homosexual |
| | Nutrition | Hospital Infection |
| | Policies (directives) | Information |
| | Prevention | Street Children |
| | Rehabilitation | Hispano Leaders |
| | Information Systems | Work place |
| | | Breast |
| | | Maternity/Paternity |
| | | Birth control methods |
| | | Medication |
| | | Communications Media |
| | | Woman |
| | | Orphans |
| | | Male/Female Preservatives |
| | | Sex Professional |
| | | Prostate gland |
| | | Races |
| | | Blood |
| | | Solidarity |
| | | HIV positive |
| | | Training |
| | | Vaccine |

**List of terms used for the classification by TARGET AUDIENCES**

This classification is intended to characterize the different audiences towards which the messages and/or information conveyed by each educational material are directed. It was achieved with the help of categories usually found in the materials themselves, particularly those filed in the above-mentioned collections. In addition, there was a concern about the more precise definition of social groups according to their socio-cultural identities and to social contexts. Table 2 contains the categories that were adopted:

**Table 2**

| Stage of Life (1) | Population Groups (2) | Context of Application (3) |
|---|---|---|
| Adult | Black People | Businesses |
| Child | College Student | Community Action |
| Childhood and youth | Diabetic | Family |
| Man | Drug user | Formal Schooling |
| Senior citizen | Educational Professional | Health Services |
| Teenager | General Population | IEC in Health/Media |
| Woman | Health Professional | Informal Schooling |
| | Health worker | Religion |
| | Hemophiliac | Scientific Dissemination/Research |
| | HIV positive | |
| | Homosexual | |
| | Indigenous population | |
| | Inmates | |
| | Manager | |
| | Office worker | |
| | Orphans | |
| | Parents | |
| | Pharmacist | |
| | Pharmacy Owner | |
| | Physically Handicapped | |
| | Pregnant | |
| | Researcher | |
| | Sex Professional | |
| | Street People | |
| | Student | |
| | Teacher | |
| | Visually impaired | |
| | Worker | |

**Results**

In this text we focused on the classification of materials presented as folders/leaflets or manuals, according to the target audience indicators and the most important topics. We found a total of 807 folders/leaflets in which the most recurrent topics were AIDS (41.0%), STD/AIDS (23.3%) and Reproductive Health (9.5%). In these two types of materials, the most common target audiences were the general population (39.4%), teenagers (12.5%) and women (12.0%), as ascertained by the data in Tables 3.1 and 3.2.

**Table 3.1:** Classification of materials presented as folders/leaflets according to the Target Audience (Banco LEAS/Biologia/IOC).

| Target Audience | Number | % |
|---|---|---|
| Community Action | 1 | 0,1 |
| **Teenager** | **101** | **12,5** |
| Adult | 6 | 0,7 |
| Office worker | 1 | 0,1 |
| Child | 17 | 2,1 |
| Physically Handicapped | 3 | 0,4 |
| Diabetic | 1 | 0,1 |
| Businesses | 2 | 0,2 |
| Student | 2 | 0,2 |
| Pharmacist | 1 | 0,1 |
| Pregnant | 23 | 2,9 |
| Man | 25 | 3,1 |
| Homosexual | 21 | 2,6 |
| Childhood and youth | 9 | 1,1 |
| **Woman** | **97** | **12,0** |
| Parents | 6 | 0,7 |
| Researcher | 3 | 0,4 |
| Street People | 2 | 0,2 |
| **General Population** | **318** | **39,4** |
| Indigenous population | 1 | 0,1 |
| Black People | 1 | 0,1 |
| Educational Professional | 25 | 3,1 |
| Health Professional | 33 | 4,1 |
| Sex Professional | 4 | 0,5 |
| **HIV positive** | **63** | **7,8** |
| Worker | 8 | 1,0 |
| College Student | 5 | 0,6 |
| Drug user | 28 | 3,5 |
| Total | 807 | 100,0 |

Source: Educational Materials Collection at LEAS, 2001.

In relation to the 334 manuals contained in the Collection, the prevalent topics were: AIDS (40.1%), STD/AIDS (15.9%) and Reproductive Health (11.7%). These materials were directed mostly at health professionals (21.3 %), the general population (19.5%) and teenagers (15.9%). Other indicators, as can be seen from the data contained in Tables 4.1 and 4.2, were not quite strong:

**Table 3.2:** Classification of materials presented as folders/leaflets according to the Topics (Banco LEAS/Biologia/IOC).

| Topics | Number | % |
|---|---|---|
| **Aids** | **331** | **41,0** |
| Aids - Drugs | 11 | 1,4 |
| Aids - Social Movements | 1 | 0,1 |
| Aids - Prevention | 1 | 0,1 |
| Aids - Reproductive Health | 9 | 1,1 |
| Aids - Sexuality | 6 | 0,7 |
| Citizenship | 8 | 1,0 |
| **Drugs** | **42** | **5,2** |
| **STD** | **28** | **3,5** |
| DST - Reproductive Health | 2 | 0,2 |
| **STD/Aids** | **188** | **23,3** |
| STDD/Aids - Tuberculosis | 1 | 0,1 |
| Education | 1 | 0,1 |
| Education - Health | 10 | 1,2 |
| Education - Sexuality | 6 | 0,7 |
| Youth | 2 | 0,2 |
| Youth - Health | 2 | 0,2 |
| Environment | 2 | 0,2 |
| Social Movements | 5 | 0,6 |
| **Health** | **28** | **3,5** |
| Health - Citizenship | 1 | 0,1 |
| Health - Environment | 1 | 0,1 |
| **Reproductive Health** | **77** | **9,5** |
| Reproductive Health - Sexuality | 2 | 0,2 |
| **Sexuality** | **29** | **3,6** |
| Violence | 11 | 1,4 |
| Violence - Sexuality | 2 | 0,2 |
| Total | 807 | 100,0 |

Source: Educational Materials Collection at LEAS, 2001.

**Table 4.1:** Classification of materials presented as manuals according to the Target Audience (Banco LEAS/Biologia/IOC).

| Target Audience | Number | % |
|---|---|---|
| **Teenager** | **53** | **15,9** |
| Adult | 4 | 1,2 |
| Child | 13 | 3,9 |
| Student | 1 | 0,3 |

| | | |
|---|---|---|
| Family | 2 | 0,6 |
| Pregnant | 4 | 1,2 |
| Manager | 3 | 0,9 |
| Hemophiliac | 2 | 0,6 |
| Man | 1 | 0,3 |
| Homosexual | 5 | 1,5 |
| Childhood and youth | 8 | 2,4 |
| **Woman** | **26** | **7,8** |
| Parents | 4 | 1,2 |
| Street People | 1 | 0,3 |
| **General People** | **65** | **19,5** |
| **Education Professional** | **32** | **9,6** |
| **Health Professional** | **72** | **21,6** |
| Sex Professional | 2 | 0,6 |
| **HIV positive** | **28** | **8,4** |
| Worker | 3 | 0,9 |
| Drugs user | 5 | 1,5 |
| Total | 334 | 100,0 |

Source: Banco de Materiais Educativos do LEAS, 2001.

**Table 4.2:** Classification of materials presented as manuals according to the Topics (Banco LEAS/Biologia/IOC).

| Topics | Number | % |
|---|---|---|
| **Aids** | **134** | **40,1** |
| Aids - Social Movements | 2 | 0,6 |
| Citizenship | 7 | 2,1 |
| Drugs | 17 | 5,1 |
| STD | 20 | 6,0 |
| **STD/Aids** | **53** | **15,9** |
| Education | 3 | 0,9 |
| Education - Health | 13 | 3,9 |
| Education - Sexuality | 6 | 1,8 |
| Youth | 1 | 0,3 |
| Health | 12 | 3,6 |
| **Reproductive Health** | **39** | **11,7** |
| Sexuality | 18 | 5,4 |
| Health Reproductive - Sexuality | 5 | 1,5 |
| Violence | 1 | 0,3 |
| Violence Domestic | 3 | 0,9 |
| Total | 334 | 100,0 |

Source: Banco de Materiais Educativos do LEAS, 2001.

These data about the most important topics and target audiences help pinpoint trends in the production of these materials. They also allow us to think about the occurrence of voids in preventive education approaches, such as the need to better integrate concerns about AIDS and reproductive health with health policies and actions. Furthermore, they indicate the importance of defining target audiences, taking into account the analysis of the associated concepts of socio-cultural, sexual and gender identities.

Despite the limitations of the data presented here, our findings converge with the arguments made by Camargo Jr. (1999) about the problems inherent to the production and use of educational materials in the field of health. One of his points is that there are many redundant productions, such as different leaflets that deal with the same matters, because of the lack of research in this field.

Our preliminary results about the contents of the LEAS Collection also converge with those of a previous investigation about the use of "educational technology" applied to health programs, particularly those seeking the prevention of HIV/AIDS. This investigation was based on a bibliographical review about the topic (Monteiro et al 2001). It sought to ask several questions about the so-called educational materials related to STD/AIDS and associated topics and to pinpoint possible interfaces between the use of these materials (to support pedagogical actions in health) and the fields of educational technology, education and information. A related goal was to identify initiatives and voids in this type of production. The search was focused on the data bases available at BIREME (Medline and LILACS) and at the libraries of ENSP/FIOCRUZ and ECO/UFRJ, besides papers presented in several conferences.[4] Publications filed in the LEAS Collection were used as a complement. Other materials were obtained through personal contacts with researchers of the Nucleus for the Study of Educational Technology for Health (NUTES/CCS/UFRJ) and from NESA/UERJ. Specifically in relation to the conference papers, the results indicated that the most intensively targeted segment of the public was that of teenagers, followed by the general population, health and educational professionals, and women. Lesser targeted audiences were health agents, cultural agents, juvenile offenders, pregnant women, children and travesties.

It is worth mentioning that the argument about the scarcity of preventive materials that take into account the specificity of a studied population or group was recurrent. However, this argument was not adequately supported by data, on account of the lack of a theoretical-methodological basis and of previous literature searches. Furthermore, there is no explicit statement about the definition of the "specificity of the population or group". There is no conceptual discussion about this topic. This same study revealed that there was a predictable recurrence of the topic of STD/HIV/AIDS and the presence of related topics such as sexuality, sexual health, and reproductive health. With lower incidence, the topics of gender, health, violence, drugs, religion and death were recorded.

Although Barros et al (1999) concluded that there is a lack of integration of certain contents in the approaches recorded in these materials, such a breadth of subjects can actually be considered positive trait, because of the importance given to the interfaces between the several components that determine the conditions of vulnerability to HIV/AIDS. Indeed, the current diversity of situations recorded in the process of expansion of the HIV/AIDS epidemic begs for the design of more complex preventive models.

## Final considerations

If we take into account the significant investments made in IEC actions, we can conclude that the analyses about the quality and impact of these productions remain spotty.[5] However, when we examine the annals of recent

[4] The following annals were searched: Congresso Brasileiro de Prevenção das DST/AIDS (1997, 1999); II Congresso Brasileiro de Ciências Sociais em Saúde (1999); VI Congresso Brasileiro de Saúde Coletiva (2000), I Fórum e II Conferência de Cooperação Técnica Horizontal da América Latina e do Caribe em HIV/Aids e DST (2000); VII Encontro "Perspectivas do Ensino de Biologia"(2000).

[5] In his study about AIDS, prevention and evaluation, Araújo (2000) concludes that the references to educational materials are infrequent, while references to topics such as education and evaluation are frequent.

conferences, there are many summaries of papers presented about this matter. We should also point out that this matter is deserving increasing attention, as attested by the inclusion of the topic "Educational Materials" in the Annals of of the III Brazilian Conference on the Prevention of STDs/AIDS. It still remains to be determined, however, if and how these papers have contributed to the discussions about the use of educational technologies applied to health programs. In this context, this analysis of the LEAS Collection, even though preliminary, is a contribution to the enhancement of the visibility of the categories, topics and target audiences of Brazilian publications on sexual and reproductive health put out during the 1990s. We argue that evaluations such as this one allow the identification of the predominant topics, pinpoint the existence of voids in the approaches of preventive education, besides contributing to the discussions about the need for an integrated approach of health actions in relation to prevention/assistance and AIDS/reproductive health.

## References

ARAÚJO, C. L. F. (2000). *Avaliação das Ações de Prevenção em DST/AIDS no Brasil: Um Levantamento Bibliográfico*. Rio de Janeiro: ABIA, Coleção ABIA - Fundamentos de Avaliação, nº 3. (mimeo).

ASSOCIAÇÃO BRASILEIRA INTERDISCIPLINAR DE AIDS (1998). *Catálogo de Organizações Comunitárias com Centros de Documentações*. Rio de Janeiro: ABIA.

BARROS , C. R. P.; MATHIAS, C. R. J. C.; CATRO, D. M. F.; OLIVEIRA, F. R. R. M.; GONÇALVES, F. N.; MESSIAS, J. A. S.; COROMACK, L. M. F.; MEIRELLES, Z. V. (1999). *Catálogo Projeto Prisma - Região Sudeste*. Rio de Janeiro: Núcleo de Estudos de Saúde do Adolescente (NESA/UERJ).

CAMARGO JR.. K. R. (1999). Políticas públicas e prevenção em HIV/AIDS. In: *Saúde, desenvolvimento e política: respostas frente à AIDS no Brasil* (R. PARKER & J. GALVÃO & M. BRESSON, Orgs) pp. 227-262. São Paulo: Ed. 34.

MINISTÉRIO DA SAÚDE (1999). *A Resposta Brasileira ao HIV/Aids – Experiências Exemplares*. Brasília: Coordenação Nacional de DST/Aids.

MONTEIRO, S; VARGAS, E. & CRUZ, M. (2001). Educação, Comunicação e Tecnologia Educacional: aproximações com campo da saúde. **24 Reunião da ANPED** (Associação Nacional de Pós Graduação e Pesquisa em Educação (GT Educação e Comunicação). Caxambu, RJ, outubro.

ODEBRECHT, Fundação Emílio. (1994). *Inventários de Materiais Educativos sobre Saúde Reprodutiva e Educação Sexual para Adolescentes*. Bahia.

REBELLO, S.; MONTEIRO, S. & VARGAS, E. (2001). A visão de escolares sobre drogas no uso de um jogo educativo. *Interface - Comunicação, Saúde e Educação*. Vol 5, nº 8.

SCHALL, V. T.; MONTEIRO, S.; REBELLO, S. & TORRES, M. (1999). *Evaluation of the ZIG-ZAIDS Game: An Entertaining Educational Tool for HIV/AIDS Prevention*. Cadernos de Saúde Pública, 15 (Sup.2):107-119.

VARGAS, E. REBELLO, S. & MONTEIRO. (1999). Aids e drogas: avaliando alternativas de prevenção. *Revista de Atenção Primária a Saúde* (NATES/UFJF). Nº 4 Nov/99 - fev/2000:17-19

**Key Words:** Education, Education Technology, Aids, Reproductive Health, Prevention

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# INTERDISCIPLINARY EDUCATION: RESEARCH ON PROFESSIONAL COMPETENCE OF IN-SERVICE SCIENCE SUBJECT TEACHERS

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**Abstract**

The paper presents the results of research on the professional competence of science teachers in elementary school as well as biology and chemistry teachers in junior high school in the area of the integration of science contents in an interdisciplinary character. 90 teachers participated in the research. The results of the studies were taken into consideration in the preparation and modification of postgraduate studies curriculum for science subject teachers organized by Maria Curie-Sklodowska University in Lublin. Also presented is a model of science teachers training which focuses on shaping their interdisciplinary skills. This is in connection with the organization of the educational process involving the problem of so-called science cross-curricular paths, which is a new educational form introduced into Polish schools in 1999. This curriculum was rewarded three times and supported by the Ministry of National Education (in the form of grants).

## Background and Framework

One of the important and necessary elements of contemporary school is integrated, interdisciplinary teaching. Its main advantages are its effects on constructing a coherent vision of the world in students' minds. This favors improvement of so-called universal skills in students, which helps them to be better prepared for life. It integrates school with the local environment which, in turn, helps to meet students' educational needs (Driver et al. 1985, Hillock 1990).

Lately the problem of interdisciplinary education has become the priority in Polish education. In elementary schools, the subject teaching of science courses (i.e. biology, chemistry, geography and physics) has been given up. Instead, one subject-science has been introduced which is taught mainly by former teachers of biology or geography, but seldom physics or chemistry. Moreover, new forms of education, so-called "educational cross-curricular paths", were introduced into the curricula of elementary and junior high schools (and in the future will also be introduced into senior high schools). At every level of education there are three paths of science character: ecological, regional, and health. The curriculum of "educational cross-curricular paths" involves the contents, which cannot be included only in one subject. They should be dealt with mainly (but not only) by teachers of individual science subjects. The above changes in the educational system made it necessary to reconsider the professional profile of contemporary science education teachers, to determine their needs for professional qualification improvement. It also made it necessary to prepare training forms to enable their passing from narrow subject specialization to broader interdisciplinary arrangements. Comprehensive understanding of the world will be a problem for students as long as teachers have difficulties with it (Malcolm 1992). The greatest need for training exists in the case of science teachers who constitute the largest group of postgraduate students, course and interdisciplinary workshop participants in Poland. However, a regular increase is found in the number of teachers of other science subjects undertaking professional training. Training programs for teachers include not only subject courses, but also the forms aiming at improving teachers' competence in solving problems connected with planning and organizing interdisciplinary activities as well as improving their skills for collaborating with teachers of different school subjects within so called cross-curricular teachers' group.

## Problems, Method and Samples

Are science subject teachers sufficiently competent and well prepared to accomplish interdisciplinary problems at school? Preliminary and general data bearing on the above question were provided by the results of a questionnaire given to science teachers in elementary school (30 persons) as well as biology teachers (30 persons) and chemistry teachers (30 persons) in junior high school. The sample of teachers for investigation was selected randomly by drawing lots in the individual groups of science, biology and chemistry teachers who were postgraduate students in science, biology and chemistry at the Maria Curie-Sklodowska University in 2000/2001.

The study focused on the following problems:

- What is the teachers' evaluation of their own competence necessary for effective teaching the problems of cross-curricular, interdisciplinary character?
- What aim-achieving procedures (i.e. methods and teaching aids) are preferred and how do they use the local environment in teaching these problems?

The questionnaire used in the studies included six categorized questions. In the first three questions the teachers were asked to rate on a scale from 1 (the lowest grade) to 5 (the highest grade) their preparation for the integration of the teaching contents of interdisciplinary character (first question), their choice of teaching methods (second question) and their teaching aids (third question) in the course of dealing with these problems during the lessons. The fourth question listed fourteen methods used during the lesson and the fifth one fourteen teaching aids. The respondents were asked to underline five methods and five kinds of teaching aids that they most frequently applied during lessons dealing with problems of interdisciplinary character. In the sixth question the teachers were asked to provide information about how often they make use of the local environment potential in science education: very often, often, seldom, occasionally, or never. Research tools were verified with respect to their applicability in the group of 90 science teachers from another university (postgraduate students).

## Results

The results of the teachers' self-evaluations concerning their competence to effectively teach science contents of an interdisciplinary character are presented in Table 1. Science and chemistry teachers evaluate highly their abilities in the area of science education contents integration. The predominant grades (or scores) given by these teachers are 4 and 5, which constitute 90% for science teachers and 83.3% for chemistry teachers. The grade of 3 was the evaluation of only a small group, and this was the lowest grade given by the teachers of these two subjects. The grades that biology teachers gave are much more variable. No fewer than 46.7 % are grades below 4. Similar results were obtained as far as abilities of teaching methods choices are concerned. A third of the biology teachers gave very low evaluations of their competence (1 and 2) whereas 10% of chemistry teachers and only 3.3% of science teachers are of similar opinion about their being professional. Grades at the levels of "very good" and "good" constitute over 80% in the group of biologists and not much less in the group of chemists. All science teachers (100%) are convinced about their abilities concerning the effective use of teaching aids in the process of teaching interdisciplinary problems (they gave grades of only 4 and 5). Positive evaluations ware also given by chemistry teachers; only 16.7% of them evaluated that their abilities were at the grade of 3 (the lowest grade in this group of teachers).

| Competence / Self-evaluation : grades 1-5 | | Skills of integrating contents from various fields of science subject | Skills of choosing and making use of effective teaching methods | Skills of choosing and making use of teaching aids |
|---|---|---|---|---|
| Teachers of science (%) | 1 | 0.0 | 0.0 | 0.0 |
| | 2 | 0.0 | 3.3 | 0.0 |
| | 3 | 10.0 | 13.4 | 0.0 |
| | 4 | 60.0 | 63.3 | 56.7 |
| | 5 | 30.0 | 20.0 | 43.3 |
| Teachers of biology (%) | 1 | 13.3 | 20.0 | 6.7 |
| | 2 | 16.7 | 13.3 | 6.7 |
| | 3 | 16.7 | 36.7 | 20.0 |
| | 4 | 43.3 | 20.0 | 40.0 |
| | 5 | 10.0 | 10.0 | 26.7 |
| Teachers of chemistry (%) | 1 | 0.0 | 3.3 | 0.0 |
| | 2 | 0.0 | 6.7 | 0.0 |
| | 3 | 16.7 | 13.4 | 16.7 |
| | 4 | 40.0 | 53.3 | 60.0 |
| | 5 | 43.3 | 23.3 | 23.3 |

**Table 1.** Level of professional competence of teachers: self – evaluation

Again biology teachers gave the lowest grades. Table 2 lists the five teaching methods and the five teaching aids most highly favored by the teachers taking part in the questionnaire concerning interdisciplinary education of science subjects. The results indicate great differences among the groups of teachers compared.

| | Teaching method | Teachers % | Kind of teaching aids | Teachers % |
|---|---|---|---|---|
| Teachers of science | Student's paper | 63. 3 | Specimens | 53. 3 |
| | Description | 60. 0 | Large-scale illustrations | 50. 0 |
| | Work with the book | 53. 3 | TV broadcast | 43. 3 |
| | Lecture | 53. 3 | Photographs and pictures | 40. 0 |
| | Discussion | 43. 3 | Films and transparencies | 40. 0 each |
| Teachers of biology | Discussion | 66. 7 | Specimens | 76. 7 |
| | Lecture | 63. 4 | Transparences | 40. 0 |
| | Project | 60. 0 | Films | 36. 7 |
| | Seminar | 53. 3 | Experimental sets | 36. 7 |
| | Experiment | 53. 3 | Large-scale illustrations | 33. 3 |
| Teachers of chemistry | Lecture | 43. 3 | Photographs and pictures | 60. 0 |
| | Student's paper | 43. 3 | Models | 46. 7 |
| | Project | 40. 0 | Reading matter and journals | 46. 7 |
| | Case study | 40. 0 | Large-scale illustrations | 43. 3 |
| | Chatty lecture | 40. 0 | Transparencies, specimens and TV and TV broadcast | 36. 7 each |

**Table 2.** Teaching methods and teaching aids favored by teachers.

The method included in the group of five methods most frequently used is the "lecture". The "lecture" method is most frequently used by biology teachers (63.4%) and most rarely by chemistry teachers (43.3%). As for science teachers every second teacher being polled prefers it. Chemistry teachers proved to be the most variable group with regard to the choice of methods (none obtained 50%). Of five methods preferred by them each is recognized in a similar way (40% - 43.3%). Only in the group of chemistry teachers did such methods as "case study", "project" and "chatty lecture" appear in the lists of the top most used five methods. As for science teachers, the differences between the most popular method (student's paper) and that in the fifth position (discussion) is 20% and in the group of biology teachers 13.4% (discussion 66.7%, seminar and experiment 53.3% each). The "project" method is as valued among biology teachers as the description method is among science teachers (60% each). Preferences for seminar and experiment in the group of biology teachers are the same as for work with the book and lecture chosen by science teachers (53.3% each). "Discussion" was chosen by biology teachers (in the first position) and by science teachers (the most rare of the five methods listed in the table). The former group used it during the lessons (23.4% of teachers). A similar difference in preferences refers to the method – "student's paper" which is in the first position in the group of science teachers (it was chosen by 63.3% of teachers) but in the chemistry group it was recognized by a 20% smaller group (43.3% of teachers).

Though "specimens" is found in the first position among teaching aids chosen by science and biology teachers, the latter are by 23.4% more than the former (chemists- 36.7%). Of similar importance for the former are "large-scale illustrations" mentioned by half of them. "Photographs and figures" essential in teaching chemistry (60%) are accepted by 20% smaller group of science teachers. The same number of chemistry teachers uses "models" as well as "reading matter and journals" and only by 3.4% smaller group appreciates educational value of large-scale illustrations (all in the range 40-50%). "Large-scale illustrations" are among the five educational aids preferred by the respondents in the three groups but the most numerous group are science teachers (50%), then chemistry teachers (43.3%) and biology teachers (33.3%). The largest number of teaching aids is that chosen by 40-50% teachers. "Transparences" are approved by almost the same number of respondents in each group. A similar relation concerns the "films" chosen by biology and science teachers (36.7% and 40%, respectively). "Experimental sets" are found among the five mostly frequently used aids only in the group of biology teachers (36.7% but 16.6% more people reported "experiment" as the teaching method).

Educational possibilities of the local environment are also used to a different extent during realization of interdisciplinary contents of education (Table 3), the most frequently by science teachers, less frequently by biology teachers and the least frequently by chemistry teachers.

| Frequency | Very often | Often | Rarely | Occasionally | Never |
|---|---|---|---|---|---|
| Teachers of science (%) | 3.3 | 50.0 | 33.3 | 6.7 | 6.7 |
| Teachers of biology (%) | 6.7 | 23.3 | 50.0 | 13.3 | 6.7 |
| Teachers of chemistry (%) | 3.3 | 16.7 | 16.7 | 13.7 | 50.0 |

**Table 3.** Making use of local environment in the process of science knowledge integration by teachers

## Conclusion

Much greater range studies are necessary to determine competence of teachers for realization of interdisciplinary contents during lessons. The presented studies provide preliminary but essential information about self-evaluation and competence as well as methods used by science, biology and chemistry teachers. The obtained data were used for establishing further scientific research in this field and for preparation research tools for the successive stage using the method of observation. The direct observation of the teachers during teaching process will provide detailed data about frequency of applying definite methods and teaching aids which will make it possible to determine correctness of their choice and application by teachers in work with pupils and to draw suitable conclusions. The studies were carried out in the school year 2002/2003 and their results will be used for modernization of postgraduate studies curricula whose aim is improvement of competence of science subject teachers.

The model of forming teaching skills of science teachers in integration of science knowledge taught in the studies of this type at M.Curie-Sklodowska University is given below. The curriculum of the postgraduate studies was awarded and supported by Ministry of National Education (Samonek-Miciuk 2000).

### Science Knowledge Integration: A Model of In-Service Science-Teachers Training

Teachers get familiar with the problems of science knowledge integration and improve their professional skills during realization of the tasks included in the successive stages of the educational process.

1. Familiarizing the teachers with science education models (i.e. interdisciplinary and multidisciplinary models); drawing attention to the interdisciplinary character of science contents included in science curricula and handbooks (Deren 1999).

*Educational tasks:* analysis of curriculum contents, establishing interdisciplinary problems, working out the three-dimensional model of teaching contents and taking into account the connections between educational aims, contents of teaching material and requirements from pupils.

The work of teachers include such notions as water, energy, weather and substances in everyday life etc. The contents are analyzed with respect to the possible realization of accepted aims, consistency, arrangement, attractiveness for the pupils, maintaining the rule from the concrete to the abstract idea as well as the possibility of forming key skills like planning, organizing and estimating learning; effective communication in different situations; effective collaboration in the group and problem solving in a creative way (arranging activities and favorable situations for their formation). Teachers prepare substantial commentaries including lists of problems and skills connected with introducing a given curriculum notion as well as methodical commentaries including suggestions for methods, forms of work and teaching aids. Based on this, the optimal educational style is worked out.

2. Integration of science contents within the "cross-curricular paths": ecological path, health path.
   A. Getting acquainted with the rules of constructing educational "cross-curricular paths" (Deren 1999).

*Educational tasks*: discussion of examples of science knowledge integration focused on structure-creating problems, concepts as well as skills, assigning objectives, contents and tasks connecting the integrated subject "science" with educational tracks.

   B. Method of the project and its role in the cross-curricular integration.

*Educational tasks:* preparation of the educational project for realization within the "cross-curricular path" including a list of teaching contents and formed skills, instructions for the project realization with suggestions about educational solutions, and tasks for pupils, as well as ways of project presentation and evaluation.

3. Field activities and integration of science problems
   A. Discussion of educational qualities and methods of field activities carried out in the closest school surrounding, local environment and in the areas of special natural quality region
   B. Determination of the educational possibilities of the local environment in the background of region in the field of general natural and ecological education:
   - making use of methodical works including, for example, a series of methodical publications "green lessons at school and in the nursery schools" prepared in the Department of Biology Education M. Curie-Sklodowska University
   - educational tracks in the region for school youths
   - curricula and methodical books for ecological education in the field (Samonek-Miciuk, Gajus-Lankamer 1998, Samonek-Miciuk 1999)

*Educational tasks:* review of methodical literature

   A. Participation by students in the field activities at the Bystrzyca River and in the Botanical Garden M.C.S. University (substantial and methodical character of activities)

*Educational tasks:* natural observations; planning the ways for realization of various natural problems included in the curriculum base; working out the plan of field activities in natural education including a list of trained pupils' competencies, styles of educational work, kinds of activities and tasks for pupils, teaching aids, project of work card as well suggested ways for evaluation of educational effects

   B. Participation of teachers in the field biological-geographical activities in Natural Roztocze Park and Kazimierz Landscape Park

These activities are of substantial character. They supplement natural knowledge and help demonstrate connections and natural relations between phenomena and processes in the environment (i.e. a holistic vision of nature).

The presented model of professional training of science teachers contributes to the formation and improvement of their competence in the field (Samonek-Miciuk 2001):

- planning and designing observational tasks, natural experiments and measurements to be used in the field activities
- preparation of science education curricula in an interdisciplinary formulation
- determination of objectives for natural and environmental-contents teaching
- selection of curriculum contents possible for realization during field activities and a list of tasks connected with teachers' and pupils' preparation for these types of activities
- designing work cards for pupils
- making use of methodical publications as well as planning one's own suggestions for educational tracks in the local environment and closest school surroundings.
- planning and organizing activities for pupils in the field of environmental protection

**References**

DEREN, A., (1999). *New School Program. Cross-curricular integration.* Warsaw: Teachers Training Center

DRIVER, R., GUESNE,E.,&TIBERGHIEN,A.(1985). *Children's Ideas in Science.* Philadelphia, PA: Open University Press

HALLACK, J. (1990). *Investing in the Future: Setting Educational Priorities in the Developing World.* Paris, UNESCO-IIEP

MALCOLM, C. (1992). *Science Teaching and Technology: A Curriculum Planning and Professional Development Guide.* Carlton, Victoria: Curriculum Corporation

SAMONEK-MICIUK, E., & GAJUS-LANKAMER, E., (1998). *To Understand Environment. Teachers Training Book.* Lublin: Foundation for the Protection of Nature

SAMONEK-MICIUK, E., (1999). *Environmental education. Teachers training book.* Lublin: Foundation for the Protection of Nature

SAMONEK-MICIUK, E., (2000). Interdisciplinary Education of Natural Science Teachers. In D. Cichy (ed.), *Science Teacher in XXI century*, Warsaw: Institute of Educational Research

SAMONEK-MICIUK, E., (2001). Improvement of Educational Skills in the Science Knowledge Integration of Science Teachers during Postgraduate Studies. In *Interdisciplinary Education in Science.*Tempus Project Seminar, Krakov: University Press

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# A CONTEXTUALIST MODEL OF PEDAGOGY FOR PHYSICS TEACHING - A CASE STUDY

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**Abstract**

The study reported here is part of a major project with the aim to investigate the interplay of pedagogical and science related issues in teachers' reconstructions and interpretations of physics classroom activities. This paper reports on one of the most interesting case studies of the project. Data collection, analysis and interpretations of this study have been carried out within an interpretative constructivist approach - a naturalistic approach (Lincoln & Guba, 1985).

This paper describes a case study of a second-year middle school physics teacher's[1] conceptions about: (a) learning and teaching science (physics), (b) the goals of science (physics) teaching, and (c) the nature of science (physics). It was found that this teacher's *model of pedagogy* (Zimmermann, 2000) for physics teaching is structured by the interaction of a kuhnian model of the nature of science (Zylbersztjn 1991) and a constructivist model of learning (Duit, 1994). The Framework of Koulaidis and Ogborn (1988) was used to investigate his model of the nature of science while Zimmermann's (1997) framework was used to examine his model of how children learn science.

Data analysis shows how this teacher has developed his pedagogical content knowledge (Shulman, 1987) and how he has accommodated this knowledge within the school's constraints. It is suggested that, usually, reflections on the structure of the discipline are not part of a teacher's planning and do not influence a teacher's instruction. However, this teacher, explicitly or implicitly, plans and makes decisions considering the nature of science. The contextualist model of science (Zimmermann, 1997) of the teacher parallels his knowledge of how learning takes place, and his awareness of how to think about teaching.

Considering the professional development of this teacher, this study suggests that reflection about learning and teaching as well as considering the nature of the subject, would be a precondition for pedagogical reorientation.

## Introduction

> What do teachers need to know?
> Where do teachers' explanations come from? How do teachers decide what to teach, how to represent it, how to question students about it, and how to deal with problems of misunderstanding? (Shulman, 1986)

Questions, such as the above, have started a research agenda that examines teachers' work in order to identify and characterise "a knowledge base for teaching" (Shulman 1986). On that account, in-depth case studies have been carried out to provide an overview of "the *sources* of that knowledge base" and "to explore the processes of pedagogical reasoning and action within which such teacher knowledge is used" (Shulman, 1987, p.5). Zimmermann (2000), after analysing a range of such case studies, suggests that a teacher sticks to a model of pedagogy which is structured by at least three interacting models: a model of science (an 'epistemological model' - what exists and can be known); a model of learning (how it can be known); and a model of teaching (how it can be made known). It means that a particular approach to teaching science not only depends on the

[1] Fernando, is a fictional name of the subject of this case study. This change was made to protect his anonymity.

teachers' understanding of how children learn science, but also on their understanding of how scientific knowledge is generated. Different epistemological models generate different views of the learning process, which in turn yield different approaches to teaching (Swift, 1982). Thus, there is a relationship between teachers' models of the nature of science and their models of learning.

Research shows a range of teacher's models of the nature of science. Much of this research has suggested that teachers' own models of science influence and shape their teaching (Brickhouse, 1991). However, Koulaidis and Ogborn (1995), in a review of the body of research on science teachers' views about the nature of science, criticise the conceptual foundations of such studies. They argue for the need to make explicit the philosophical position employed to elicit science teachers' models of science. The authors further suggest that the explicit positions adopted by teachers include an inductivist, a hypothetico-deductivist, a contextualist, and a relativist model of science. In earlier work, Koulaidis and Ogborn (1988) proposed that the distinctions delineating each model should be based upon "the issues of unity of scientific method, criteria of demarcation, patterns of scientific change and status of scientific knowledge" (p. 497). Finally, they advise that one must be aware that there is not necessarily a clear relationship between teachers' models of science and their classroom practice.

**Models of Science in the Philosophy of Science – the Koulaidis & Ogborn framework**

Conducting research concerning teachers' models of science seems to imply that there is an accepted model, which is to be compared with teachers' models. This is not the case, for even among philosophers of science there is no consensus about the nature of science, a range of different models of science being adopted. Contemporary philosophers of science have been inclined to emphasise the variety of scientific practices in use. This, far from producing a consensus, has enlarged our views of the nature of science. The work of Koulaidis and Ogborn (1988, 1995) has delineated the major philosophical models of science. It is enough, for the purposes of this paper, to outline these models in the way suggested by them. It should be realised that, in the attempt to dismember the main models of philosophical thought into dimensions (see table 1), a distortion of these positions has probably taken place. However, this is a way of helping one to recognise the main characteristics of each stream.

According to an *inductivist model* (see table 1), scientific activity follows a rigorous stepwise sequence that starts with observation. Scientists formulate their theories from particular facts, recognising regularities in them, and so inducing general laws from those observed regularities. Later sets of observations contribute to the corroboration of these laws. The criteria of demarcation between science and non-science are related to the truth of scientific theories. Scientific knowledge is an accumulated body of proven knowledge and thus is the truth about the behaviour of nature. Science gives us an objective account of nature in which opinions and speculations have no place.

By contrast, the *hypothetico-deductivist* (table 1) model denies that science starts with observation and proposes that it starts at the point of the problem. Unlike the inductivist, the hypothetico-deductivist scientist always makes observations within the context of the language of some theory. For him/her, observations are fallible, as are the theories behind them. Theories are constructed as speculative and tentative - they are guesses. Theories that fail to predict observation and experiments are falsified and so are replaced by new conjectures (theories). Thus, scientific method starts with theories that guide observations and experiments, which may in turn falsify the theory. The better the theory the more open to falsification it is. In other words, the hypothetico-deductivist scientist sees science as a set of tentatively proposed hypotheses that must be open to falsification. For such a person, science is a rational activity that aims to bring knowledge nearer to the truth. Science is an objective account of nature and progresses by trial and error.

There are two established models for a *contextualist* scientist to choose between, both drawn from Kuhn's work. Within the first, there are many methods that are agreed upon within the scientific community (i.e. a consensus exists). The criterion for demarcation between science and non-science is said to be rational. The main characteristic of this model is the view of scientific progress. Such contextualists assert that, over a period of time, there is a steady growth of mutually compatible knowledge (normal science) interspersed by periods of incompatibility (revolutionary science). The second contextualist model maintains that there is no rational criterion for demarcation between science and non-science. Instead, there are internal rules intrinsic to the knowledge involved. The growth of knowledge is through the acquisition of incompatible elements, discontinuous in structure, such that no linear progress of science can be seen. Both models however see science as a systematic pattern of thought.

Finally, the relativist position can be seen as an extreme version of *contextualism* (Koulaidis & Ogborn, 1995). Its main characteristic is the view that there are no rational criteria for demarcation between science and non-science: science is not a special form of knowledge, but rather one ideology amongst others. Science does not progress - it moves on to a different theory, not a better one. People, within a given time and context, simply prefer one theory to another.

## Methodology

The study reported here is a case study. Data collection, analysis and interpretations have been carried out within an interpretative constructivist approach (Lincoln & Guba, 1985). Purposive sampling (Lincoln & Guba, 1985) was made on the basis of teachers' different views, and only a single teacher was asked to participate. The selected teacher, who we refer to as Fernando, was interviewed twice, for two hours in each audio-taped interview. His classroom was observed for three months, and informal interviews (called on-the-spot interviews) were made prior to, or sometimes after, selected lessons. We also collected curriculum policies, school documents, textbooks, tests, worksheets and similar materials. Fernando was given copies of the interview transcriptions and asked to check, comment and modify them, as he felt appropriate. The analysis of the interviews involved reading the verbatim transcripts to develop a system of categories based on his viewpoints.

Literature suggests that teachers use metaphors, either in conscious or unconscious ways, to describe their roles. These metaphors are good indicators of their conceptualisations of teaching (Briscoe, 1991; Munby, 1986). Hence, a search for metaphors used in the interviews, that could account for the teachers' views, was carried out. Analysis of the interviews was also used as a basis for generating questions that could be answered from the classroom observations. Data from the interviews were examined for possible differences between the teacher's described perceptions and those that might be inferred from classroom observation. Questions about his aims and perceptions emerged from the interviews. Classroom observations served to explore contradictory data and to expand or restrict categories.

## Fernando's Formative History

Fernando, the subject of this case study, is 33 years old. He has a background of employment that includes working as an electrician and as a primary and secondary science teacher. After completing his physics education degree, Fernando continued to work as an electrician and as a teacher, which totalled 60 working hours per week. As a teacher, he has five years of experience at various grade levels. In his first year of teaching, he taught science at the primary level as well as physics at secondary level. Then from his second year on, he only taught physics at secondary schools. During the study, Fernando was teaching physics to Terms 3 and 4 (Grade 10), in which he was going to cover thermometry, thermodynamics, hydrostatics, hydrodynamics, and acoustics.

The most predominant theme about his teacher education is that he finished it lacking content knowledge. He points out that, due to this lack of content knowledge, he had difficulties in introducing modern physics at the secondary school level.

> *I believe that even the future teacher of physics should have the same knowledge as the future physics researcher. (...) You see, we work with classical mechanics, optics, and thermodynamics and we only 'scratch' a little bit the discussion that involves modern physics. In fact, to give a qualitative jump in the discussion of thermodynamics for instance, you should enter modern physics. You should enter statistical mechanics, kinetic theory of gases and the structure of matter. However, when you got there, you escape - you avoid it. So, this, perhaps, shows that*

> *our teacher education was lacking. The fact that we are not able to 'transport' it to our secondary classroom indicates that something was wrong with our course. This, perhaps, shows that my knowledge is deficient, since it is difficult for me to make the necessary bridges in my classroom.*

Fernando shows that the depth in which he explores any content in his classroom is dependent upon his content knowledge. Thus, he recognises that he should have had more content knowledge during his physics education course, knowledge that would help him to make links which students can follow. Further, he points out that teachers who have a lack of subject matter knowledge do not feel comfortable in doing experiments, or in undertaking a qualitative discussion of the concepts, or even discussing the history of science. He has also developed an appreciation of the difficulty of transforming and representing physics knowledge in such a way that his secondary students can grasp it (Shulman, 1986). According to him, he lacks accessible language to discuss physics ideas in a simple manner.

> *We are not able to discuss the same principles and concepts without using mathematics, without 'mathematising'. We should have had more discussions of the physics ideas. My course should have enabled me with language, a more accessible language, without, of course, putting the formalism aside. For instance, in quantum mechanics they taught us all its formalism (as they should have), but, unfortunately, the conceptual parts of it, the ideas behind and beyond it, were given less weight.*

It is not a surprise that Fernando is complimentary about his degree's courses in sociology, psychology and pedagogy.

> *From everything I've learnt in my degree ... er ... what I most use in classroom today is ... is my knowledge in the humanities field, mainly sociology, pedagogy, psychology, and the like.*

However, he complained about the 'small discussion spaces' given to it. He pointed out that he acquired a great deal of knowledge in these areas, but only in informal forums at the university and at educational meetings he attended. He acknowledged that during his undergraduate courses he learned the basics of pedagogy. However, he commented on the unrealistic model of the classroom he had been given. He claimed that this model gave him an incomplete account of the problems that may occur in a real classroom.

> *In our degree we were trained as if we were going to teach in an ideal classroom, as if we were going to have an ideal group of students, and so as if there were no problems to be dealt with. Well, then when you go into the classroom it is chaos.*

It is important to mention Fernando's opinion about the study of the philosophy of science he undertook during his teacher education.

> *Today I understand that the fact that we were going to be physics teachers presupposes that we should have been prepared for the classroom. However, this wasn't happening. The emphasis was more on the way "you should study the history and the philosophy of science to know it deeply" and they did not say that this knowledge could help us to improve our secondary teaching. They did not say that it could be good to give a historical and philosophical focus in our classrooms. (...) They did not say that it would be productive to give a historical context of the concepts being studied.*

He values the knowledge he acquired in informal forums. It appears that over the years he has consistently sought information that can help his teaching practice by participating in meetings and by reading whenever he can. Each new piece of information is critically evaluated and integrated into his existing knowledge. It is clear that from the start Fernando could be said to have been preparing himself for his teaching career. As he says, from the time he left his work as an electrician he "began to make strong links between education and experiences and between education and life".

## Fernando's Model of Science

Fernando's understandings of scientific activity can be seen to fall within a contextualist model of science (compare table 1 and 2). Fernando describes science as a human activity that systematically organises thought and observation. He suggests that science employs several methodologies, which are a consensus within the specific scientific community that works within agreed paradigms.

> *This shows that science is historically determined, and today ... er ... the major part of it is done co-operatively and done by large teams, which work within determined paradigms.*

Fernando believes that scientists are guided by theories and says that some theories and principles are internalised ("embodied") in the scientists minds in such a way that, even in face of contradictory observations, they are unable to give them up.

> *Thus, we see things like the neutrino discovery in which the guy only ends up with its discovery because of not giving up the principle of conservation of energy. The experiment has given a difference in the energy. The scientist thought: "Has it given a gap? Well, shall we see what we can do". For him, the starting point was that energy should always be conserved. Thus, at the moment that he observed this gap he invented a particle, the neutrino. Why? - To fit and maintain the principle.*

For Fernando, the Heisenberg's uncertainty principle came to show the impossibility of scientific objectivity.

> *Another main example is the understanding of the object-subject relationship of research that, with the development of quantum physics, made a very significant rupture with determinism.*

Fernando suggests that there are numerous 'styles' for attempting to know nature. Yet, for him, the only constant in this process is the need to align one's ideas with reality. From Fernando's standpoint, reality is constructed through the construction of thought.

> *So, for me, reality is in all the stimuli that we receive through our senses (our perceptions), and you try to reflect upon them. When you return to this ... er to this same nature with your reflections to capture elements of connection, then you have a 'thought reality'. Thus, when I speak about reality, I'm thinking about this thought reality, which still has the sense elements, but it also has the elements of our reflections and experiences.*

He conceptualises two distinct realities, reality *per se* and reality in thought. He remarks that "reality is always present in our knowledge since it interacts with our constructions - you cannot only construct at your will". For Fernando, the progress of science is socially and historically determined. Scientific progress is made upon changes, 'ruptures' in his words, with prior knowledge. He says that after a rupture the scientists change an entire world view - they change, he says, "their philosophy".

## Fernando's Models of Pedagogy

Literature not only proposes that the teaching of science is influenced by teachers' models of science, but also is influenced by their models of learning science (Aguirre & Haggerty, 1995; Gustafson, & Rowell, 1995). Once Fernando's model of science was discussed, the focus is now on his models of learning, teaching and his classroom practice, in an attempt to find out the way his model of science may or may not influence his understanding of learning and his teaching practice.

Because of this experience, Fernando believes that it is useless when students spend a great deal of time solving algorithmic problems. He defends that there is no point in having his students becoming experts at using the appropriate exact formula and "running after the correct answer", but he thinks that students need to know the conceptions that underpin a physics problem.

Fernando is a visionary thinker. He sees science as dynamically changing into the future.

> *As technology is developed, it enlarges our senses (for instance the Hubble's telescope), and so you can have a more extended view of the universe. Today, you can "see" [He signs inverted comas with the hands] things that, in the olden days, you couldn't. All this new data can question the standard model for instance or ... er ... the theory of the big bang. From this you can have a new ... you can have a new space to work.*

In the same way, he also sees his students' knowledge as dynamically changing. One major theme in his accounts of his teaching involves "opening spaces for classroom dialogue" so that students can have "a more extended view of the world" (like the Hubble's telescope). Fernando sees that his job as a teacher is 'to open up spaces' so that students are able to "bridge their knowledge", as he says "to see applicabilities or to make predictions and connections". He understands that by "opening discussion spaces" students are more able to "see the landscape", and seeing it means to contend with life's difficulties in a more informed way. Education, experience and life are intertwined in Fernando's way of thinking. Consequently, his metaphor "open spaces" is valid for science and for science education. Once the spaces are open the students are able to see the obstacles that are obstructing their learning. Fernando sees that the landscape is full of obstacles (barriers) that need to be crossed in order to open up other perspectives. In other words, the objective of crossing a barrier is to reach a new "space" to keep "moving forward". When an obstacle is perceived, Fernando's job is to support his students to overcome it by means of "building bridges" or "jumping" or "flying". When he talks about overcoming barriers, Fernando uses predominately the metaphor "to make a bridge". When a barrier is met, his main work is to build a bridge so that students can cross it. However, less frequently, he gives guidance so that students can build bridges (or jump, or fly over the barriers) for themselves. Jumping over a barrier has the connotation of enhancing one's knowledge in quality and not in quantity. The most advanced way of overcoming a barrier is by flying. Thus, from those metaphors it was inferred that he sees himself as a 'pioneering guide'.

The metaphors Fernando employs to conceptualise teaching and learning are very congruent with his model of science. His teaching process is undertaken in two distinct stages. In the first stage, he 'opens discussion spaces'. He wants his students to act as 'revolutionary scientists' in the same way as Kuhn's revolutionary scientists behave (raising 'anomalies'). Fernando understands that learning science is a kind of struggle between common-sense ideas and scientific ideas. Thus, he promotes discussions that go on until students realise problems (anomalies) with their existing knowledge. Once those are recognised, he takes on his 'pioneering guide' role. To some extent, at this time he acts as "the revolutionary scientist" himself by presenting the scientifically accepted concept to his students. In other words, he helps his students to build the bridges to cross 'epistemological obstacles' (Bachelard, 1977; Tiles, 1984). In the educational literature the above process is called 'conceptual revolution stage' (Zylbersztjn, 1991, p. 58). The next step in Fernando's teaching can be compared to the times of 'normal science' (Kuhn, 1970). It is in this stage that, in Fernando words, "students move forward articulating their conceptions and making connections".

In short, our classroom observation has corroborated that Fernando employs a conceptual change model of teaching (conceptual revolution). He understands that students bring their own conceptions to the classroom and that those can be at odds with the scientific conceptions. In this case, they need to change these ideas and his task is to guide them.

## Discussion

Fernando's school experiences, of solving quantitative physics problems by means of "running after the correct solution", taught him that he has not learned physics through such an approach. As he declares, he was good at solving quantitative problems, but without understanding the physics concepts that underlay in these problems. By attending several informal in-service courses, he came to understand that learning is a process of changing old knowledge and/or fitting new knowledge into an existing framework. He also came to understand that scientific knowledge is a tentative endeavour and that because of this there is nothing such as "the correct approach". Viewing science as a tentative endeavour has strengthened his view of learning as conceptual change.

Indeed, Fernando's teacher education courses had a very different substance from those taken by the other teachers we met at his school. During his years of study he started to take a strong interest in human problems.

> *I entered university to do electrical engineering because my secondary school course was in electricity. I was an electrician. So, it was quite reasonable that I would enter university to do electrical engineering.(...) After two and a half years of doing it, I realised that very little was being added to my knowledge as an electrician. So, I was not very happy. (...) Also, my involvement with the university life, on the other hand, pushed me into the humanities. So, the discovery of the human areas, and the understanding that the engineering course was not being useful, caused me to choose a new option. So, where could I go from where I was? I was already involved in the exact sciences. So, what were the options? The options were in the educational areas; in the exact sciences. So, I thought about physics because it was the nearest science to my background. (...) So, this shift was a landmark, it represented my life style option.*

This may explain Fernando's enthusiastic way of teaching - a teacher who emphasises the necessity of discussing human problems, and who encourages his students to be involved in a variety of activities that involve such issues.

Also, during his teacher education, he was introduced to several theories of learning and to the history and philosophy of science. However, he declares that his views are not a reflection of these courses, but are rather derived from the informal learning forums in which he attended. Finally, it might be said that a big difference between Fernando and other Brazilian teachers lies, perhaps, in the differences in their background content knowledge in physics. Despite claiming that he lacks content knowledge, Fernando knows physics! He says that the depth in which he explores any content in his classroom is dependent upon his content knowledge. But, as commented above, he recognises that he should have had more content knowledge during his physics education degree, knowledge that would help him to make links which students can follow.

Apparently, his idea that both science learning and doing science are similarly tentative endeavours guides his classroom behaviour. During the interviews it was noticeable that he only defined teaching after having made clear what learning means, because, for him, the way of teaching will be dependent on the way one learns. It is clear that for Fernando it is not the concept of teaching itself, but rather the concept of learning that is pivotal for teaching. Moreover, Fernando claims that the concept of teaching is inseparable from the concept of learning. Literature exists which demonstrates that rather than having a causal dependence, the concept of teaching has an "ontological dependence" on the concept of learning (Fenstermacher, 1986). That is, for Fenstermacher, as for Fernando, the meaning of teaching rests upon the existence of learning.

Another point to be made is that the basis of Fernando's understanding of learning seems to rest upon the way he perceives the content of science; he sees it as tentative. Taking into account the nature of science, Fernando understands learning science as a tentative endeavour. Consistently, he engages his students in producing answers to questions (problems), rather than just presenting what is maintained to be true.

Classroom observation has corroborated the analysis of Fernando's metaphorical language shown during the interviews. He was observed playing the role of pioneering guide and opening spaces for discussion. Such discussions were clearly aimed at encouraging students' ideas and at making them aware of their own ideas. In his classroom, students are given the opportunity to think through alternative approaches to problems and to consider the merits and disadvantages of applying different perspectives. Fernando sees knowledge as socially constructed. Accordingly, he raises discussions by questioning his students, who, in turn, also question him. In consonance with his contextualist view of science, he sees scientific knowledge as tentative, thus changeable, growing by means of human creation and connected with other domains of knowledge, culture, and social life. Such views are strengthened by remarkable examples he takes from the history of science. His teaching employs such knowledge to humanise physics by relating it to personal, ethical, cultural and political issues. Whenever it was appropriate, he illustrated his teaching with historical instances. Fernando's teaching is based on a conceptual change model. He wants his students to understand the dynamics of scientific changes, because he wishes his students to understand their own paradigmatic changes. According to a conceptual change teaching approach, Fernando's classroom behaviour encourages students' active participation. For Fernando, dialogue is the source of the construction and reconstruction of knowledge. It can be said that his approach to teaching is substantially different from approaches that prevail in school today. Fernando shows a powerful way of thinking about teaching and learning science. In his classroom, the content is presented in a balanced way; it is presented both as a theoretical and as an empirical and powerful, yet limited, way of knowing.

## Conclusions

From Fernando's case study it is suggested that a teacher's most powerful tool in understanding and changing his/her practice lies in his/her adherence to a theory of learning that is coherently based on an awareness that learning science or producing scientific knowledge is a tentative process of solving problems. It is a process, in which new conceptualisations fit or change old ones, such as how Fernando understands both processes. There is a need to understand that students, as well as scientists, do not memorise what is known. Such are the views that should drive the concept of teaching. The teaching of science is undermined if there is no coherent view of learning science that takes into account the content of science. Teachers' views of learning, teaching and of the nature of science not only affect each other, but are driven by social forces and by teachers' reflections on their past experiences. Evidence suggests that, to be empowered, teachers need to hold views of learning, of teaching and of the nature of science that are coherent with each other. That is, study suggests that a teacher who holds coherent views is less vulnerable to external pressures. Such a teacher feels more securely that he/she is qualified, and as such possesses the necessary knowledge of science and its learning and teaching. Thus, when facing pressures, he/she is empowered to argue consistently to defend his/her ideas.

The study shows that in order to foster student's understanding, a physics teacher may need to, in a dynamic and interacting way, bring together three areas of knowledge: physics, psychology of learning and philosophy of science. Moreover, as practised by Fernando, science teachers may need to produce alternative approaches that take into account differences in students' ways of learning. In summary, understanding the subject matter one teaches, how students learn science, how scientific knowledge is constructed and the way these three areas of knowledge interact may enable the teacher to make instructional decisions to foster understanding.

As an overview, it can be said that a teachers' epistemological models (his/her understanding of the nature, origin, and warranting of knowledge and truth) and models of scientific methodology (the methods and techniques that are appropriate and valid to use, generate and justify knowledge, given the epistemology) inform their models of learning (how it can be known), and through their interaction inform their models of teaching (the means to facilitate learning according to the teachers' epistemology). That is, there exists a complex tripartite relationship in which one model informs the other through interaction (Swift, 1982).

### Implications and Future Research

This study indicates that a teacher's most powerful tool in understanding and changing practice is a theory of learning based on the awareness that the construction of knowledge is tentative. This study indicates that insights into teacher's models of science and learning science are required in attempts to change their approaches to teaching. However, after analysing this case study, some questions remain do teachers 'models influence students' views of science? Do teachers' models have any influence on students learning of scientific concepts? Hence, further analysis could look in detail at the model of science the students acquire from their teachers.

As we can conclude from this case study, the opening question "What do teachers need to know?" in fact, has no single answer. So, it must be acknowledged that this research work has only started a discussion and has suggested opportunities for more research. There is a need for further description in other instructional settings. Could Fernando teach in the same way in a completely different setting? How does curriculum affect teaching? Finally, it might be helpful to conduct this sort of research within the context of teacher education. In this way, we can look at the development of future teachers' models of science and how this development affects their understandings of learning and teaching. Thus, we can look at the development of their models of pedagogy.

**References**

AGUIRRE, J.M. & HAGGERTY, S.M. (1995) Preservice Teachers' Meanings of Learning. International Journal of Science Education, 17(1): 119-131.

BRICKHOUSE, N.W. (1991) Teachers' Beliefs About the Nature of Science and Their Relationship to Classroom Practice, Journal of Teacher Education, 41(3): 53-62.

BRISCOE, C. (1991) The Dynamic Interactions Among Beliefs, Role Metaphors, and Teaching Practices: A Case Study of Teacher Change. Science Education, 75(2): 185-199.

DUIT, R. (1994) The Constructivist View in Science Education - What it Has to Offer and What Should not be Expected from it. Paper presented at the International Conference "Science and Mathematics for the 21st. Century: Towards Innovatory Approaches". Set/Oct.: Conception, Chile.

FENSTERMACHER, G.D. (1986) Philosophy of Research on Teaching: Three Aspects. In: M.C. WITTROCK (Ed.), Handbook of Research on Teaching (3rd Ed.). New York: Macmillan.

GUSTAFSON, B.F. & ROWELL, P.M. (1995) Elementary Preservice Teachers; Constructing Conceptions about Learning Science, Teaching Science and the Nature of Science. International Journal of Science Education, 17(5): 589-605.

KOULAIDIS, V. & OGBORN, J. (1988) Use of Systematic Networks in The Development of a Questionnaire. International Journal of Science Education, 10(5): 497-509.

KOULAIDIS, V. & OGBORN, J. (1995) Science Teachers' Philosophical Assumptions: How Well Do We Understand Them? International Journal of Science Education, 17(3):273-283.

LINCOLN, Y & GUBA, E.G. (1985) Naturalistic Inquiry. London: Sage.

MUNBY, H. (1986) Metaphor in the Thinking of Teachers: An Exploratory Study. Journal of Curriculum Studies, 18(2): 197-209.

SHULMAN, L. (1986) Those Who Understand: Knowledge Growth in Teaching. Educational Researcher, 15: 4-14.

SHULMAN, L. (1987) Knowledge and Teaching: Foundations of the New Reform. Harvard Educational Review, 57(1): 1-22.

SWIFT, D.J. (1982) Curricular Philosophy of Science Today. In: SWIFT D.J. et al, Philosophies of Science in Science Education. Gilford: IET mimeograph, University of Surrey.

ZIMMERMANN, E. (2000) Structure and Development of Science Teachers'Models of Pedagogy: Implications for Teacher Education. In: John K. Gilbert; Carol Boulter - Models and Modeling in Science and Technology Education:ed. 1 ed., Kluwer, v. 1, p. 254-279

ZYLBERSZTJN, A. (1991) Revoluções Científicas e Ciência Normal na Sala de Aula. In: M.A. MOREIRA & R. AXT (Eds.), Tópicos em Ensino de Ciências [Issues in Science Education]. Porto Alegre: Sagra.

**Table 1.** Summary of the Models of Science in the Philosophy of Science

| | INDUCTIVISM | DEDUCTIVISM | CONTEXTUALISM | RELATIVIST |
|---|---|---|---|---|
| **METHODOLOGY** | **One method**<br>Observation to theory (verification) - Observations are not as fallible as theories. | **One method**<br>Theory to observation<br>Falsification by observation and experiment (verification). | **Many methods**<br>Two models:<br>1. Methods are consensus.<br>2. Methods are intrinsic to a paradigm | **Many methods**<br>(anything goes)<br>Methods are relative to interests, people and circumstances |
| **DEMARCATION** | **Rational**<br>The truth | **Rational**<br>Nearer to truth<br>Improvement of existing knowledge. | Two models:<br>1. **Rational** - consensus.<br>2. **Not Rational** - Internal rules intrinsic to the knowledge involved. | **Not Rational**<br>A matter of values - no demarcation to be drawn. |
| **GROWTH** | **Compatible - Progress**<br>Accumulation of facts | **Compatible - Progress**<br>Improvement of theories - science progresses by trial and error. | Two models:<br>1. **Compatible & Incompatible - Progress** Development by consensus<br>2. **Incompatible Change - No progress** Paradigms with intrinsic criteria - discontinuity | **Incompatible change - No Progress**<br>It moves to a different theory, not a better one. Groups of people at given time, in a given context, prefer one to another. |
| **STATUS** | **Special**<br>Objective account of nature | **Special**<br>Objective account of nature | **Special**<br>Systematic pattern of thought | **Not Unique**<br>An ideology amongst others |

**Table 2** - Summary of Fernando's model of science

| Theme | Fernando's Overall View |
|---|---|
| **Science in General** | • A human activity in which one sets up a distinct object to study;<br>• Socially constructed, it is a rational activity that systematically organises thought and observation leading to the organisation of a language without internal contradictions. |
| **Aims of Science** | Science tries to:<br>• Describe;<br>• Explain; and<br>• Predict, nature's behaviour. |
| **Starting point of science** | • Scientists' knowledge;<br>• Scientists' belief that nature can be accessed, and that events in the universe occur in consistent patterns that are comprehensible, through careful systematic study. |
| **Methodology** | • There are many methods;<br>• The object of study determines the methodology;<br>• Methods are a consensus within the specific scientific community (paradigm). |
| **Criteria of theory choice** | • As a last resort is set by reality;<br>• A rational triangular negotiation (scientist-reality-scientist) until a consensus is reached;<br>• Theories can be maintained even in the face of contradictory data. |
| **Scientific Progress** | • Historically, and socially determined;<br>• Discontinuous - periods of growth by accumulation of knowledge interspersed by periods of ruptures with previous knowledge. |
| **Status of ScientificKnowledge** | • Coherent discourse based upon logic and internal consistency;<br>• Opposes mere opinion;<br>• Opposes common-sense thinking (appearance is different from essence);<br>• Systematic pattern of thought. |

**Table 3.** - Summary of Fernando's Model of Teaching and Learning Science

| | |
|---|---|
| **Aims of education** | • to situate each person historically; and<br>• to open spaces for individuals to challenge existing knowledge;<br>• to help people<br>• to make sensible decisions in conducting their daily lives;<br>• to enhance one's competence as a social actor. |
| **Aims of Science Education** | • should be the bridge that establishes a new relationship between the individual and nature. |
| **Concepts of Teaching** | Teaching is:<br>1. Challenging students' ideas;<br>2. Discussing;<br>3. Questioning;<br>4. Helping students to reflect. |
| **Approaches to Teaching** | • Revolutionary conceptual changes by challenging students' ideas during whole classroom discussions. |
| **Teacher's Role** | • Pioneering Guide (space opener). |
| **Concepts of Leaning** | Construction of knowledge by:<br>• Dialoguing |
| **Process of Learning** | • Overcoming epistemological obstacles;<br>• Making sense of information; and<br>• Fitting information into previous knowledge. |
| **Students' Role** | Builders of their own knowledge -<br>• revolutionary and normal scientists. |
| **The role of experiments in science teaching** | Context bound:<br>• To reply to questions that have been formulated by students themselves. |

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# NON-TRADITIONAL CAREERS FOR BLACK CHILDREN IN SOUTH AFRICA

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## Abstract

This study sought to investigate if black grade 7 learners in South Africa are beginning to think about getting into non-traditional careers. The study also sought to investigate whether the learners have an interest in learning science and technology. It was found that the learners had positive attitudes toward science and technology. However, they were not so sure about their abilities to succeed in science and technology oriented careers. There appeared to be a lack of self-confidence and self-esteem with reference to being able to operate a computer or successfully studying engineering. Careers that were chosen by girls consisted of 81.48% traditional service careers, which involve caring for people. Among boys only 56.67% chose traditional careers while 43.33% chose engineering. Although a sizeable number of boys chose engineering, none of them specified the field of engineering they wanted to pursue. The study showed that there was a need to expose black learners to other careers they may not know about. Lack of access to television and the internet denies a lot of black children access to information.

## Introduction

Never before in the history of the world has the quality of people's lives been so closely linked to science and technology. There is no doubt that there is a strong link between sound economic well being and scientific and technological literacy. Our struggling economies in Africa and poor advancement in technological expertise places us in the category of undeveloped nations. In South Africa, a significant portion of our population lives in dire poverty with no basic amenities and proper schooling facilities. It is this poor majority of black people consisting of a population of predominantly young people that are not in the mainstream of science and technology. These young people are found in rural areas where most schools are without electricity and running water. The teachers of these schools face a great challenge to demystify and popularise science and technology among these communities of learners.

## Motivation for the study

The new democratic government in South Africa has made it its priority to deliver service to communities that had no access to clean water, telephones and electricity. Rural communities in particular and their schools are being assisted to embrace technology. Barriers to access to technology by rural populations are gradually being broken down. The teaching of mathematics, science and technology are being encouraged in all black schools. The teachers in black schools are in most cases hardly qualified to teach science subjects but they are doing their best under the circumstances. Because of all these changes that positively promote the learning of science and technology, I wished to research whether grade seven learners were being positively stimulated to choose non-traditional careers. The choice of non-traditional careers by learners would indicate the impact of learning science and technology.

## Methodology

Two hundred grade seven learners from four primary schools in rural areas of South Africa, answered a pre-tested questionnaire. Issues covered by the questionnaire were the learners' attitude toward science and technology and what their future career aspirations are. The aim of the research was to find out if grade seven learners are beginning to think of choosing non-traditional careers that are science and technology related. Secondly, I wanted to find out how the girls choices of careers would differ from those of boys. It is important from time to time to determine if we as a country are achieving equity in the field of education. Women's education is of strategic importance hence the expression that if you educate a man you educate an individual but if you educate a woman you educate a nation. It is important that women are encouraged to embrace science and technology because gender inequality in opportunities to learn is the root of inferiority complex that affect women throughout their lives.

## Results and discussions

Learners' responses to statements of interest in Science and Technology

| Statements | Responses in percentages | |
|---|---|---|
| | Agree | Disagree/Uncertain |
| 1. I would like to be a scientist | 89.13 | 10.87 |
| 2. We learn important things in the science classroom | 76.29 | 23.71 |
| 3. I think I have an ability to become an engineer | 55.57 | 43.43 |
| 4. I don't think I have an ability to operate a computer | 51.61 | 48.39 |
| 5. I want to be an engineer to help develop my country | 79.17 | 20.83 |
| 6. Everyone should learn about science and technology | 95.92 | 4.28 |
| 7. I don't think I have an ability to do science | 29.17 | 70.84 |

The results show that the majority of grade sevens have a positive attitude toward science and technology. The positive attitude toward science and technology are shown by scores for items 1,2,5, 6 and 7 which are 76.29%, 89.13%, 79.17%, 95.92% and 70.84% respectively. However, it was noticed that self confidence and self esteem was lacking as indicated by items 3 and 4. These items show a dramatic indication of uncertainty about being able to cope with a career in engineering and operating a computer. One may say, therefore, that it is necessary to help learners develop self-esteem that will encourage learners to think about breaking the mould and get into non-traditional careers. It is true that embracing science and technology will not be easy for black learners who have in the past been made to believe by the past apartheid government that they had no ability to pursue science.

In a study undertaken by the South African Forum for Research and Development, Kgaphola (1999) confirms that the numbers of black students in science, engineering and technology (SET) is very little. The black students listed the following reasons as major obstacles in pursuing science:-

(a) Poor mathematics and science education at school. Infact for some reason, a phobia of mathematics and science is entrenched in black schools.
(b) The teaching language barrier, that is, students learning in a foreign language. Black learners speak different indigenous languages but are taught different subjects in English. Communication therefore becomes a major problem. Sometimes the teacher teaching the subject is himself not competent in the foreign language.
(c) The learners are discouraged from following science and technology at school level because of the teachers' perceptions.
(d) The lack of positive role models.

The issue of role models is important, but in reality there are very few black role models in non-traditional careers. With proper training in mathematics, science and technology education, teachers can act as role models. They can act as sources of information about different non-traditional careers. They can inspire the learners, help them to understand and accept that they can learn science and succeed in doing so. Past studies have shown that role models are important in motivating youngsters to think about taking non-traditional careers. The route of using role models has been used by Americans to encourage Black Americans to take mathematics, science and technology careers.

The Museum of Science in Chicago (1988) presented a teacher's guide on "Black Achievers in Science" which an emphasised that scientists are real people and that some are black persons. There was a clear message that science and technology careers are within reach of anybody who is prepared to work toward achieving his/her goal. One of the objectives of Black Achievers in Science was to make black youths aware of science and engineering as desirable careers; as well to make them aware of how they prepare for such careers.

**Grade Seven Choices of Careers**

| Boys career choices | % | Girls career choices | % |
|---|---|---|---|
| Teachers | 6.67 | Nurses | 29.64 |
| Engineers | 43.33 | Medical doctors | 37.04 |
| Policeman | 16.67 | Engineers | 7.42 |
| Medical doctors | 26.67 | Social worker | 3.70 |
| Technicians | 3.33 | Climatologist | 3.70 |
| Scientist | 3.33 | Computer technician | 3.70 |
| | | Computer programmer | 3.70 |
| | | Policewoman | 3.70 |
| | | Farmer | 3.70 |
| | | Teacher | 3.70 |

Although the most favoured career for boys was engineering, none of the boys identified the engineering field they wanted. It was also not surprising since engineering has always been identified as a career for gifted boys. What was disappointing among the boys' choices of careers was that the choices are still limited and dominated by traditional careers like doctors, policemen and teachers. There is a very strong likelihood that the learners are limited by what they know, hence a need for career education in black schools.

The girls had a larger variety of career choices than boys. It was interesting to note that they had included non-traditional careers like climatologists, computer technicians and computer programmers. However, it is still significant that 81.48% of girls chose traditional service careers (involving caring for people), like nursing, medical doctors, social workers, farmers, teachers and policewomen. All these are careers that have for years been recognised as suitable careers for women. There are many non-traditional careers that these grade sevens seem not to be aware of. Some of these careers learners could choose from are medical biologist, pilot, chemist, forensic scientist, medical biophysist, Information Technology Specialist, coastal geologist, web designer, meteorologist etc. All these careers need a thorough and firm background in mathematics, physical science, and technology. Most of the black primary school children, particularly those in rural areas will not have heard of these careers. It is therefore unthinkable that they would aspire to get into careers they have not heard about. There is therefore a great need for career education to be emphasised from primary school level.

**Conclusion**

Most young people unless guided very well, do not realise the need for a strong early education in mathematics, science and technology in order to prepare for a scientific career. Given freedom to choose their curriculum, most black children would avoid the "difficult" subjects and choose easy subjects that do not prepare them adequately to function in a fast changing scientific and technological world. Since the fall of apartheid in South Africa in 1994, there are now no careers that are not open for other races. The teachers of black children therefore need to help the learners to claim personal power and venture into new non-traditional careers that are now open to them. When the learners take science and technology seriously, human development will be promoted. One of the main functions of science and technological literacy is to enable people to take their destiny into their own hands so that they can contribute meaningfully to the progress of the society in which they live.

## References

Kgaphola, M.R. (1999). Restructuring Higher Education in South Africa: A Case for Development Oriented Curriculum Structure in Science and Technology Policy Foundation for Research Development.

Museum of Science and Industry, Chicago (1988). Black Achievers in Science

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# PREPARATION OF POLISH NATURAL SCIENCE TEACHERS FOR ENVIRONMENTAL EDUCATION IN THE LIGHT OF RESEARCH

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## Abstract

In Poland, the condition of environmental awareness is not satisfying. To improve this situation, environmental awareness should be developed very early. Result achieved in this area depend, on teachers, and also on the education system. Due to the education system reform there appeared a feasible opportunity to improve the state of environmental awareness among pupils. It is connected with the introduction of environmental issues to each stage of education. In all types of schools the realisation of environmental issues in the didactic process is carried out in two dimensions. One of them consists in comprising the issues in subject blocks or in traditional subjects. The other dimension is an interdisciplinary educational path named environmental education.

Interdisciplinary paths are a new form of teaching in Poland. They refer to those areas of education which cannot be ascribed to only one school subject. The realisation of the paths is the responsibility of each teachers who include the contents of a given path in their subject programme. Before the introduction of the school reform, it was only very keen teachers that carried out environmental education. Most often, teaching about the environment was carried out in biology lessons. Nowadays, teachers of all subjects must be prepared to participate in environmental education and they should be trained to perceive the interdisciplinary connections and the possibilities of environmental education within the framework of their subjects. In connection with a new role and place of environmental education in the Polish educational system, there appears a necessity to introduce changes in teachers' training. But before such changes are comprehensively introduced into high schools where students train to become teachers, it is currently necessary to provide various forms of supplementing education for presently working teachers.

Teachers in pre-secondary level, which is a new type of school introduced, are in especially difficult situation. To know their opinion about their preparation for environmental education, and about their needs in the education scope, we have conducted the following research.The obtained results reveal insufficient preparation of pre-secondary natural sciences teachers to take charge of environmental education in the newly changed conditions. They also show that the surveyed persons are aware of that fact. The teachers know which didactic solutions are most efficient in developing pupils' knowledge, skills and attitudes. That is why most teachers acknowledge the need to train in the area in question. The teachers show interest in various training topics. The presented research results are used in organising teachers' training.

## Introduction

The aim of environmental education is to prepare society to live in accordance with the principles of sustainable development. It is connected with the Earth inhabitants' awareness of the fact that the future of our planet depends on how we will be using the environment. This awareness should be based on broad knowledge concerning the environment on the global scale, and the knowledge of its natural, economic and social aspects.

In Poland, the condition of knowledge in this area is not satisfying. Research carried out among students and adults indicate that problem. To improve this situation, environmental awareness should be developed as early as one's childhood. Results achieved in this area depend, to a large extent, on competent, highly-qualified, conscious of their role teachers, and also on the condition of the education system. In Poland, this system has undergone a radical change since 1999. Due to the education system reform there appeared a feasible opportunity to improve the state of ecological awareness among Polish pupils - the future ordinary users of the environment or decision-makers. It is connected with the introduction of environmental issues to each stage of education. In primary, pre-secondary and secondary school the realisation of environmental issues in the didactic process is carried out in two dimensions. One of them consists in comprising the issues in subject blocks or in traditional subjects. The other dimension is an interdisciplinary educational path named environmental education.

Interdisciplinary paths are a new form of teaching in Poland. They refer to those areas of education which cannot be ascribed to only one school subject. The headmaster of a school is responsible for including the educational paths issues in the school curriculum. The realisation of the paths is the responsibility of each teachers who include the contents of a given path in their subject programme.

Before the introduction of the school reform, it was only very keen teachers that carried out environmental education at schools. The contents of the teaching programmes were treated cursorily and fragmentarily. Pupils' knowledge concerned mostly the disastrous state of natural environment. There was no emphasis on developing abilities to use the environment in accordance with the principles of sustainable development, or on adopting proper attitudes towards the environment. education within the framework of their subjects. These are new tasks for them Most often, teaching about the environment was carried out in biology lessons. Nowadays, teachers of all subjects must be prepared to participate in environmental education and they should be trained to perceive the interdisciplinary connections and the possibilities of environmental. This is caused by a lack of proper preparation of teachers, while they are still at university, to fulfil the tasks. At the university level, before the education reform was implemented, environmental education issues had been treated marginally or they had not been included at all.

Forms, methods and techniques of the realisation of didactic aims included in the environmental education programme is a very important and difficult matter. In this area, apart from passing on information, it is vital to develop numerous abilities and attitudes. Traditional verbal methods (a lecture, talk) do not make it possible to realise fully the assumed aims. It becomes essential to use other, little known to Polish teachers methods in the educational process. The use of activity methods is a novelty in environmental education. Here, simulation methods, discussion combined with visualising , role games and the case study are used. The project method is especially recommended in the realisation of interdisciplinary paths. This method, known for a long time and widely used in the USA and western Europe, has been neglected lately in Poland. In the years 1945-1990 it was not applied in the general education. Teachers training for the profession within those years did not actually know it. The method reappeared in Poland at the beginning of the 90ies together with the inflow of various ecological education projects co-ordinated and financially supported by international organisations. Outdoor activities are also an essential form of environmental education. The laboratory method should also be widely used in environmental education, especially when linked with environment monitoring. All forms of environmental education can and should be aided by the computer.

In connection with a new role and place of environmental education in the Polish educational system, there appears a necessity to introduce changes in teachers' training. But before such changes are comprehensively introduced into high schools where students train to become teachers, it is currently necessary to provide various forms of supplementing education for presently working teachers, so that they may function well in the new reality and complete their tasks properly.

Teachers in pre-secondary level (gymnasium), which is a new type of school introduced by the reform, are in especially difficult situation. To know their opinion about their preparation for environmental education provided in accordance with the Ministry of Education recommendations, and about their needs in the education scope, we have conducted the following research.

**The aim and characteristics of the research**

The aim of the research was to arrive at a diagnosis and evaluation of pre-secondary natural sciences teachers' preparation for environmental education and to recognise their needs concerning the forms and topics of professional training. The diagnostic survey method was used in the research. The questionnaire technique was used. With this in view, a questionnaire was worked out to contain closed questions, including closed, half-open and also conjunctive responses.

The research applied to natural sciences teachers in all pre-secondary schools in one of the south-eastern regions of Poland. 700 questionnaires were mailed to schools. 249 teachers filled in and returned the forms. The research was conducted between February and June 2001.

## Results

### Characteristics of the surveyed teachers

The surveyed persons were biology, chemistry, physics, geography and mathematics teachers. The most numerous group (35,8%) consisted of biology teachers. Chemistry teachers and geography teachers made up quite a big part of the whole surveyed group: the former – 29,7%, and the latter – 28,9%. Physics teachers were few, they made up only 1,6% of the respondents and there were even fewer mathematics teachers- about 0,5%.

The above results indicate the involvement of individual school subjects in the process of environmental education. Biology still (as it was before the reform) has the major role. Chemistry and geography are also of great importance. Participation of the other natural subjects – mathematics and physics – is insignificant.

The research revealed that a predominant group of the surveyed persons (71,1%) had trained to become a teacher at university, most often in the faculties of biology, chemistry and geography. A small group graduated from geology, history or library management. Quite a numerous group were agricultural college graduates (16,9%). The least numerous group were graduates of colleges of education (10,4%). A former research demonstrated that environmental education received the most sufficient attention in colleges of education. At universities, this issue was often kept in the background due to a decreasing number of natural subjects didactics lectures, classes and practice activities in the study syllabus. That forced academic teachers to select programme contents and to give up those concerning environmental education. Graduates of most agricultural colleges were able to achieve teaching qualifications in courses, where environmental education contents were skipped because of the necessity to realise the basics of psychology, pedagogy and subject didactics.

The time the surveyed persons have been working as teachers varied immensely. It ranged from 3 months to 39 years. The most numerous group were teachers working for 16 – 20 years (31,2%). Quite a big group were those working for 11 – 15 years (23,2%) and for 21 – 39 years (22,5%). Teachers working less than 6 years constituted about 14%. The least numerous group consisted of teachers working for 6 – 10 years (10%).

As the research results indicate, the natural sciences teachers in pre-secondary schools have been working long and very long. They prepared for the profession long before the introduction of the educational reform and its demands and thus resulting consequences for environmental education. These teachers particularly need to supplement their education in the area of new solutions used in the environmental education process.

The surveyed teachers worked mainly in countryside schools (58,2%). There was a lesser number of those teaching in small towns (36,1%) and a small group comprised teachers from city schools.

### Supplement training

The respondents were asked to point to teachers training forms in the scope of environmental education, in which they had taken part within the last three years, i.e., since the introduction of the reform. One third of them (34,5%) did not participate in any form of ecological education training. The remaining 65,5% took part in various types of training. Among these teachers, a majority took part in various didactic workshops, which are the shortest form of training devoted to dealing with one, quite narrow issue. Almost half of the surveyed teachers pointed out exactly this form of training.

A less numerous group of the surveyed persons (42,8%) participated in training courses devoted to environmental education. The group of environmental education post-graduate study participants was also quite numerous (35,5%). A prevailing part of the respondents took part in one form of training (71,8%). A small group (16,9%) had an opportunity to participate in two kinds of ecological education training. There appeared people who very actively attend training in the discussed issue: 7,5% of the respondents have undertaken three various forms of training for the last three years.

A majority of the teachers expressed the necessity of their training in the scope of environmental education. They constituted 83,1% of the respondents. 12,4% of teachers did not recognise such a need, and 4,4% did not express their opinion about that.

The respondents outlined the forms of training they would like to participate in in future. The biggest group, i.e., approximately 62,9%, would be willing to take part in didactic workshops with a view to improving their environmental education competence. They were less interested in training courses. About 37,8% of them were willing to participate in such a quite time-consuming training form. The least popular were the environmental education post-graduate study. Over 77,2% of the respondents chose one form of training, from among the possible three. 21,5% were willing to participate in two forms. And only a small percentage were interested in all the forms of training.

The obtained results indicate that teachers would be most eager to take part in short forms of training, didactic workshops being one kind of them. Workshop activities enable one to develop and perfect a number of skills in an active and efficient way. In this kind of activities a process of mutual learning is used which, among others, consists in:

- sharing one's experience
- solving reported problems together
- creative adaptation of techniques suggested by the leading person
- sharing feedback information.

Workshop activities equally engage all participants, who are expected to be ready for reliable individual and group work, ready to share their experience, to define their standpoint, thoughts and creative expression. Teachers especially appreciate the workshop form because it enables one to work out immediate, practicable solutions for school practice . Training courses and post-graduate studies were less popular with them. This must be connected with the fact that teachers are most often charged with the cost of their job training. Longer forms, to which courses and post-graduate studies belong, are very expensive and for that reason they are not easily available for teachers in Poland. The necessity to devote a lot of time is also important, however, new duties connected with the changes in the education system and imposed on teachers make their time scarce.

The surveyed teachers were also asked to indicate training topics which would interest them most. In the question items the conjunctive response was used, which enabled the respondents to choose several answers and thus to create a hierarchy. The given answers imply that all the training topics mentioned in the questionnaire are similarly attractive. The hierarchy looks as follows:

1. Planning and conducting outdoor activities in the closest surroundings (44,6%)
2. Activity methods in environmental education (43%)
3. Laboratory method and environment monitoring(40%)
4. Project as a method of realising interdisciplinary paths (39%)
5. Planning an interdisciplinary path (36,5%)
6. The aid of the computer in environmental education (34,1%)

The above results reveal shortcomings in the preparation of Polish teachers to run outdoor activities, which is confirmed by didactic research. This is connected with insufficient preparation for this didactic form during studies. It is considered to be time-consuming, laborious and difficult to conduct with a big group of pupils. Environmental education does demand this kind of activity, though. The closest surroundings provide an opportunity to develop knowledge, skills and attitudes in accordance with the principle "think globally – act locally". This may explain such a big interest in the outdoor activities training.

The high rank of activity methods in our hierarchy is not a big surprise. These methods appeared in the Polish school at the end of the 90ies. They are new for teachers, that is why teachers want to learn them also in connection with environmental education. The laboratory method and environment monitoring were in the third position. Although lab teaching has a long tradition in natural sciences teaching in the Polish school, it is still scarcely used. This is caused by technical and organisational difficulties. The fourth place was occupied by the project method training. The situation of this method has been presented earlier in this paper. Planning interdisciplinary paths and the use of computers in ecological education were regarded as the least necessity. The first problem was the subject of numerous didactic workshops and was discussed at school pedagogic meetings in connection with the reform. The rate of computer use at Polish schools including pre-secondary schools, however, leaves a lot to be desired. There is little chance for the knowledge in this respect to be put into practice soon. This can explain little interest in training in the scope of computer use in ecological education.

## Summary

The obtained results reveal insufficient preparation of pre- secondary natural sciences teachers to take charge of environmental education in the newly changed conditions. They also show that the surveyed persons are aware of that fact. The teachers know which didactic solutions are most efficient in developing pupils' knowledge, skills and attitudes. That is why most teachers acknowledge the need to train in the area in question. Short forms of training, i.e., didactic workshops are preferred. Only a small group of teachers would be eager to take up post-graduate studies, as they are the longest form of training. The teachers show interest in various training topics. The most popular is the training in the usage of the most efficient methods and forms of environmentsl education, that is, outdoor activities, laboratory method and activity methods. The topics favoured by teachers refer to new issues in the Polish education, and also to difficult problems, unpopular with natural sciences teachers.

The presented research results are used in organising teachers' training. They will make it possible to prepare a didactic workshop offer for pre-secondary teachers. They also served to work out an educational project which was realised on the recommendation of the Local Department of Education and in co-operation with the OIC Poland Foundation. The project contained a 40-hour-training course programme devoted to environmental education.

The research results should be taken into consideration while establishing programmes of pre-secondary teacher training for university students.

The presented research is only a part of a wide research on ecological education implementing in various types of Polish schools in the new education system.

## References

DEREN, A. & Grondas, M. (1999). Integracja międzyprzedmiotowa. CODN. Warszawa.

FILHO, W.L., (1996). An overviewof current trends In European environmental education. The Journal of environmental Education, 28 (1).

KAFEL, K., (2001). Edukacja ekologiczna w zreformowanej szkole. Współpraca Międzynarodowa w edukacji ekologicznej : 109-113.

PLICHT, T., (1995). Metody badań pedagogicznych. Wydawnictwo Żak. Warszawa.

WALOSIK, A., (1997). The influence of environmental education on integration of science knowledge. In: Science and technplogy education for social and economic development. Proceedings of second IOSTE Symposium.

ZILLMER, H., (2001). Edukacja ekologiczna w jednoczącej się Europie. Współpraca międzynarodowa w edukacji ekologicznej: 81-87

**Keywords:** environmental education, natural science teachers, forms of teachers training, topics of professional training, result of the research (This research was supported by Committee of Scientific Research, Poland)

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# THE INTEGRATION OF AGRICULTURE, SCIENCE, AND TECHNOLOGY: WHAT CAN BRAZILIAN AGRICULTURAL EDUCATION LEARN FROM THE UNITED STATES AGRISCIENCE MOVEMENT?

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**Resumo**

No artigo, algumas recomendações pertinentes ao futuro da educação agrícola brasileira são formuladas, partindo de uma análise histórica comparativa das trajetórias da educação agrícola no Brasil e nos Estados Unidos, e considerando as profundas mudanças na agropecuária e no meio rural brasileiro. O referencial é o movimento denominado *agriscience*, nascido nos Estados Unidos em 1988 a partir de um estudo do Conselho Nacional de Pesquisa que recomenda expressamente estender o conceito de educação agrícola para além da produção agropecuária, e promover a integração do ensino de ciências e tecnologia com ensino da agropecuária. Após extensa revisão bibliográfica os autores recomendam que: 1) os programas de educação agrícola no Brasil devem promover uma maior integração curricular entre agropecuária, ciência, e tecnologia, como forma de intensificar as relações entre oportunidades de aprendizagem contextualizadas e a transferência de conhecimentos e habilidades entre diversas situações; 2) a educação agrícola no Brasil transcenda os limites das escolas agrícolas e seja estendida principalmente para as escolas rurais, não como programas com objetivos profissionalizantes, mas sim como oportunidades de uttilizar os conteúdos e experiencias agropecuárias como contexto para a integração de princípios e conceitos oriundos de várias ciências; 3) os programas de educação agrícola no Brasil sejam revistos no sentido de incluir conteúdos que transcendam os aspectos puramente produtivos da agropecuária e mesmo a agropecuária própriamente dita, visando preparar os estudantes para carreiras dentro e fora do setor, uma vez que o meio rural não é exclusivamente agrícola e a agropecuária não é exclusivamente rural. Para tanto, é imprescindível que as escolas agrícolas dotem seus alunos de compreensão científica para que sejam capazes de entender, aplicar, e gerar tecnologia; 4) se conduzam pesquisas em escolas agrícolas e rurais para avaliar a validade da experiencia americana onde foi comprovado que a utilização de conceitos agrícolas no ensino de ciências melhora sensivelmente o aproveitamento dos alunos em ciências. Finalmente, o conceito de educação através da agricultura é contruido ao longo do trabalho, como uma estratégia adequada à realidade brasileira, em complementação aos conceitos de educação em agricultura e sobre agricultura propostos pelo Conselho Nacional de Pesquisa dos Estados Unidos em 1988.

## Introduction

As society continuously moves towards a knowledge-based economy, jobs have become technologically complex and are demanding sophisticated work skills. As pointed out in the call for papers for the 2002 International Conference on Technical and Vocational Education and Training, the potential contribution that an individual can make in acquiring and applying knowledge for improving processes, products and services is becoming more important than the physical labor. Raw materials, capital, and labor itself has been, many times, replaced by the application of knowledge as the main mean of production. In this sense, Chiasson & Burnett (2001) indicate that the importance of a good education goes far beyond just employment and job skills in today's demanding society. To live properly in a modern society, it is imperative that people have a quality education simply to develop everyday life skills and to take full advantage of all information available today. In an environment like this, scientific literacy is vital to a nation's cultural well being and economic competitiveness (Trexler & Miller, 1992).

The nature of agriculture lies in its intrinsic and direct relationship with the natural world. Agriculture is, in fact, an essentially interdisciplinary and complex subject that cuts across many scientific, social, and practical disciplines (FAO, 1996). Since agriculture is intrinsically connected with the primary source of food and social well being agricultural education helps students to develop awareness about the complexity of human actions introduced in the natural world. Yet, the role of agricultural education has been historically challenged by the dichotomization of its purposes and content in vocational and academic education. This dichotomy lies behind the degree of integration between agriculture and science, and defines the character of agricultural education programs.

Agricultural education must address these new demands bridging the gap between its vocational and academic tracks in order to provide students with scientific literacy needed to judge evidence and draw conclusions from the scientific point of view.

## Purpose of the paper

This theoretical paper assumes that the remarkable transformations undergoing the Brazilian agriculture and rural milieu bring about tremendous changes in expectations and perspectives for agricultural students. These changes bring extraordinary challenges for Brazilian agricultural education, which require a new equilibrium between the vocational and the academic aspects of agricultural education programs in order to make students able to understand, apply, and generate technology.

The primary purpose of this paper is to engage educators, school administrators, and policy makers in a dialogue to think and debate about new roles to science education and agricultural education to enhance the relationship between opportunities to learn in context and the ability to transfer knowledge and skills across situations. The concept of agriscience is the background in which the discussion is grounded. To fulfill its purpose, this paper specifically examined:

1. The historical trajectory of agricultural education in Brazil and in the United States as related to the dualism between vocational and academic tracks.
2. The transformations undergone and undergoing in the Brazilian agriculture and rural milieu.
3. The foundations of the agriscience movement in the United States
4. The potential contributions of the agriscience movement to the Brazilian agricultural education.

## Theoretical Framework

### Agricultural Education in Brazil and in the United States: A Brief Historical Perspective

The first agricultural education school in Brazil was established in 1875 (Franco, 1987) during the imperial period, designed to prepare agronomists with the express mandate to "always connect theory and practice of such a broad and important science" ("Carta Régia," 1812). However, agricultural education was formally recognized as an educational field only in 1910, through the Presidential Decree 8319. This legal instrument divided agricultural education hierarchically into 11segments, 6 of which dealt with formal and 5 with non-formal education. The top two segments in the hierarchy – higher education and middle education[1] - were supposed to be theoretical and practical based on the ground rules of the agricultural science to promote the scientific advancement of agriculture. Those two segments differed only in terms of complexity of the programs. In short, agricultural education, as defined in those two early legal instruments, embraced both the science and the practice of agriculture, as well as higher education in agriculture.

The Decree 9613 issued in August 1946, also known as Organic Law of Agricultural Education, limited the concept of agricultural education in Brazil to formal education programs below the college level devoted to the professional preparation of people working in agriculture. The Organic Law of Agricultural Education shifted the definition of agricultural education from being science-based to a strictly vocational definition. The situation remains essentially the same today. The first Directives and Basics of National Education Law (1961) did not

[1] Equivalent to grades 9 – 11.

bring any significant change in this situation. Eleven years later, vocational education became mandatory in all secondary education programs throughout the country (Law 5692, 1971). Such a legal requirement was revoked eleven years later through the Law 7044 (1982). Current Brazilian educational legislation (Directives and Basics of National Education Law, 1996; Decree 2208, 1997) placed agricultural education into a broad educational modality named professional education, which shall be delivered in independent form, but articulated with general education programs. In short, since 1946 agricultural education in Brazil has become focused more on training than in science.

Agricultural education in the United States began with a strong link with agricultural research, as part of general education. The Hatch Act of 1887, which established agricultural experiment stations, also called for the diffusion of agricultural information to the public. The federal government officially recognizes agricultural education with the passage of the Smith-Huges Act in 1917, when over 90,000 students were enrolled in agriculture classes in 4,665 high schools (Moore, 1987). The passage of Smith-Huges Act in 1917 promoted the concept of vocational agriculture as a separate program devoted to education for farming (production agriculture). Hillison (1996) indicates that the Smith-Huges Act shifted the definition of agricultural education from being science-based and academic-oriented to a strictly vocational definition.

With the passage of the Vocational Education Act of 1963 the concept of agricultural education in the US was broadened to encompass off-farm occupations. McCormick, Cox, Zurbrick, & Miller (1988) point out that even with a broadened instructional mission, the primary purpose of vocational agricultural education programs remains in preparing individuals for employment in agricultural occupations. However, the concerns about the declining profitability and international competitiveness of the US agriculture in the late 1970s and early 1980s (NRC, 1988), and the great decline in laborers in the middle 1970s due to advancements in technology (Shelley-Tolbert, Conroy, & Dailey, 2000), indicated a need for increased education in both science and technological applications in high school agricultural education programs.

As a result, from 1985 to 1988 the Committee on Agricultural Education in Secondary Schools of the National Research Council (NRC) conducted a study on agricultural education in the US secondary schools to address the concerns about declining enrollments, instructional contents, and quality in agricultural education programs. Such a study resulted in a 1998 report titled "Understanding Agriculture: New Directions for Education," which has become one of the most cited documents in relevant agricultural education publications in the United States (Conroy, 2000). Recognizing the changing forces acting in agriculture and education, the report points to two major challenges: agricultural education must become more than vocational education and major revisions are needed within vocational agriculture (NRC, 1988).

The literature (McCormick, Cox, Zurbrick, & Miller, 1988; Hillison, 1996; Conroy, 2000; Shelley-Tolbert, Conroy, & Dailey, 2000; Chiasson & Burnett, 2001) indicated two major impacts the NRC report has caused in agricultural education: 1) a new broadened mission to agricultural education encompassing education in agriculture (vocational agriculture) and education about agriculture (agricultural literacy), and 2) the acceptance of some systematic instruction in agriculture should be provided to all students, with an understanding of basic scientific concepts. In short, the NRC report brought the science-based nature of the agricultural curriculum back to a position of prominence. Figure 1 provides a graphical description of the historical trajectory of agricultural education in Brazil and in the United States.

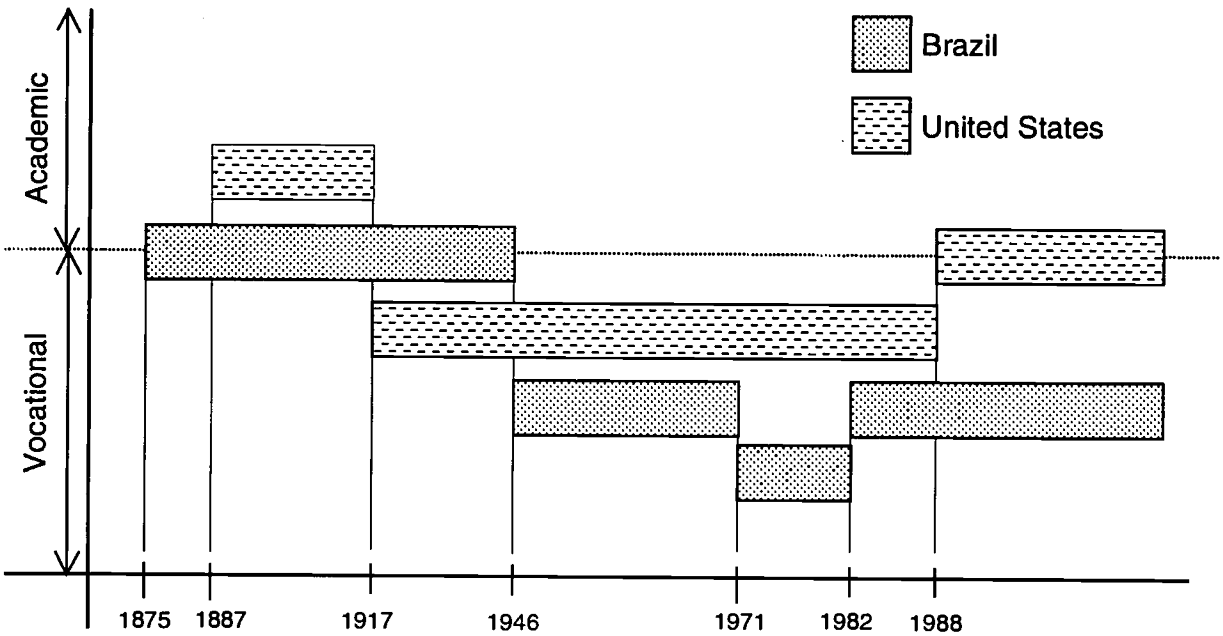


**Figure 1.** The academic and vocational aspects in the trajectory of agricultural education in Brazil and in the United States.

**The Changes in the Agriculture and in the Rural Milieu**

Agriculture has changed dramatically, becoming highly scientific and technical in all areas. During many years, the definitions of agriculture[2] and farming were pretty much the same – cultivating the soil, harvesting crops, and raising livestock. However, the modernization of the means of production and the continuous growth in complexity and interdependency of cultural, social, and commercial relationships between urban and rural milieus brought up a need to re-define agriculture. Herren & Donahue (1991) defined agriculture beyond its productive aspect, as a broad industry engaged in the production of plants and animals for food and fiber, the provision of agricultural supplies and services, and the processing, marketing, and distribution of agricultural products. Krebs & Newman (1994) and Solbrig (2001) indicated the scientific and technological advancements in mechanization, biology, genetics, microelectronics, and chemistry as the major contributors in changing agriculture. These technological advancements reflected on new machinery, crop varieties, animal breeds, immunization technologies, chemical fertilizers, herbicides, pesticides, computers, communication technologies, and so on, which in turn impacted not only the physical, but also the cultural, economic, and social aspects of the rural milieu.

Solbrig (2001) indicated that the changes taking place in agriculture due to scientific and technological advancements has impacted the rural milieu in four major areas: the production process, the economy of farming, the rural social structure, and the environment. According to Solbrig, the production process has been affected essentially by new input technologies, management operations, and by the advances in molecular biology (biotechnology). The increase in productivity brought about by new technologies has contributed to keep agricultural prices in their downward secular tendency, with tremendous effects on the economy of farming. In addition, new technologies are often capital intensive and labor sparse, which impact not only the economy of farming but also the rural social structure, as a result of the reduction in the rural labor force and employment opportunities. All these transformations in agriculture created a major disturbance in the environment, which requires constant investments in new knowledge in order to restore and/or maintain the sustainability.

The transformations in the agriculture are bringing a new face to the rural milieu. Graziano da Silva & Del Grossi

2 The word "Agriculture" is used in this text as related to the Portuguese word "Agropecuária."

(n.d.) indicated that since middle of 1980s a new pattern is emerging in the Brazilian rural milieu, based on three main attributes: a) a modern agriculture based on commodities and closely linked with processing industries, b) the existence of a set of non-agricultural activities related to dwelling, leisure, service, and non-agricultural industries, and c) a set of new agricultural activities related to special markets. Such a new pattern has as major characteristics the emergence of the part-time farmer and the phenomenon named pluriactivity, which means the combination of agricultural and non-agricultural economic activities. According to Graziano da Silva & Del Grossi (n.d.), the income originated from non-agricultural activities was greater than the income generated by agricultural activities among rural residents in Brazil in 1998. The pluriactivity has been related in the literature as also occurring in Europe and in Israel (Eikeland & Lie, 1999; Sofer, 2001).

The transformations in agriculture and in the rural milieu have lead to changes in expectations and perspectives for agricultural students. Studying two different rural settings in the states of Rio de Janeiro and Rio Grande do Sul, Brazil, Carneiro (1999) found that rural youth are dramatically affected by the transformations occurring in the agriculture and in the rural milieu. According to Carneiro, rural youth perceive education as the main alternative to a new standard of living, due to the physical, economic, social, and cultural integration between the rural and the urban milieus. The point is that rural youth are considering occupations outside of agricultural careers as major alternatives to a better standard of living, even when they do not see themselves living in urban settings. American literature (Duval, 1988; Whent, 1992; Chiasson & Burnett, 2001) also documented changes in agricultural students. They are planning for careers not previously associated with agriculture and are reaching for career opportunities that extend far beyond the familiar face of agriculture in the local community to dimensions that have national and international scope. Another interesting point indicated by the literature (FAO, 1997; Chiasson & Burnett, 2001) referred to the fact that many agricultural students have no agricultural or rural background, showing interest in agricultural as a secondary economic activity and/or as a way to understand agriculture technology to apply in associated activities.

Agricultural education is expected to supply students with the tools to face the challenges of a changing agriculture and rural milieu. Such tools must address issues beyond the merely productive aspect of agriculture and the merely agricultural aspect of the rural milieu. Agricultural students should be prepared to pursue careers in and outside of agriculture. This is the new dimension of the social role of agricultural schools, emerged from the transformations in agriculture and in the rural milieu. Figure 2 summarizes the transformations in agriculture and in the rural milieu, and its implications to agricultural education.

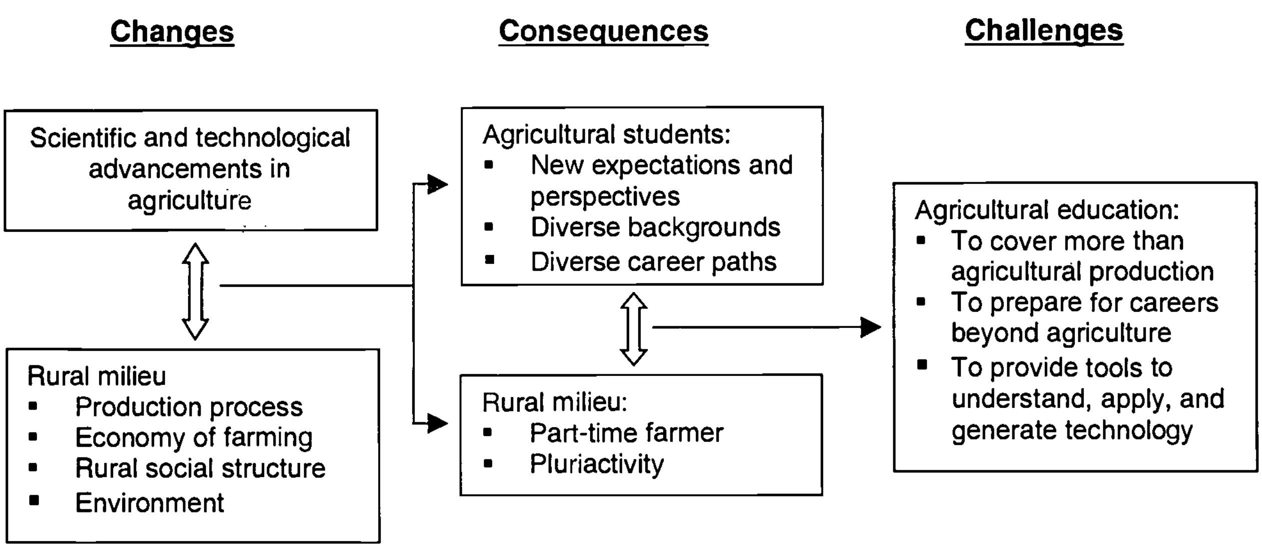


**Figure 2.** Schematic representation of the transformations in agriculture and in the rural milieu

**The Agriscience Movement**

American education turned its attention to science in basic education, in recent times, through the "A Nation at Risk" report issued by the National Commission on Excellence in Education in 1983. Such a report alarmed many Americans with students' low levels of basic skill performance in science (Thompson, 1998), and had tremendous impact in the United States education. As a result, an educational reform was launched with the intent to improve the quality of education, especially in basic education.

In the midst of the reforms brought about by the "A Nation at Risk" report, the National Research Council (NRC) established the Committee on Agricultural Education in Secondary Schools at the request of the U.S. Secretaries of Agriculture and Education to assess the contributions of agricultural education to the nation. As asserted early in this paper, a report titled "Understanding Agriculture: New Directions for Education" was issued by the NRC in 1988 as a result of the committee's work. Along with several other recommendations, the report advocated that subject matter of instruction in and about agriculture should be revised and broadened. In this sense, one of the major revisions suggested by the NRC was the incorporation of additional science-based curriculum in agricultural education as a way to keep the programs updated. This is recognized as the starting point of the agriscience movement in the United States.

The main idea behind the concept of agriscience is the integration of agriculture, science, and technology to help students develop skills to understand, apply, and generate technology by giving them opportunities to learn in context and ability to transfer knowledge and skills across situations. Agriscience is defined as "the notion of identifying and using concepts of biological, chemical, and physical science in the teaching of agriculture and using agricultural examples to relate these concepts to the students" (Conroy & Walker, 1998, p. 12). In short, agriscience are programs that emphasize the technological and scientific aspects of agriculture (Duval, 1988). Its goal can be described as to enhance the effectiveness of the teaching in science and in agriculture through increasing the student's awareness of the interrelationship of technology, science, agricultural and environmental science, and natural resources.

Trexler & Miller (1992) indicated that students see science as textbook-driven, with little personal relevance, rather than as a web of interconnected ideas helping them to solve problems and bringing understanding to their world. To them, science education must connect to real world applications by bringing relevance to learners. In this sense, Thompson & Balschweid (1999) highlighted that scientific concepts should be taught in the agricultural education classroom where students would be allowed to apply their knowledge of science to a rich and meaningful context, since disciplines do not stand apart in isolated subjects. It means, according to Shelley-Tolbert, Conroy, & Dailey (2000), to take advantage of the active learning opportunities created by agricultural education, enabling learning where pupils employ their academic understandings and abilities in a variety of out-of-school contexts to solve complex, real world problems, both alone and in various group structures. There is a synergetic relationship in the integration of science and agriculture: the instruction in one reinforces the instruction in the other.

There are two final important points to consider regarding the agriscience movement in the US. First, the integration between agriculture, science, and technology, is improving not only the quality of the agricultural education programs, but also giving them a new image of being more than farm crops, animal and machinery. Second, research findings (Mabie & Baker, 1996; Thompson & Balschweid, 1999; Chiasson & Burnett, 2001) support that integration of science into agriculture curricula is the more effective way to teach science, and that students taught by integrating agricultural and scientific principles demonstrated higher achievement in both, agriculture and science than did students taught by traditional approaches.

## Conclusions and Recommendations

1. Agricultural education started in Brazil in 1875 as well-balanced programs in agriculture and science at all levels. The Organic Law of Agricultural Education (1946) restricted the concept of agricultural education to programs below the college level and shifted its definition to a strictly vocational meaning. This situation persists until today, with minor changes. In the Unites States, agricultural education followed pretty much the same

course, except that from 1988 on a strong academic movement starts integrating science and technology, bringing the science-based curriculum back to a position of prominence in agricultural education programs. This movement has giving agricultural education a new face and broadened its concept to education in and about agriculture.

Agricultural education in Brazil should integrate more science and technology into the curriculum to enhance the relationship between opportunities to learn in the context and the ability to transfer knowledge and skills across situations. This integration has the potential to break the agricultural schools' stigma in being non-college bound institutions, giving them a new identity and image. Also, agricultural education programs should be extended on a regular basis to rural schools, not as a vocational program, but rather as an exploratory opportunity to take advantage of the students' agricultural/rural background/interest and utilize agricultural content and experiences as a context for integrating principles and concepts from many sciences.

2. Following a worldwide trend, Brazilian agriculture and rural milieu are changing due to scientific and technological advancements. New social and economic actors are emerging. Farming is no longer the only economic activity in rural settings; in some cases it is not even the major one. Neither the rural milieu is exclusively agricultural, nor is agriculture exclusively rural anymore. This brings substantial changes in the students' expectations, perspectives, and backgrounds.

Brazilian agricultural education programs should be redesigned to cover beyond the production aspect of agriculture and even beyond agriculture itself, to prepare students for careers in and outside agriculture. It is critical that agricultural schools give students awareness about the complexity and implications of changes introduced in the natural world by human actions and make them, through scientific literacy, able to understand, apply, and generate technology.

3. Since 1988 the US started a movement to enhance the effectiveness of the teaching in science and in agriculture. This movement, known as agriscience, consists of agricultural programs that emphasize the technological and scientific aspects of agriculture. The integration between agriculture, science, and technology, is improving the quality of the agricultural education programs, since students taught by integrating agricultural and scientific principles have demonstrated higher achievement in both, agriculture and science, than did students taught by traditional approaches.

The use of agricultural concepts in the teaching of science in rural schools in Brazil could represent a great opportunity to the practice of contextual teaching and learning as well as to bring more equity to the educational system since students could have higher achievement in science with this approach. Research in this area is highly recommended in Brazilian agricultural and rural schools. On the other hand, the increment in the use of scientific and technological concepts in the teaching of agriculture in Brazilian agricultural schools could face the challenge of giving agricultural students a stronger base to understand and solve real world daily problems, as well as more consistent motivation to lifelong learning or even to pursue higher education in any field. We call this two-way approach "education through agriculture." According to this approach, agricultural education is not an end in itself, but rather a means to give students a deep understanding of the natural world and the ability to judge evidence and draw conclusions from the scientific point of view.

**Educational importance**

The understanding of the context in which agricultural and rural schools operate in Brazil is critical to promote effective equity in the scientific literacy of their students as compared to non-agricultural and non-rural students. In this sense, any official school classification as rural and agricultural based upon merely geographical, structural, and administrative criteria, should be revised to include the social, cultural, and economic interfaces. Such a revision must reflect into the curricula as the sum of all activities taking place into the school.

Recognizing the close interrelationship between agriculture, science, and technology implies that agricultural education is given a new status in the educational system as well as given the responsibility to be the main supporter of the environmental, economic, and social welfare. Agricultural education has an enlarged social role as programs devoted to prepare people with scientific literacy beyond agricultural careers and beyond agriculture itself.

The education through agriculture as suggested in this paper has vast implications to teacher preparation programs in Brazil. Teacher preparation programs must provide opportunities to explore and reflect within each discipline the linkages with the natural world and agriculture. Interfaces are needed to explore ways to combine rigorous science education with the practice of agriculture and vice-versa.

**References**

Carneiro, M. J. (1999). O ideal rurbano: campo e cidade no imaginário de jovens rurais [The rurbano ideal: Country and city in the rural youth imaginary]. In F. C. Teixeira da Silva, R. Santos & L. F. C. Costa (Eds.), *Mundo rural e política: ensaios interdisciplinares*. Rio de Janeiro, Brazil: Campus/Pronex.

Carta Régia do Principe D. João, de 25 de Junho de 1812 [Regal Letter of the Crown Prince D. João of June 25, 1812]. In Biblioteca Nacional (n.d.), *Coleção de Leis do Brasil de 1812 a 1890 [Collection of Brazilian Laws from 1812 to 1890]* (pp. 42 – 46). Rio de Janeiro, Brazil: Author.

Chiasson, T. C. & Burnett, M. F. (2001). The influence of enrollment in agriscience courses on the science achievement of high school students. *Journal of Agricultural Education, 42(1), 60 – 70.*

Conroy, C. A. (2000). Reinventing career education and recruitment in agricultural education for the 21st century. *Journal of Agricultural Education, 41(4), 73 – 84.*

Conroy, C. & Walker, N. (1998). *National aquaculture curriculum evaluation phase II: Final Report*. Ithaca, NY: Cornell University.

Decreto N. 2208 de 1997 [Decree 2208 of 1997], Diário Oficial da União, 18 de Abril de 1997, p. 7760 (Imprensa Nacional, 1997).

Decreto N. 8319 de 20 de Outubro de 1910 [Decree 8319 of October 20, 1910], Coleção de Leis do Brasil, V. 2, pp. 1046 – 1122 (Imprensa Nacional, n.d.).

Duval, C. L. (1988). The agriscience movement. *The Agricultural Education Magazine, 61(5), 18 – 21.*

Eikeland, S. & Lie, I. (1999). Pluriactivity in rural Norway. *Journal of Rural Studies, 15, 405 – 415.*

FAO (1996). *Teaching and learning in agriculture: A guide for agricultural educators*. Rome, Italy: Author.

FAO (1997). *Issues and opportunities for agricultural education and training in the 1990s and beyond*. Rome, Italy: Author.

Franco, M. L. P. B. (1987). Introduzindo a problemática do ensino técnico agrícola e um pouco de sua história [Introducing the problematic of the technical agricultural education and a little of its history]. *Revista Brasileira de Estudos Pedagógicos, 68 (158), 41 – 64.*

Gordon, L. (2001). *Brazil's second chance: En route toward the first world*. Washington, D.C.: Brookings Institution Press.

Graziano da Silva, J. & Del Grossi, M. (n.d.). O *novo rural brasileiro: uma atualização para 1992-98 [The new Brazilian rural: An update to 1992-98]*. Retrieved August 15, 2001, from UNICAMP, Institute for Economics Web Site: http://www.eco.unicamp.br/projetos/rurbano/textos/downlo/atualizacao.html

Herren, R. V., & Donahue, R. L. (1991). *The agriculture dictionary*. Albany, NY: Delmar Publishers, Inc.

Hillinson, J. (1996). The origins of agriscience: Or where did all that scientific agriculture come from? *Journal of Agricultural Education, 37(4), 8 – 13.*

Krebs, A. H., & Newman, M. E. (1994). *Agriscience in our lives* (6th ed.). Danville, IL: Interstate Publishers, Inc.

Lei 5692 de 1971 [Law 5692 of 1971], Diário Oficial da União, 12 de Agosto de 1971, pp. 6377 – 6381 (Imprensa Nacional, 1971).

Lei 7044 de 1982 [Law 7044 of 1982], Diário Oficial da União, 19 de Outubro de 1982, p. 19539 (Imprensa Nacional, 1982).

Lei de Diretrizes e Bases da Educação Nacional de 1961 [Directives and Basics of National Education Law of 1961], Diário Oficial da União, 27 de Dezembro de 1961, pp. 11429 – 11435 (Imprensa Nacional, 1961).

Lei de Diretrizes e Bases da Educação Nacional de 1996 [Directives and Basics of National Education Law of 1996], Diário Oficial da União, 23 de Dezembro de 1996, pp. 27833 – 27838 (Imprensa Nacional, 1996).

Lei Orgânica do Ensino Agrícola de 1946 [Organic Law of Agricultural Education of 1946], Diário Oficial da União, 23 de Agosto de 1946, pp. 12019 – 12024 (Imprensa Nacional 1946).

Mabie, R. & Baker, M. (1996). A comparison of experiential instructional strategies upon the science process skills on urban elementary students. *Journal of Agricultural Education*, 37(2), 1 – 7.

McCormick, F. G., Cox, D. E., Zurbrick, P. R., & Miller, G. M. (1988). *A model for agricultural education in secondary schools.* Unpublished manuscript, University of Arizona at Tucson.

Moore, G. E. (1987, December). *To tell the truth: The impact of the Hatch Act on secondary agricultural education.* Paper presented at the meeting of the American Association of Teacher Educators in Agriculture, Las Vegas, NV.

National Research Council (1998). *Understanding agriculture: New directions for education.* Washington, DC: National Academy Press.

Shelley-Tolbert, C. A., Conroy, C. A., & Dailey, A. L. (2000). The move to agriscience and its impact on teacher education in agriculture. *Journal of Agricultural Education, 41(4), 51 – 61.*

Sofer, M. (2001). Pluriactivity in the Moshav: Family farming in Israel. *Journal of Rural Studies, 17, 363 – 375.*

Solbrig, O. T. (2001). The impact of globalization and the information society on the rural space: Conceptual analysis and some policy suggestions. In O. T. Solbrig, R. Paarlberg & F. di Castri (Eds.), *Globalization and the rural environment* (pp. 3 – 21). Cambridge, MA: Harvard University David Rockefeller Center for Latin American Studies.

Thompson, G. (1998). Implications of integrating science in secondary agricultural education programs. *Journal of Agricultural Education, 39(4), 76 – 85.*

Thompson, G. W. & Balschweid, M. M. (1999). Attitudes of Oregon agricultural science and technology teachers toward integrating science. *Journal of Agricultural Education, 40(3), 21 – 29.*

Trexler, C. & Miller, N. (1992). Improving scientific literacy through an agriscience curriculum. *The Agricultural Education Magazine, 65(4), 14 – 16, 23.*

Whent, L. (1992). Bridging the gap between agricultural and science education. *The Agricultural Education Magazine, 65(4), 6 – 8.*

**Key words:** agricultural education, rural education, agriscience, science education, agricultural schools.

030

# TRANSFORMING AN UNDERGRADUATE CURRICULUM. THE DEPARTMENT OF BIOLOGICAL SCIENCES EXPERIENCE.

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## Abstract

This paper describes two periods in the 1990's when sets of particular circumstances impacted the curriculum of the Department of Biological Sciences, University of Calgary. In the period, 1990-1995, the Alberta Provincial Government in an effort to deal with a budgetary crisis imposed budget cuts of five percent on all government run operations. In an effort to meet its five percent reduction, the University of Calgary relied on voluntary measures. Unfortunately, this resulted in differential cuts across the campus and the Department of Biological Sciences suffered a 15% loss of full-time faculty. This loss occurred at a time of ever increasing demand for places in the programmes offered by the Department. To combat the synergistic effect of these two trends the Department proactively redesigned its curriculum in an effort to maintain instructional quality.

The second period, from 1998 to the end of the millennium, was a period of introspection by the University. The University defined a set of institutional goals against which all its undergraduate programmes would be measured. The way in which the programmes of the Department of Biological Sciences measures up to this institutional framework is the subject of the second part of the paper.

## Introduction

In the two decades leading up to the turn of the millennium, university and college campuses in North America experienced an explosive growth in the number of students requesting places in biological sciences programmes. Unfortunately, in the late 1980's and early 1990's another trend, the state of the economy, had an inordinate impact on the ability of universities to deliver quality programming to their undergraduates. State-supported institutions were particularly vulnerable to the impact of both trends. The Department of Biological Sciences at University of Calgary was swept up by both these trends. I discuss this period in the early1990's when the Department took steps to redesign its curricula to maintain instructional quality. The University started a process of curriculum examination and renewal as we neared the turn of the millennium. The balance of the paper is devoted to discussing how the Department participated in this university-wide exercise.

*Note to the reader*: The University of Calgary bases graduation requirements on full-course equivalents where a full course is one that is spread over two academic terms. In a half course, course work is completed in one term. When students complete two half courses, they are awarded one full-course equivalent. In the Department of Biological Sciences, students must complete successfully 20 full-course equivalents to graduate.

## Innovation at a time of Fiscal Restraint

A brief history of the Department of Biological Sciences shows an ongoing process of curriculum evaluation and redesign. This history includes amalgamation of the Departments of Botany and Zoology (1965) to form a Department of Biology. In 1986, that Department united with biochemists from the Department of Chemistry to form the current Department of Biological Sciences. This was accompanied by internal reorganization to form the five Divisions: Biochemistry; Botany; Cellular, Molecular and Microbial Biology (CMMB); Ecology and Zoology. Each transition in this history stimulated consideration of how best to educate students in the diverse biological sciences, given an exponential growth in knowledge, but a fixed duration for an undergraduate programme. Each Division administers an undergraduate programme and collectively the Department organizes a broad-based, more generalized one. The current programmes offered by the Department of Biological Sciences reflect identifiable fields of study within the biological sciences as represented by the perspectives of professional scientists around the world.

In the early1990's, the financial situation in the Province of Alberta was starting to set off alarm bells and the then Department Head, Dr. R.W. Davies, heeded these before most other people on the campus of University of Calgary. He foresaw impending reductions in resources at a time when the number of students was increasing sharply. He appointed an ad hoc committee early in 1991 and charged them to design a curriculum that would allow the maintenance of quality of experience with sharply curtailed resources. In 1993, the Provincial Government announced a provincial budget of five percent across the board.

For the Department of Biological Sciences, the collision of curtailed resources against rising student numbers was very sharp indeed. In 1990 the Department had 678 second-to-final year students registered in the six-degree programmes but by 1994 these numbers had grown substantially by some 47% to almost 1000 students. To meet the mandated budget cut of five percent, the University engaged in a series of voluntary retirements and severance packages. The net result of this policy was to distribute the budget cuts unevenly across the campus. The Department of Biological Sciences took an inordinate hit: in 1990, the Department has 46.8 full-time faculty equivalents, but by 1995 this number had diminished to 39.8 full-time faculty equivalents, a decrease of almost 15%.

To deal with these problems, the Department implemented two different kinds of strategies. Firstly, the Department was able to convince the senior administration to cap the number of students admitted to Departmental programmes. Thus 1994 represented the apex in student numbers, and the enrollment-management plan that was adopted slowly reduced these numbers to below 800 by the end of the decade. About 300 second-year students are admitted each year into the Department. Unfortunately, this selectivity results in roughly 40% of qualified students who apply to enter Biological Sciences programmes being turned away each year. Even with enrollment limitations, the ability to provide undergraduates with the best education is still constrained by the number of faculty and support staff available for teaching. Although majors in Biological Sciences programmes represent 40% of all undergraduate majors in the Faculty of Science, academic and support staff in Biological Sciences comprise less than one quarter of the personnel in the Faculty. Thus, the average course section includes 226 students in junior-level courses and 47 students in senior-level courses (Fact Book 1999-2000, Office of Institutional Analysis). Nonetheless, the enrollment-limitation policy has enhanced the achievement level of the graduates from the Department.

*Development of the current curriculum* – the second measure that was implemented was curriculum reform. Prior to 1994, all students in Biological Sciences were required to complete a common core of seven half-courses in biology and biochemistry (Bio-core). These courses were supposed to serve as the underpinning for all degree programmes. Unfortunately other programme requirements made it difficult for students to complete all these courses during their first two years and many students treated some of the core courses as exit requirements, rather than as foundations to their programme. Prompted by these shortcomings and the anticipated consequences of looming budget cuts, in 1991 the Department of Biological Sciences initiated an extensive redesign of the Bio-Core and the curricula of all programmes.

In that year, a seven-member committee presented the Department with four options for restructuring the Bio-core and in 1992 a five-half course Bio-core was adopted in principle. Then followed a year-long Departmental debate that resulted in the finalization of the content of the five half courses and in the Fall of 1993 the University gave its approval to these changes. The new Bio-core is designed for completion during the first two years of a student's programme, thus giving all students a common set of skills and knowledge on which to build. The new first-year courses were offered in the fall of 1994 and the second-year courses were phased in a year later. The Department formalized a mechanism for periodic review of the Bio-core at the same time; i.e., the fall of 1994. The Department is currently restructuring the first-year courses following recommendations of the second periodic review.

*Cooperation on Academic Matters among Alberta Universities* – In 1994 Dr. A.P. Russell became Head of the Department of Biological Sciences, University of Calgary. Since the budget reductions had affected all universities, he invited sister departments at the Universities of Alberta and Lethbridge to work together to ameliorate some of the damage caused by the budget reductions. A series of meetings in 1994 and 1995 resulted in the formation of the Alberta Tri-Universities Biological Consortium. The major work of this partnership has been to facilitate transfer of students between institutions under a Block Transfer Agreement. The group recognized that although course models at each institution were different, there was significant commonality in the content and concepts covered in the first two years. Thus, the three Departments agreed on a 10 full-course equivalent block of courses which if completed at a particular institution would satisfy the requirements for third-year standing at any of the other Alberta Universities. The agreement dealt with the necessary content that comprised this course block, rather than the detailed organization of content into specific courses. For this process, the newly designed Bio-core served as the model for content requirement in Biological Sciences courses. The Transfer Agreement has since been extended to all public-funded colleges and some private universities and colleges within the Province of Alberta, allowing relatively easy transfer among post-secondary institutions within the Province. This Agreement has been so successful that it is serving as a model across the country.

The Consortium also looked for ways to share resources because the cutbacks of the mid-1990's have resulted in specific areas of expertise being lost from particular departments, but not necessarily from the entire province. As an example, at the University of Calgary one such loss has been in animal parasitology. Considerable strength in this area remained at the University of Alberta. The decision was made to develop and share a videoconferenced course in this area between the Universities of Alberta and Calgary with primary delivery coming from the University of Alberta. This shared course, at the third-year undergraduate level, has operated successfully since the winter 1997 session.

## The University of Calgary Strategic Transformation Initiative

In 1998 the University of Calgary embarked on a campus-wide effort to have all undergraduate programmes meet a defined set of institutional goals. Firstly, Dr. R. Day led a team (1998) from across campus that devised a learner-centred model based on Schwab (1962) to serve as the basis for curriculum redesign. The team proposed a framework of seven identifiable features for all undergraduate programmes; viz., a clearly identifiable field of study, a defined interdisciplinary component, an international component, an experiential-learning component, provision for broad and extended faculty-student interaction, integration of research and an explicit programme syllabus. The University previously had identified several core competencies that were desirable for all graduates to possess. To fast track the process, faculty members were awarded fellowships to champion curriculum redesign in their particular undergraduate programme.

G.B. Bourne was appointed the first fellow in the Department of Biological Sciences and was joined at various times by the following people: J.R. Post (replaced by L.D. Harder), C.C. Chinnappa (replaced by P.J. Facchini), R.E. Huber (replaced by E. Lohmeier-Vogel) and M.J. Lohka. During 1999 and 2000 fellows met biweekly except for the summer months. These Biological Sciences fellows consulted widely within and outside the Department. The opinions of both graduate and undergraduate students were sought at various stages in the process. The sentiments expressed by Seymour and Hewitt (1997) and in Boyer Report figured prominently in the deliberations of the group. Finalization of the syllabus occurred during fall 2000 under the coordination of Bourne and Harder. During December and early January 2001, as Bourne prepared for and left the city on sabbatical leave, Harder assumed the greater share of coordinating the project. In the end a single document covering the six undergraduate programmes offered by the Department was submitted to the University.

*How Biological Sciences Measured Up to the Seven Features* – the initial step was evaluating the programmes to see how they stacked up against the seven features. This evaluation, described below, demonstrated that by and large the Departmental programmes matched up well.

*Identifiable Field of Study* – Broadly, the biological sciences consider all aspects of life from the structure and function of biologically active molecules to the control of global, atmospheric concentrations of carbon dioxide by photosynthesis and respiration of the world's biota. Given this scope and the diversity of species (>3,000,000 alive today), no student of life can expect to develop facility with the entire field of the biological sciences. Therefore the study of life has become partitioned into several disciplines. Life can be studied from two perspectives, by focusing on a particular group of organisms (micro-organisms, plants, animals), or by focusing on a level of organization of life processes (chemistry of life; cells, tissues and organs; individuals, populations and ecosystems). The five specialist programmes offered by the Department of Biological Sciences allow students to adopt either perspective, whereas the generalist Biological Sciences programmes allow students to take advantage of the merits of both perspectives.

*Interdisciplinary Component* – the biological sciences, in general, and of our programmes, in particular, have a rich tradition of adopting and adapting the knowledge and approaches of other disciplines when they promote understanding life. In many cases, the linkage between biological sciences and other scientific disciplines is obvious. Life on Earth exists in a physical, chemical, geographic and geological context. As a result, programmes in Biological Sciences necessarily incorporate physics, chemistry and geology courses and, more importantly, integrate concepts from these disciplines in many Biological Sciences courses (e.g., courses on biochemistry, physiology, aquatic ecology). In addition, the biological sciences are quantitative, drawing on a variety of mathematical and statistical approaches to understand complex processes and distinguish interesting occurrences from natural variation. Finally, medicine is in part a branch of biological sciences that specializes in human well-being. Given the self-interest of humans, medicine receives more financial resources than biology, so that much of our understanding of the structure and function of animal bodies and their interaction with micro-organisms was initiated by medical research. As a result, there are many parallels with medicine in the content of courses in our programmes in Biochemistry, Cellular, Molecular and Microbial Biology, and Zoology.

Although less obvious, the biological sciences have also borrowed many ideas from humanities and social sciences. Like all sciences, biological sciences incorporate a method of logical analysis with a strong philosophical foundation. Students are taught this method implicitly during discussions of the development of biological knowledge and through repeated application during practical exercises. In addition, many aspects of organismal biology share considerable common ground with disciplines in the social sciences. In many cases, this commonality arises from shared subjects considered for animals other than humans or our close relatives. For example psychology, sociology and physical anthropology all consider topics that are inherently biological. The development of aspects of these disciplines and the study of animal behaviour and evolution has involved a cross-disciplinary interplay. In other cases, the linkage between biological sciences and social sciences has been conceptual. The most obvious examples involve the incorporation of approaches from economics to identify physiological, behavioural and ecological characteristics that maximize an organism's performance. In addition to the incorporation of ideas and approaches from the humanities and social sciences in biological sciences courses, the programmes encourage direct participation in humanities and social sciences courses to allow students to understand the human context of their discipline.

*International Component* – this feature may be interpreted in two ways, which are distinguished as international versus global. Reference to "nation" in the term "international" implies an anthropocentric perspective. From this view, an international curriculum component would expose students to the geographical diversity of cultures and outlooks among human societies. Such a curriculum objective seems reasonable because at some point aspects of human experience or endeavour come into play in all programmes, so that an international component is a worthy goal. However, biological sciences consider all organisms, not just humans. Hence, programmes in biological sciences should include the geographic diversity of all life on Earth. To encourage an appreciation of this global perspective, education in biological sciences requires some different curriculum elements than that in human-centred disciplines.

Teaching students from the University of Calgary biology elsewhere in the world provides a much richer global and international experience. On occasion, faculty from the Department of Biological Sciences lead foreign field courses and so incorporate both the international and global perspectives. Some students take advantage of existing bilateral exchange agreements; e.g., University of Lancaster, University of Lund and University of Queensland. A few students in the Ecology Co-op programme have independently found foreign work-term placements. Unfortunately, the cost of such activities and the size of the Departmental undergraduate student body mitigate against any but a small proportion of students engaging in study abroad opportunities.

*Experiential Learning* – the Department of Biological Sciences emphasizes the pedagogical approach characterized by the American Association for the Advancement of Science as "teaching science as scientists practice science." As a result, the programmes offered by the Department of Biological Sciences excel in enabling students to learn by experience. The following list partially illustrates means by which this outcome is achieved:

- Students are exposed to laboratory experience from first year. The Department has steadfastly refused to follow the trend of dropping laboratories, which was part of budget cutting exercises across North America during the 1990's. Successive Department Heads have been praised at annual meetings of the Canadian Council of University Biology Chairs for this stance;
- Some first-year laboratories are investigative and this approach continues and intensifies as students move through their programmes;
- Several courses include field trips;
- Students have access to summer courses and the Fall Programme offered by the Bamfield Marine Sciences Centre;
- Each year, several Ecology and Zoology courses are delivered at the Kananaskis Field Stations as part of the spring and summer offerings;
- All programmes includes half-year (507) and full-year courses (528 and 530) that allow students to conduct their own research;
- Undergraduates, particularly those enrolled in the research courses, are encouraged to attend and participate in seminar/workshop courses for our graduate students;
- Each year, many faculty members in our Department hire undergraduates to assist with laboratory and field studies. These students are hired from external research funds, sometimes supplemented with National Science and Engineering Research Council summer studentships and Alberta Heritage Foundation Medical Research summer studentships;
- The Department teams up with both the Public and Separate School Boards and the Science Centre to offer a Biology Curriculum Enhancement course. In this course, students act as content specialists and aid elementary school teachers to implement the grades K-6 science curriculum;
- Undergraduates are encouraged to volunteer in research laboratories;
- Sometimes senior undergraduates are employed as teaching assistants.

*Integration of Research* – research is the source of all knowledge that comprises the biological sciences, so it is natural to integrate both the process and the outcome of research in our programmes. Students are exposed to research continuously. Most lecturers use contemporary examples from the primary research literature to illustrate conceptual and technical developments. When relevant, these examples are drawn from research conducted at the University of Calgary by professors, graduate students, or undergraduates in independent research courses. Annual Divisional open houses further expose students to research conducted in the Department. Many courses in our programmes include written assignments for which students are expected to use the primary literature to develop and support an argument. In addition, many laboratory and field exercises are inquiry-based, so that students must learn and use research techniques to discover the mechanism responsible for an observed biological phenomenon. Such research experience is implemented most fully in independent research courses, which are taken by about half of the majors in the specialized programmes and are required of all Honours students. Some of these projects have produced research of sufficient merit to be published in international research journals. Finally, our faculty hire roughly 50 undergraduates each summer to assist with the research projects, providing students with a sense of many facets of the pursuit of knowledge.

*Provision for Broad and Extended Faculty-Student Interaction* – the Department of Biological Sciences has a long history of initiatives for both formal and informal interaction between undergraduate students, graduate students and faculty, including:

- Monthly socials, one of which is hosted by the Biology Students' Association each year;
- Annual Divisional open houses, which introduce students to the research of each faculty member and their graduate students;
- Most Divisions hold an annual dinner and/or Christmas party to which undergraduates are invited;

- Students in courses with field components interact with their instructors extensively;
- Independent research courses (507, 528, 530) which allow students to work on a one-on-one basis with Faculty;
- Meritorious students are honoured each spring at the Annual Achievement celebration; all spring graduates are honoured immediately after convocation at the Annual Strawberry Tea, held on the lawn east of the Biological Sciences Building;
- An Advising Guide Book, written by A.P. Russell, G.B. Bourne & N. Klein, helps Faculty understand the importance of and their roles in interacting with students;
- The Department offers two orientation courses (Biology 007 & 009) which provide advice on how students may access Departmental services;
- Some Divisions assign students to specific advisors.

Despite these initiatives, the size of the student body remains a major impediment to more extensive interactions between faculty and undergraduates.

*Explicit Syllabus* – the development of an Explicit Syllabus is the most important outcome of the current curriculum initiative. The University Calendar in its semi-legalese conveys no sense of either the joy of learning or the rationale for the structure of different programmes. We anticipate that students who have used the Explicit Syllabus will have much more realistic expectations of our programmes and will be better prepared to plan a programme that satisfies their personal educational objectives.

## References

Kenny, Robert W. 1997. The Boyer Commission on Educating Undergraduates in the Research University. REINVENTING UNDERGRADUATE EDUCATION: A Blueprint for America's Research Universities http://naples.cc.sunysb.edu/Pres/boyer.nsf/

Schwab, Joseph J. 1962. The Teaching of Science as Enquiry. Harvard University Press, Cambridge, MA

Seymour, Elaine and Nancy M. Hewitt. 1997. Talking about Leaving. Why Undergraduates Leave the Sciences. Westview Press. Boulder, CO.

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**Keywords:** biological sciences, budget cuts, curriculum redesign, explicit syllabus, undergraduates

# 031 USING ACTION BASED RESEARCH TEAMS AND TECHNOLOGY TO FOSTER CONSTRUCTIVIST APPROACHES TO REFORM UNDERGRADUATE COLLEGE SCIENCE TEACHING

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## Abstract

Reforming undergraduate science courses is a continuing and on-going concern of university and college faculty. Reports such as the National Science Foundation's, *Shaping the Future* (1996), and the Boyer Commission Report, *Reinventing Undergraduate Education* (1998), underscore this concern. Both reports indicate that undergraduate science courses tend to isolate students from the content and from the professor. Much of this is attributed to a teacher-centered autocratic style of teaching which is quite often the norm for the university science classroom. These reports recommend that learning should be integrative, collaborative, constructivist, and utilize technology to foster teaching and learning. Further, these reports recommend that the goal should be to have a student-centered classroom where students take an active role in their learning process and that the professor becomes a guide or mentor.

Action based research involves the identification of a problem and what needs to be improved in the science curriculum. The second step is to develop a plan to address the problem and to assign roles for the team members. The third step is to put the plan into action. Finally, a variety of data sources are used to evaluate the impact of the implemented changes. After the analysis of the data sources, the cycle begins again with a return to the step of identifying the problem.

Using Earth science as an example, this presentation will address the issues of developing an action based research team along with the infusion of technology into the undergraduate college science content curriculum. Illustrations will be provided regarding how faculty in the School of Science at Purdue University developed, implemented, and assessed the use of action based research teams and technology to improve the teaching and learning of science. How to develop a partnership among scientists, science educators, master teachers, graduate students, and undergraduate students will be presented.

## Introduction

Improving undergraduate science courses is a continuing and on-going concern of university and college faculty. Reports such as the National Science Foundation's *Shaping the Future* (1996) and the Boyer Commission Report, *Reinventing Undergraduate Education: A Blueprint for America's Universities* (Boyer Commission, 1998) underscore this concern. Both reports indicate undergraduate science courses tend to isolate students from the content and the professor. Much of this is attributed to a teacher-centered autocratic style of teaching, which is quite often the norm for the university science classroom. These reports recommend that learning should be integrative, wherein the professors incorporate laboratory work, group work, and discussion sections into their lesson plans. Faculty in the School of Science at Purdue University have developed action based research teams in the Departments of Biological Sciences, Chemistry, and Earth and Atmospheric Sciences to develop student-centered classrooms.

The goal of a student-centered classroom, where students take an active role in their learning process and the professor becomes a guide or mentor, is reflected in many of the innovations suggested for undergraduate science instruction. For example, *Powerful Ideas in Physical Science* (American Association of Physics Teachers, 1996) has students actively constructing their understanding of physical science concepts through investigation and small group discussions while the professor facilitates student work through carefully worded dialogue with the investigative groups or whole class discussions. Other examples of student-centered teaching are found in the articles published in journals such as *The Journal of College Science Teaching* (Adams &

Slater, 1998). These teaching tips and ideas appear to have worked well for the individuals that have tried them. Yet, if these techniques and materials are effective why are there not more institutions and individuals implementing these elements into their instruction?

## Obstacles to Change

The greatest difficulties that we have faced with implementing curricular innovation in our science courses stem from both peer faculty and students. Some of the concerns and reasons expressed by these individuals are:

- It won't work in our setting.
- This isn't the way we teach this topic.
- The students won't be prepared for the upper level courses.
- We didn't learn it this way in high school.
- I don't like to work with other students; they don't pull their share.

These comments reflect the inertia that all of us face when we try to implement change in our classrooms. Despite this, there are those who do succeed in implementing curricular innovations that appear to be successful. The question that should be asked is, "How can I succeed in improving my courses and convince my colleagues that it was a positive action to take?"

Faculty members at Purdue University in the departments of Earth and Atmospheric Sciences, Biological Sciences, and Chemistry decided to address this issue head-on. The faculty collaborated on a National Science Foundation funded project (Purdue University, 1996) which utilized a partnership of scientists, science educators, master teachers, graduate students, and undergraduates who focused on promoting improvements in the teaching of introductory courses in biology, chemistry, and earth sciences. The goal of the collaboration was to enhance the education of preservice teachers and the education of science, mathematics, engineering and technology majors in their introductory courses. The method of changing the curriculum was through the use of action based research teams.

## What is Action Based Research?

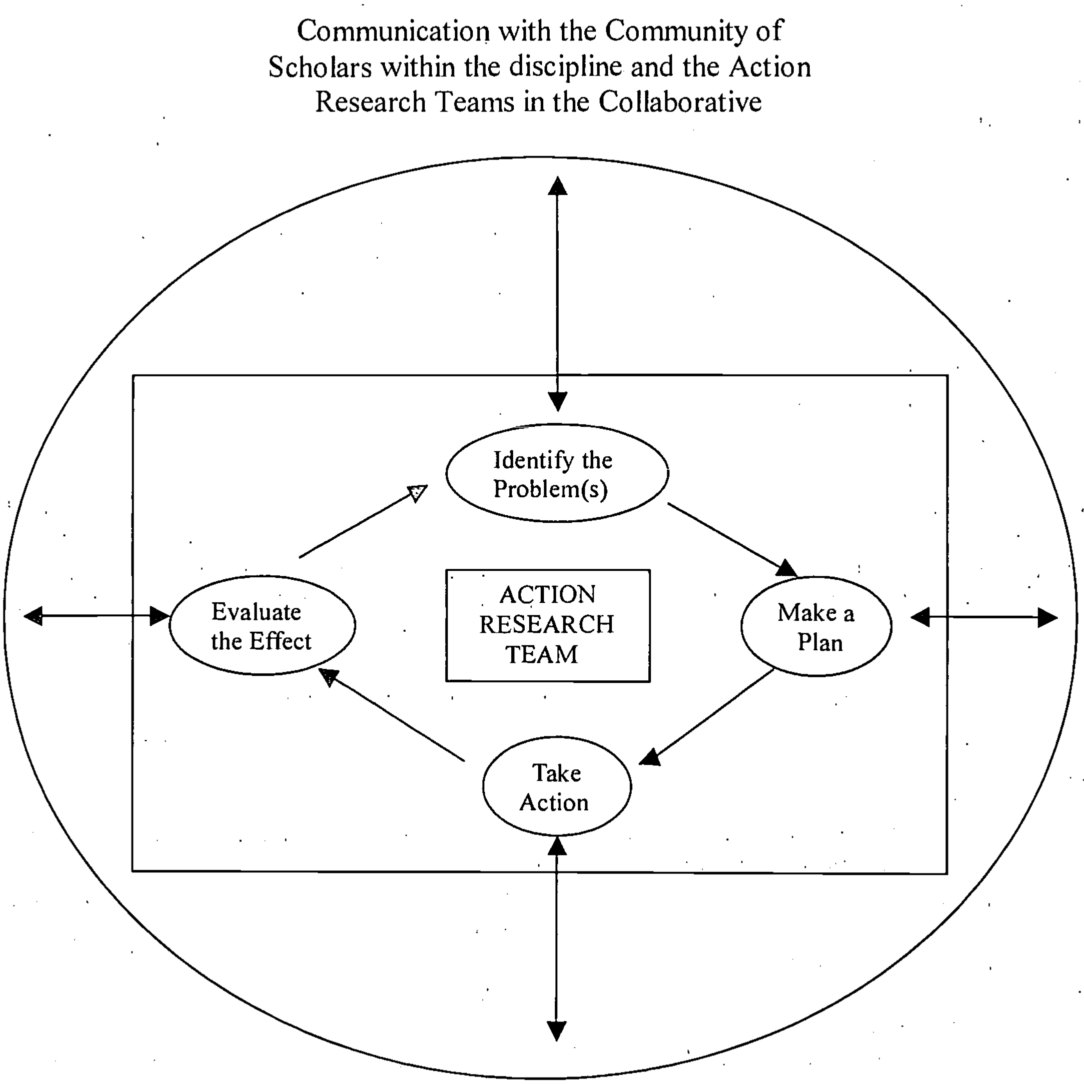
Action based research provides a method to manage change in an instructional setting, produce documentation as to the effectiveness of the changes, and provide information on further changes (Keating, Diaz-Greenberg, Baldwin, & Thousand, 1998). Action based research is defined as: "an ongoing, self reflective process that involves critical examination of teaching practices or theories to improve personal practice and the education of the students" (Hamilton, 1995, p. 79). Thus, "the action research framework is most appropriate for participants who recognize the existence of shortcomings in their educational activities and who would like to adopt some initial stance in regard to the problem, formulate a plan, carry out an intervention, evaluate the outcomes and develop further strategies in an iterative fashion" (Hopkins as cited by MacIsaac, 1995). "In this way 'the process of teaching and the role of research in science teaching have a common end – to enhance science instruction, students' learning, and the assessment of both" (Kyle, Linn, Bitner, Mitchener, & Perry, 1991).

Efforts of implementing action research models in higher education settings, though limited in number, support our belief that action research is an effective means for the reform of teaching introductory college and university science (Chism, Sanders, & Zitlow, 1987; Cross, 1990; Fedock, Zambo, & Corbern, 1996). Additionally, results from the action based research project at Purdue University indicate that involving action based research teams in the study of both content and pedagogy increases the amount of connected knowledge and student-centered pedagogical knowledge gained by students, undergraduates, graduate students, and university faculty.

## Purdue University Action Based Research Model

The first step in implementing an action based research project to improve the way a course is taught is to identify a research team. At Purdue University the course teams for Biology 205/206 Biology for Elementary Teachers, Chemistry 115/116 General Chemistry, and Geoscience 102 Earth Science for Elementary Teachers were designed to include a scientist, science educator, beginning teacher, preservice teacher, and a graduate teaching assistant. This team structure was used to provide multiple perspectives in interpreting collected data about the effectiveness of the implemented changes. This structure was unique to the task of improving science instruction of preservice teachers. The structure of teams at different institutions should be reflective of the intended goal. If it is to improve science classes for non-science majors it might consist of the faculty involved in these courses and undergraduates who assist with or take the courses. While action based research can be a solitary activity, our experience indicates that a team approach is very productive for making sense of the data collected and using this to support and modify changes, especially when defending these changes to other faculty.

Once the team is identified, the action research process begins. Figure 1 illustrates the steps in the process of action research and its emphasis on continual improvement.




*An Action Research Team consists of: (1) a scientist, (2) a science educator, (3) a beginning teacher, (4) a pre-service teacher, and (5) a graduate teaching assistant.

**Figure 1.** Action Research Team Model

The first step is to identify a problem. What is it that is not working in the classroom or what needs to be improved? The faculty participating in the action research project at Purdue University established an overall goal of improving instruction by having the students take a more active role in their learning. Each team then identified questions that they wanted to address through action research as shown in Table 1.

**Table 1.** Action Based Research Team Questions

| Course | Question |
|---|---|
| BIOL 205: Biology for Elementary Teachers<br>Enrollment: 500/year | What are effective teaching, learning, and professional development modeling activities about ecosystems for preservice teachers and teaching assistants? |
| CHM 115: General Chemistry<br>Enrollment: 2,000/year | Does the construction and use of concept maps lead to an increased achievement and learning about thermochemistry?<br>Can the technique of concept mapping be integrated successfully into the learning activities for Chemistry 115 students, graduate instructors, and faculty? |
| GEOS 102: Earth Science for Elementary Teachers<br>Enrollment: 56/year | Are students better able to understand a complex system or cycle if they participate in field trips that examine individual components of a system and construct small-scale physical models (simulators) of the system? |

The questions identified by each of the action based research teams, shown in Table 1, were a result of the team members reviewing the literature on teaching innovations in their area and then deciding as a group on one aspect to change in the courses.

The second step in implementing the change is to develop a plan and assign roles for the team members. The plan needs to include details such as at what point in the course will the change be implemented, what are the team and student actions, what resources are needed, and what data needs to be collected to document the impact of the change. A timeline is critical for successful implementation and data collection. An outline of the procedure developed by each of the Purdue University research teams is provided in Table 2.

**Table 2** Implementation Procedures for the Action Research Projects at Purdue University

| Course | Procedure |
|---|---|
| BIOL 205 | 1. Modify the instruction on ecosystems to include three different models for students to investigate (previously only two models were used).<br>2. Student groups will develop a model-ecosystem in an aquarium over a ten-week period. The information gathered will be used to write a final report based on the growth, changes, and interactions occurring in the model.<br>3. The students will use a computer simulation as an interactive ecosystem model to manipulate biotic and abiotic variables.<br>4. The students participate in a field trip to a nearby park for a hands-on opportunity to see an ecosystem in its natural setting.<br>5. The students will complete a written survey that addresses the effectiveness of these models as teaching and learning tools. |

| | |
|---|---|
| CHM 115 | 1. Introduce graduate instructors to the technique of concept mapping during a regularly scheduled weekly staff meeting.<br>2. Introduce students to the concept mapping process using familiar chemical concepts.<br>3. Include concept maps, along with mathematical problem solving, in each of two weekly CHM 115 assignments when thermochemistry is studied.<br>4. Have individual students construct a concept map involving thermochemistry as one of their weekly quizzes.<br>5. Use and show concept maps during faculty lectures.<br>6. Compare student performance on paired (i.e. conceptual versus algorithmic) thermochemical exam questions. |
| GEOS 102 | 1. Students participate in a three-week minicourse focusing on the hydrologic cycle.<br>2. Students will participate in a one-half day field trip and make observations about water flow during the field trip.<br>3. The students will conduct experiments using a small-scale hydrology model that they construct based on observations made during the field trip.<br>4. The students will complete an inquiry-based question set and a multiple-choice comprehensive examination.<br>5. The students will work in collaborative groups of 4 - 5 students during each stage of the minicourse.<br>6. The students will maintain a journal during the minicourse describing their observations and interpretations of the activities conducted in the field and laboratory.<br>7. The course instructor, graduate teaching assistant, and geoscientist facilitated student learning and will not lecture on the content or methods of the minicourse. |

The third step is to put the plan into action. As noted in Table 2, the implemented plans did not take place throughout the whole semester but rather were a subsection of the semester. The advantage of this implementation is that it allows the instructors to concentrate their efforts on a single revision rather than developing a whole course. Another advantage is that a focused effort allows quick data collection and analysis that can then be used to improve the course, as shown in the fourth step of Figure 1.

The Purdue University teams used a variety of data sources to evaluate the impact of the implemented changes as shown in Table 3. The key factor is not the number and variety of data sources, but rather the quality of these sources in informing the action based research team on what worked, what did not work, and why. This information is vital in deciding what should be modified, kept, or dropped.

**Table 3** Data Sources Used to Evaluate Implemented Changes

| Course | Data Sources |
|---|---|
| BIOL 205 | Comparison of lecture exam results from previous years.<br>Analysis of teaching assistant surveys on the effectiveness of the models.<br>Analysis of student surveys on the effectiveness of the models. |
| CHM 115 | Student questionnaires on concept mapping.<br>Graduate assistant questionnaires on concept mapping.<br>Compare performance on ten traditional thermochemistry exam questions between a section of the course not using concept maps and the section using concept maps.<br>Statistical analysis of grade distributions of students in two sections of chemistry (one with concept maps and one without concept maps). |
| GEOS 102 | Student interviews before and after the minicourse instruction.<br>Item analysis of the written exam.<br>Analysis of student written summary of the minicourse. |

After the analysis of the data sources, the cycle begins again with a return to the step of identifying the problem. In the case of the action research teams at Purdue University several actions resulted from the analysis of the data. For example, the original intent of the chemistry team was to only utilize concept maps during the thermochemistry portion of the course. Analysis of the grade distributions on the thermochemistry exam indicated that there was a shift in grades in the lower end of the range toward the "C" range in the section of the course that used concept maps. Based on this the instructor of the course continued to use concept maps as part of the weekly homework assignments until the exam following the thermochemistry unit.

Even though student survey response towards concept mapping was mixed, there was some evidence that the innovation might be of use in helping students learn. Analysis of all the data sources lead the chemistry team to identify a series of actions to consider as they implement concept mapping in subsequent semesters. Some of these actions are to develop strategies for helping students see the connections between concept maps, learning, and exams; examine the terms used on the concept maps and number of terms used; and establish a reward system for doing the concept maps.

The biology team's analysis provided insight about the relative effectiveness of the three models that they used in the classroom as discussed in Table 2. In general students indicated that the computer activity was repetitive and therefore not very effective in comparison to the other activities. There was also some confusion in reporting findings on the model ecosystem between different laboratory sections. Based on these comments the team has planned to revise the course by streamlining the data transfer between sections. The biology team is also looking for a replacement computer program that models a forest ecosystem like the park visit, rather than an aquatic ecosystem in order to better tie the models together.

The geoscience team's analysis indicated that not all of the directions were concise or clear for the activities, tests should more closely reflect the content of the minicourse, and more explanation was needed on the hydrologic cycle. Changes have been made in the course structure to reflect these suggestions. Additionally new activities have been developed to address areas in the minicourse that the team did not feel were working.

## Benefits of Action Based Research

It should be evident that the process of action based research led us back to where we started: a set of questions to address for improving instruction. The Purdue University action based research teams are now in the process of conducting new action based research projects based on the outcomes of their first investigation. The process provides evidence to make instructional decisions based on what works within the context of the institution.

The model illustrated here provides a mechanism for implementing a curriculum innovation and documenting its effectiveness. So, for example, if an instructor wanted to use collaborative groups to develop understanding of physics concepts, the steps outlined here will help with the implementation of the innovation and provide the evidence to defend its use and improve the implementation.

As illustrated in Figure 1, an important element of the action research based model is communicating the outcomes of your efforts to others. This can be done through a variety of forums. At Purdue University the faculty teams have reported their results during faculty colloquia. An apparent outcome of this is that peers will know what you have done, why you have done it, and what impact it has had on students. You have shown, with data, that a particular innovation works within the context of your institution. A secondary outcome we have observed at Purdue University is that evidence collected through action research speaks to science faculty. One of the teams in this project has reported that other faculty members have seen the changes that are occurring and are now in the process of bring these innovations into their classrooms...classrooms that have not changed methods in 20 plus years. Not only does this have the potential to substantially improve undergraduate education in the sciences, but it also carries recognition by peers of efforts to improve teaching prowess.

Another aspect of using action based research as an ongoing practice for college science instruction deals with the issue of accountability. The data collected as part of a project, not only helps to evaluate and improve instruction, but also documents the "value added" or achievement of course and program goals. The political climate, which translates into issues related to accreditation, make it clear that the products of action based research can provide the type of evidence that is being sought by entities external to the institution.

The literature on college science teaching is replete with examples of teaching innovations. Each of these innovations is, to a greater or lesser extent, unique to the setting in which they originate. Action based research provides a mechanism for faculty to implement change, systematically analyze the impact of the innovation, and finally adapt it to the needs of their institutions.

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**References**

AMERICAN ASSOCIATION OF PHYSICS TEACHERS. (1996). *Powerful ideas in physical science.* College Park, MD: Author.

BOYER COMMISSION ON EDUCATING UNDERGRADUATES IN THE RESEARCH UNIVERSITY. (1998, April). *Reinventing undergraduate education: A blueprint for America's research universities.* Available: http://naples.cc.sunysb.edu/Pres/boyer.nsf/

CHISM, N., SANDERS, D, & ZITLOW, C. (1987). Observation of a faculty development program based on practice-centered inquiry. *Peabody Journal of Education, 63*(3), 1-21.

CROSS, K.P. (1990). Teaching to improve learning. *Journal of Excellence in College Teaching, 1*, 9-22.

FEDLOCK, P.M., ZAMBO, R., & COBERN, W.M. (1996). Professional development of college science professors as science teacher educators. *Science Education, 80*, 5-19.

HAMILTON, M. L. (1995). Relevant readings in action research. *Actions in Teacher Education, 16*(4), 79-81.

HOPKINS, D. (1985). *A Teacher's Guide to Classroom Research.* Philadelphia: Open University Press.

KEATING, J., DIAZ-GREENBERG, R., BALDWIN, M., & THOUSAND, J. (1998). A collaborative action research model for teacher preparation programs. *Journal of Teacher Education, 49* (5), 381-390.

KYLE, W. C., Jr., LINN, M. C., BITNER, B. L., MITCHNER, C. P., & PERRY, B. (1991). The roles of research in science teaching: An NSTA theme paper. *Science Education, 75*, 413-418.

NATIONAL SCIENCE FOUNDATION (1996). *Shaping the future: New expectations for undergraduate education in science, mathematics, engineering, and technology.* Washington, DC: NSF Division of Undergraduate Education.

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# THE USE OF SEMIQUANTITATIVE COMPUTER MODELLING IN SCIENCE EDUCATION: THE STUDY OF PREDATOR-PREY SYSTEM

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**Abstract**

The article presents results of the investigation on integration of computer modelling environment in the exploratory learning in topics of Science. The article presents results of the investigation about the integration of computer modelling environment to the exploratory learning of Sciences. The results here presented are relative to the study of the interaction and performance of students acting during the use of the semiquantitative computer modelling environment WLinkIt in an activity of specific content in Ecology: the predator-prey system. The results show that the students presented abilities to develop a model about proposed system and to relate and make comparison among the results of the model simulation with their previous expectation. In relation to the difficulties these were related to the delimitation of the system to be studied, in knowing where it is the value zero of the variable, to understand the function of a connection among two variables and in knowing as it is the influence of a variable on the other. Thus, this study presents important results for the continuation of research works about the use of computer modelling environment WLinkIt in the study of topics of Sciences.

## 1 - Introduction

The use of new technologies in the educational context has been discussed worldwide. Recently in Brazil the federal government destined funds to public secondary schools for the acquisition of computers. However there is no clear policy or guidelines for the acquisition of softwares and Computer Modelling Environment.

This fact generates the need for the development of research aiming at promoting, in practice, the integration of the resources of the communication and information technology to the daily life in classroom (Ferracioli, 2000). In this context the objective of this research is to investigate the use of a Computer Modelling Environment in the study of topics in Sciences.

A Computer Modelling Environment is a software that in the context of this study is labelled in such way due to the existence of a underlying pedagogical proposal where they are seen as Learning Environment: in this perspective they are seen as tool for helping students to improve their ability of formulating question instead of simply find answers (Ferracioli, 2001).

## 2 - Theoretical Framework

The use of Computer Environment in classroom can be developed starting from the study of topics of specific contents in Science using an alternative approach through the **concept of modelling**.

This proposal consists of asking students to build a pencil-paper model about a specific topic in Science and afterwards to represent it in a Computer Environment. Once represented the model in the Computer Environment it can be simulated generating the possibility of deepening the study of this topic.

### 2.1 - About Modelling Activities

According to Bliss & Ogborn (1989) the activities of construction of models can be developed in two ways:

- **Exploratory**, when the student is asked to explore, in the computer environment, a model developed previously by a expertise;

- **Expressive**, when the student is requested to develop his/er own model in a computer environment.

In this work the modelling activities were developed in the exploratory and expressive way. In both perspectives the modelling activity naturally involves the process of reasoning and Bliss et al (1992) suggest that this process can be conceived in three dimensions:
- Quantitative
- Qualitative
- Semiquantitative

The quantitative reasoning involves a variety of aspects from the recognition of simple numeric relationships such as comparing sets of numbers as far as the manipulation of algebraic relationships. This reasoning dimension involves the understanding of how a change of a variable will affect others in a specific system such as in the case of the study of queues in a supermarket: how the increase of costumers will affect the waiting time in a queue.

The qualitative reasoning involves making categorical distinctions and taking decisions. This may consist of examining a set of choices and taking decision based on consideration of their consequences such as in the case of a journey when different means of transports can be chosen or considering a given goal that would be necessary to reach it. Therefore this perspective of reasoning demands the observation and consideration of alternatives and the careful analysis of evidences: a student who desire to entrance in the a university course needs larger dedication to the studies.

The semiquantitative reasoning involves the description of daily situations where the direction of a change in a part of a system is known but not the size of the effect of this change on the other parts. For instance, it is known that the increase of the intensity of light causes the decrease of the pupil aperture of the human eye (Sampaio, 1996): the analysis of this effect requests the understanding of the direction of the causal relationship - increase or decrease - but not the knowledge of the numeric values. In this work exploratory and expressive modelling activities demanded the use of semiquantitative reasoning.

The ground for analysing this dimension of the reasoning is based on the fact that as much the quantitative reasoning as the qualitative do not capture all the important aspects of the daily reasoning. Thus, the arguments used in the case of the pupil of the human eye includes a quantitative part and a qualitative part: the involved reasoning recognises the ordering of the amounts but not the magnitude through the use of the terms such as increase and decrease (Ogborn and Miller, 1994).

Therefore, the construction of models in a semiquantitative way can be based on a systemic thinking view (Forrester, 1968) that demands the understanding of the behaviour of a system based on the causal relationships among the variables that describe it. In this sense, causality plays fundamental role in the semiquantitative modelling because its underlying role in the reasoning for establishing the relationships among the variables.

**2.2 - Causal Diagrams**

The causal relationships among variables that describe a system can be understood and represented through a graphic representation of Cause-Effect Pair, labelled Causal Diagram (Roberts et al, 1983). Considering the example of the human eye behaviour a change in the light source intensity causes a change in the pupil aperture. This causal relationship is represented in the Figure 01 in a causal diagram format:

*light source intensity* ⟶ *pupil aperture*

**Figure 01**: *Example of a pair of Cause and Effect.*

The Causal Diagrams can be represented in the WLinkIt, a computer modelling environment based on an Iconic Metaphor.

**2.3 – The Computer Modelling Environment Based on Iconic Metaphor, WLinkIt**
WLinkit is an Computer Modelling Environment based on an Iconic Metaphor for the construction and simulation of dynamic models in a semiquantitative way. In this environment is possible to build models that represent causal relationships among important variables of phenomena, events, objects of the world to be modelling (Sampaio, 1996).

When opening the WLinkIt environment, the main screen is presented to the user as shown in Figure 02:

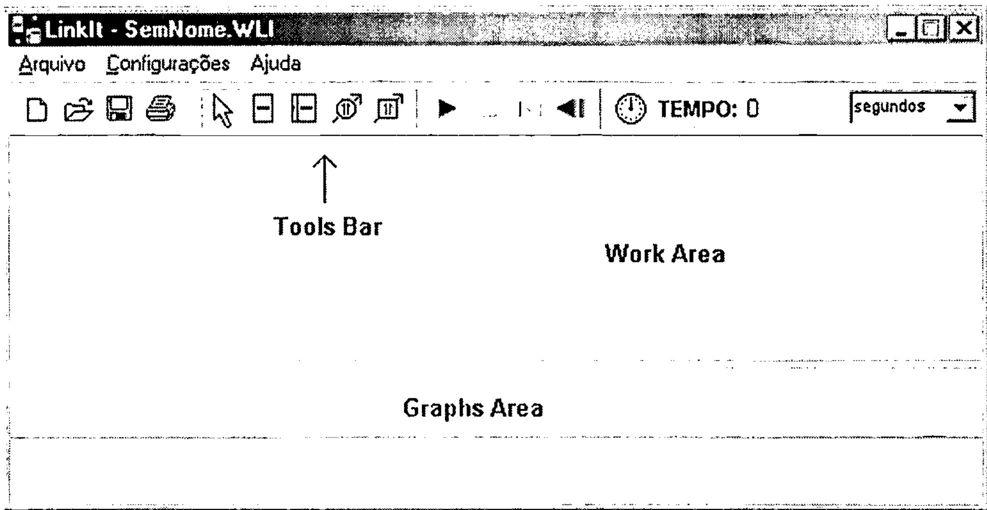



**Figure 02:** *The WLinkIt Main Screen*

The screen consists of 3 basic areas:

- **Work Area** - this is the area for the construction of the model by the user;
- **Graphs Area** - this is the area for the visualization of a graphic output;
- **Tools Bar** - this is the area that contains the building blocks necessary for the construction of the model and tools for working with it.

The construction of models in this Environment demands reasoning in a semiquantitative way. Thus, it is not necessary to know the mathematical relationships among the variables for the construction of a model because the WLinkIt building blocks establish the necessary calculations for the model to be simulated with the help of computational procedures avoiding the user cognitive load demanded by the programming and mathematical knowledge. In other words, it is possible the construction of a iconic model that will be translated in an adapted symbolic information from which calculations will be performed and inferences will be executed using those information whose results will be, for its time, translated again for the iconic form.

The model built through the Causal Diagram shown in Figure 01 can be represented in WLinkIt Environment as it is shown in Figure 03.

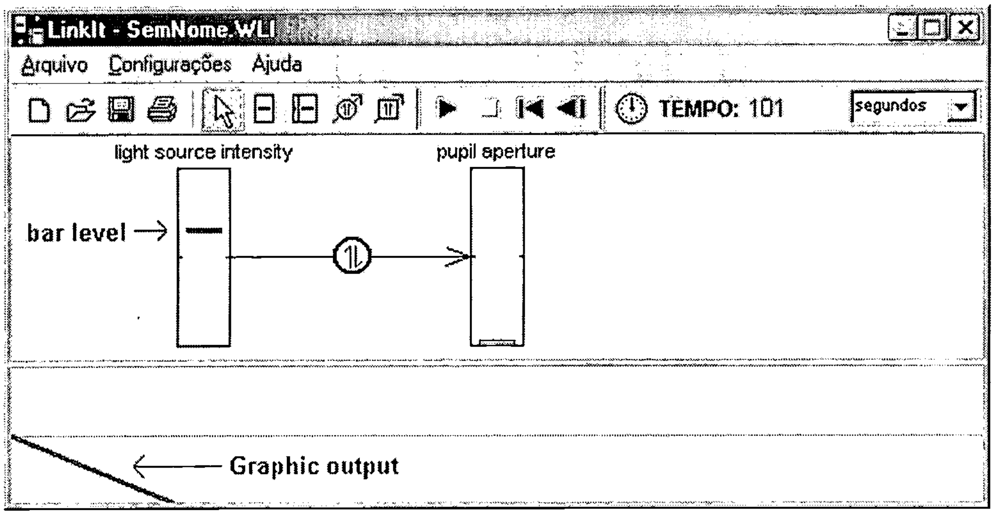



**Figure 03**: Representation of the Causal Diagram about the behaviour of the pupil of the human eye and the graph of the variable pupil aperture.

While the paper version of the model reveals its static nature, where an instantaneous view of the physical reality is privileged, its computational version is dynamic in the sense of the model can be simulated and the results help the process of restructuring and improvement of the initial model, facilitating, in that way, to visualise the temporary evolution of that same physical reality (Ferracioli, 1997a). During the simulation of a model the behaviour of each variable can be visualized through either its default bar level or the graph output that can be requested by the user, both identified in Figure 03.

**2.4 - Strategy to Models Building**

The process of building of a model and its representation in an Environment Computer Modelling is denominated Model Building Process. When building their own models students are requested to follow 7 basic steps:

- Definition of the *system to be studied*;
- Choice of the *phenomenon of interest* to be studied in the defined system;
- List of *important variables* for the building of the model;
- Building the model through Causal Diagrams;
- *Representation* of the model in the WLinkIt Environment;
- *Simulation* of the built model;
- *Validation* of the model from the analysis of its behaviour in relation to the waited behaviour of the phenomenon in study.

This procedure was proposed by Camiletti (2001) and represents global systematisation for the building model process beyond the consideration of the laundry list proposed by Mandinach (1989). The first two steps are based on fact that it should promote broadening of students view about the problem being studied.

This process can be developed to the study of the behaviour of the pupil exposed to a light source whose intensity can be varied. The steps are shown below:

- system to be studied is the pupil of the eye;
- *phenomenon of interest* is the behaviour of the pupil of the eye;
- the *important variables* are, at first, *light source intensity* and the *pupil aperture*;
- the construction of the model through a Causal Diagram is shown in the Figure 01;
- the *representation* of the model in Ambient WLinkIt and the result of the simulation, through graphic output, are shown in the Figure 02.
- The *validation* of the model is made by the user through the resources the animation of each variable and the graphic output. Thus, observing the graphic output of the variable *pupil aperture* it can be verified that it decreased when the *light source intensity* increased: this is in agreement with the observed phenomenon.

## 3 - Study Conception

In the last years it has been growing the number of studies about the integration of Computer Modelling Environment based on icon metaphor in the educational context. In the Physics teaching at university level it can be quoted Santos, Sampaio and Ferracioli, 2001; Camiletti & Ferracioli, 2001; Ferracioli and Sampaio, 2001 and in the teaching of topics of Science in general at basic and secondary level it can be quoted Bliss et al (1992), Santos and Ogborn (1992; 1994), Sampaio (1996), Sampaio and Torres (1999). These works report results that show that the use of the concept of modelling and the computer modelling based on the iconic metaphor in the educational context for the study of topics in Sciences is promising.

In this context, the present study was carried out to explore the possibilities of using the WLinkIt Environment for exploratory learning in Sciences at university level looking to two basic research questions:

1. Which abilities the students showed during the development of the model?
2. Which are the difficulties presented by the students during the development of the model?

### 3.1 - The Course

For the development of the research work it was structured a course *Modelling and Representation of Physical Systems with Computer Modelling Environment* ministered in 2 educational modules with duration of 2 hours each for university level students.

The two educational modules were organised according to:

- **Module 1 (02 hours) - Exploratory Activities**
  *Introduction to the study of the System Thinking Reasoning and to the WLinkIt Environment.*
- **Module 2 (02 hours) - Expressive Activities**
  *Modelling and Representing Systems with the WLinkIt Environment.*

The objective of the Module 1 was to introduce the students to the system thinking reasoning (Forrester, 1968) and to the Computer Modelling Environment WLinkIt through activities of exploratory modelling.

The objective of the Module 2 was to take the students to develop activities of expressive modelling with Environment WLinkIt on the Spring-Mass system and Predator-Prey system. The first activity to be developed was on the spring-mass system and soon after the activity was developed on the predator-prey system.

In this work only the result of the activities of expressive modelling with the Predator-Prey system are reported . For the development of this activity each peer was introduced to a text with basic information as described below:

> *An important characteristic in the Nature is the existent balance among species. A typical example is the relationship between rabbits and foxes in a forest without human interference.*
>
> *It is known that in this environment rabbits eat plants and are the main source of food for foxes. Therefore, when foxes eat rabbits they can grow and procreate. However, when the population of foxes begins to grow more and more rabbits are necessary to feed them what causes a decrease in the population of rabbits. So, the food availability for the fox population starts to decrease. Consequently the remaining rabbit population has more chance to succeed in procreating and increasing its population.*

Soon after students were requested to build a model in the computer about this system and to discuss their ideas about it aloud.

### 3.2 Sampling

The participants in the course were university students from the second year of Sciences and Engineering courses at Federal University of Espírito Santo, Brazil. The students worked in peers and each peer attended classes at a time. The study sample consisted of 6 peers that completed the whole activities of Modules 1 and 2.

### 3.3 - Data collection

All the activities developed by each peer were video registered and the students' written annotations were collected.

### 3.4 - Data

The data considered for the analysis consisted of the students' written annotations, versions of the model built by the peers during the expressive activity and students' comments.

## 4 - Data Analyses

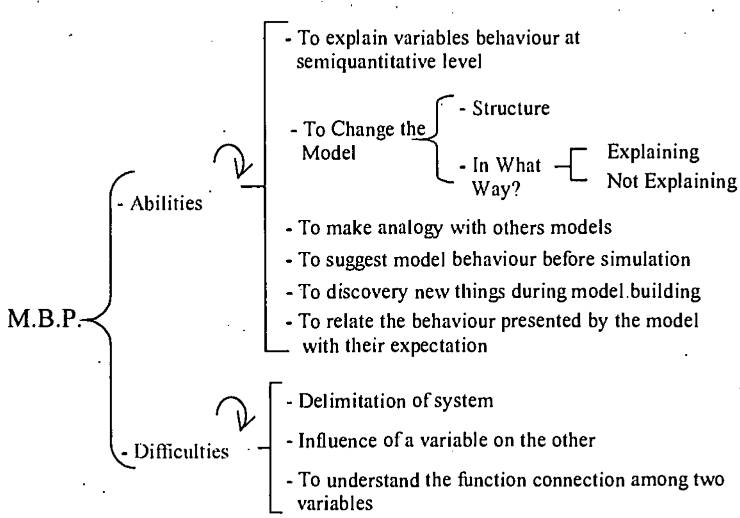
The data are of qualitative nature and the technique used for the data analysis was the Systemic Network (Bliss et al, 1983) due to possibility of structuring of categories in an broadening and complex way. According to Ogborn (1994), a systemic network can be seen as a grammar independent of the context that defines a 'language' built to describe the data. The basic elements of a systemic network are:

- **Bar** – a notation used to represent a group of exclusive choices;
- **Bra** – a notation used to represent a group of choices that happen simultaneously or a co-selection

The analysed aspect was the Model Building Process (M.B.P.) described in the section 2.4. The systemic network built for the analysis of this Process is shown in the Figure 04 and consisted of two basic aspects: **Abilities** and **Difficulties**. These aspects are represented in the first key what means that there is a group of choices that happen simultaneously. Thus, the analysis of the Model Building Process is made according to the abilities and difficulties aspects. It is important to remind the reading of a systemic network is started from the leftmost end related to the more general aspects towards the right end when the detailed level is increased as far as rightmost end that represents information closer to the raw data.

These two aspects are related to the basic research questions and they consisted of categories that can be seen at the left end in Figure 04. These categories reflect peers characteristics that were presented during the development of the expressive modelling activity about the predator-prey system. At the right extreme of the Figure 04 a summary is shown in a table format where a reading in a column provides a view of each peer's behaviour in relation to the aspects of Abilities and Difficulties while a reading in a line provides a view of the all the peers' behaviour in that specific aspect.

**Predator-Prey System**




| Peers | | | | | | |
|---|---|---|---|---|---|---|
| 01 | 02 | 03 | 04 | 05 | 07 | Total |
| x | x | x | x | x | x | 06 |
| | x | x | | x | x | 04 |
| | x | x | | | x | 03 |
| | | | | x | | 01 |
| x | | | x | | | 02 |
| | | x | | | | 01 |
| | | x | | | | 01 |
| x | x | x | x | x | x | 06 |
| | | x | | | | 01 |
| | | x | | | | 01 |
| | | | | | x | 01 |

**Figure 04**: *Systemic Network and Summary for the Expressive Modelling Activities with the Predator-Prey System.*

As an example of the Model Building Process analysis firstly data from peer 01 is presented. In relation to the aspects of Abilities presented during this process this peer was capable to relate the behaviour presented by the model to the expected for them. In this case, they considered the first version of the model built as the final model and the peer did not present difficulties to develop this activity.

Yet, in relation to the peers' behaviour in each aspect considered in the systemic network considering the Abilities presented by each peer all of them were able to relate the behaviour presented by the model with their expectation. In relation to the Difficulties peer 03 had difficulties in the delimitation of system.

## 5 - Discussion e Conclusion

The conclusion of this report will be made answering the basic research questions of this work, described in the section 3. The answer of each question is based on the summary presented in the table in Figure 04.

### 5.1. Which abilities the students showed during the development of the model?

The observed abilities varied from peer to peer. All peers were able to build a version of the model, simulate the model and draw comments about the behaviour presented by the built model relating them to their expectation about it.

All peers were able to make explanations at the semiquantitative level about the behaviour of the variables: they were able to explain what happened with a variable when the others varied. This result seems to indicate that the students were capable to reasoning at the semiquantitative level for the development of the expressive modelling activity.

All peers were capable to change the model, inserting or removing variables and connections among them. Most of them were able to explain these changes in the model indicating that the peer presented a certain understanding on what they were doing and do not simply using a trail and error strategy.

Two peers were able to make analogy with the model developed previously of the spring-mass system. This is an important ability because the student was able to visualise a relationship between two models that represent systems of different nature. This result seems to be in agreement with Mandinach and Hugh (1994) because of the fact that these two peers succeeded in transferring acquired abilities from one system to another.

Forrester (1991) argues that the modelling process can help students to organize, to understand and to structure their knowledge about a system in study. Thus, in this research it was observed that a peer seems to have understood some aspects of the predator-prey system during the model building process, what seems to corroborate the author's argument.

### 5.2. Which are the difficulties presented by the students during the development of the model?

For the development of the expressive modelling activities some peers presented a series of difficulties related to the use of WLinkIt Environment and others related to the use of the reasoning at systemic level.

In relation to the WLinkIt Environment use some peers presented difficulty in understanding the function of the connection among two variables. After the peer establishing a connection among variables they seemed to not understand its function: they were not able to understand which would be the behaviour generated by the built structure. Thus, it seems that the peer that presented this kind of difficulty did not presented a good understanding about the function of the connection among two variables of the WLinkIt Environment.

In relation to the use of the system thinking reasoning for the construction of the model a peer had difficulties to understand as a variable influences other: they had difficulties in conceiving a variable as being responsible for the variation of the other variable.

Another aspect related to the system thinking reasoning is the difficulties presented by a peer in the delimitation of the system to be studied. This ability is fundamental to the construction of the model given that it leads the student to select all relevant aspect necessary for modelling it. The lack of this ability may cause the students to consider unimportant aspects and translate them in variables that can be used for building a model which do not represent the system in study.

It seems this difficulty has its roots in the traditional teaching which do not highlight appropriately this process of delimitation of a system: it is taken for granted that the arrangement and manipulation of the system with the establishment of the initial conditions do not belong to the study of the system because they are provided a priori without any discussion. This fact is continually observed throughout problems section at the end of any chapter of Science books: masses are compressed and placed in movement without any comment about the sources for the establishment of those conditions (Ferracioli, 1994).

**5.3 - Final Considerations**

The objective of this research was to investigate the use of Computer Modelling Environment in the study of topics of Sciences. Thus, the results presented are fundamental to design future studies for promoting, in the practice, the integration of this kind of environments in daily classroom related to the study of topics in Sciences.

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## 7 - References

BLISS J. OGBORN J (1989) Tools for Exploratory Learning. A Research Programme. *Journal of Computer Assisted Learning*, 5:37-50.

BLISS, J. et al. (1983) *Qualitative Data Analysis for Educational Research: a guide of systemic networs*. 1. ed., London: Croom Helm. 215 p.

BLISS, J. et. al. (1992) Reasoning Supported by Computational Tools. *Computer Education*. Vol.18. p1-9.

CAMILETTI, G. (2001) *Modelagem Computacional Semiquantitativa no Estudo de Tópicos de Ciências: Um Estudo Exploratório com Estudantes Universitários*. Vitória, ES, Curso de Pós-Graduação em Física da Universidade Federal do Rio Grande do Sul. Diss. mestr. ensino de física.

CAMILETTI, G. & FERRACIOLI, L. (2001) A Utilização da Modelagem Computacional Quantitativa no Aprendizado Exploratório de Física. *Caderno Catarinense de Ensino de Física*, v.18, n 2.

FERRACIOLI, L & SAMPAIO, F. F. (2001) Informação, Ciência, Tecnologia & Inovação Curricular em Cursos de Licenciatura. *Revista Brasileira de Informática na Educação*, 8(1): 77-85.

FERRACIOLI, L. (1994) *Commonsense Reasoning About Processes: A Study of Ideas about Reversibility*. Ph.D. Thesis. London: Institute of Education University of London.

FERRACIOLI, L. (1997) As Novas Tecnologias nos Centros de Ciências, nos Centros de Formação Profissional e na Formação de Professores. In: *Atas do XII Simpósio Nacional de Ensino de Física*. Belo Horizonte: Universidade Federal de Minas Gerais. 27-31/Janeiro/1997. p. 127-33.

FERRACIOLI, L. (2000) *A Integração de Ambientes Computacionais ao Aprendizado Exploratório em Ciências*. Projeto de Pesquisa apresentado ao CNPq, Processo Nº 46.8522/00-0.

FORRESTER, J. (1968) *Principles of Systems*. Cambridge, Ma: Wright-Allen Press.

FORRESTER, J. W. (1991) System Dynamics and the Lessons of 35 years. In Grenne, K. B. *The Systemic Basis of Policy Making in the 1990's.* Cambridge (MA): The MIT Press.

MANDINACH, E. B (1989) Model-building and the Use of a Computer Simulation of Dynamics Systems. *J. Educational Computing Research*, 5, (2): 221-243.

MANDINACH, E. B. & HUGH, F. C. (1994) *Classroom Dynamics: Implementing a Technology-Based Learning Environment.* Hillsdale, New Jersey, Lawrence Erlbaum Associetes, Publishers. 211p.

OGBORN, J. & MILLER, R. (1994) Computational Issues in Modelling. In Mellar, H.; Bliss, J.; Boohan, R.;Ogborn, J. & Tompsett, C. (eds.) *Learning With Artificial Worlds: Computer Based Modelling in the Curriculum*, (p.117-27). London: The Falmer Press.

OGBORN, J. (1994) The Nature of Modelling. In Mellar, H.; Bliss, J.; Boohan, R.; Ogborn, J. & Tompsett, C. (eds.) *Learning With Artificial Worlds: Computer Based Modelling in the Curriculum*, (p.11-15). London: The Falmer Press

ROBERTS, N. et all. (1983) *Introduction to Computer Simulation - A System Dynamic Modelling Approach.* New York: Addison Wesley.

SAMPAIO, F. F. (1996) *LinkIt: Design, Development and Testing of a Semi-Quantitative Computer Modelling Tool.* Ph.D. Thesis, Department of Science and Technology, Institute of Education, University of London.

SAMPAIO, F. F. TORRES, A. S. (1999) Trabalhando o conhecimento qualitativo de taxa de variação num ambiente de modelagem dinâmica computacional. *III COINFE – Congresso Estadual de Informática na Educação.* Instituto de Educação. Rio de Janeiro.

SANTOS A.C.K.; SAMPAIO, F.F. & FERRACIOLI, L. (2001) Um Experimento de Modelagem Dinâmica Semiquantitativa com a Utilização da Técnica dos Hexágonos. *Revista Brasileira de Informática na Educação*, 7(1): 21-35.

SANTOS, A.C.K. & OGBORN, J (1994) Sixth form students' ability to engage in computactional modelling. *Journal of Computer Assisted Learning.* 10:182-200.

SANTOS, A.C.K. & OGBORN, J. (1992) A Model for Teaching and Research into Computational Modelling. *Journal of Computer Assisted Learning.* 8:67-78.

**Keywords:** Exploratory learning, semiquantitative modelling, computer modelling, learning environment.

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# TECHNOLOGY IN THOUGHT AND ACTION: UNIVERSITY STUDENTS IN TEACHER TRAINING REFLECT ON PUPILS' CONCEPTIONS AND EXPERIENCES OF TECHNOLOGY AS A SCHOOL SUBJECT

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**Abstract**

Students in teacher training reflect on school pupils' conceptions and experiences of technology as a school subject. The reflections by the students were mostly related to the practical studies of the pupils, with wishes of more of such things as design, and how to build and construct things, and also with the desire that technology be placed in the context of everyday life. The subject provided the pupils with a comprehensive picture as well as that the school subject should be fun. The pupils who had been taught by teachers fully qualified to teach the subject, showed an increase in their interest in technology. Half of these pupils stated that they might consider choosing the technology program in upper secondary school. Furthermore, this study indicates that discussions in classrooms about the consequences of technology in society are largely missing. Lastly, the school subject technology must be clarified considering content and aims for the school pupils.

## Background, Aims and Framework

The study presented in this paper is about the new school subject named technology, curriculum Lpo94, showing how the university students and pupils reflect on the teaching in this school subject. The purpose is to get a picture of technology in school and in teacher training, and based on our findings inform the university and school of ways to better teach the school subject technology. The Swedish school curriculum in technology is broad-based. It covers contents such as development of technology, what technology makes, practical constructions, components and systems, and interactions between technology and human needs as consequences and impacts on community, nature and individual persons. Many researchers (e.g. Herschbach, 1995, Vincenti, 1984, Layton 1974, Solomon 2000) have stated that technology, among other things, includes problem-solving, describing, tacit knowledge in human activity, using knowledge from traditional academic disciplines and interdisciplinary knowledge (Andersson, 1994, 1997).

Most school children have a very vague understanding of what exactly constitutes the school subject technology. The hope is that school-teachers can be more clear and aware in their teaching of technology. The aim of this study is to analyse the written reflections by the university students in technology courses on school pupils' answers about the school subject technology, and also about technology itself. Furthermore, I myself have analysed the pupils' answers.

One research aim is to detect what, in fact, are the conceptions that university students in technology courses have concerning the subject technology. Another aim is to find out the content and the way of working in technology in schools, and how this experience may influence teaching in a way to increase the pupils' future interest in technology.

## Methods and Samples

In this study, I am working as a researcher, action researcher (Tiller, 1996) and also as a constructivist (Andersson, 1996) teacher in training at Göteborg University in technology courses. The university students study technology as a school subject, as part of their teacher training for a nine-year Swedish compulsory school with pupils aged 7-15. I have carried out pilot studies during some years before this investigation, and the need of knowledge about the new school subject technology became evident.

## Datasources

The study covered:

- Responses of 258 pupils who answered questions about technology and school subject technology. For example, What is technology? What do pupils want to do? What was actually done? What was learned? Motivation? Questions were put in order to get school pupils' attitudes to and conceptions of technology as a school subject.
- University students (55) made written reflections on pupils' responses.
- University students (55) made brief comments on their own vision for technology education.

## Analysis

University students' written reflections were analysed through an iterative process. Common features of their responses were identified and checked with another researcher. 18 aspects were initially identified, though these were later subsumed into 9 categories. As a result the students' conceptions about teaching technology were obtained. The school pupils' responses, as well as those of some teachers' reflections, were then analysed in a similar way.

When I analysed the responses of the 258 pupils, I chose specifically the questions/answers that are relevant for discovering the potential of the future interest among the pupils. It is intended that, through this research, recommendations for technology teacher training can be advanced.

## Results

The results show that the statements of the university students covered the *practical work* for the pupils, how *to build and design things* and also technology put in the *context of everyday life*, consistency for the pupils, as well as the school subject was said to be *fun*. The university students also pointed out in their answers the multi-faceted features of technology and the importance of *problem-solving activities*. They also stressed the importance of working with pupils, in which one considers each one's talent and capabilities. The students found that a majority of the pupils had a very *unclear picture of technology* teaching since they often could not describe what they had worked with, and what they had learned. In some cases, they could not even recall whether they had actually had any technology lessons at all.

Yet in the university students' reflections (on answers from the 113 pupils) about what they had been taught by *teachers fully qualified* to teach the subject (according to the official Curriculum Lpo94), it was pointed out that *almost all the pupils showed an increase of interest in technology. More than half of these pupils* stated that they might also *consider choosing the technology program in upper secondary school.*

As a teacher trainer, I have also studied the answers of the pupils. I found that in the answers of the pupils and to some extent also in the students' reflections, *discussions about evaluation of the positive and negative consequences of technology were largely missing*. Furthermore, the answers indicated that the *aims of the technology subject had rarely been made clear to the pupils.*

## Conclusions and Implications

One of the major aims of technology education is to *develop pupils' practical skills in designing and making artifacts/objects*. This means that a considerable part of teaching technology ought to be practical work (e.g. construction, design and building things). That this practical work should get more appreciation and higher status seems to promoted by the pupils, students and teachers. In this practical work, there are found problem-solving, individual work and group work, the context of everyday life, creativity and integration with other subjects, and much of the source of joy.

The practical work should be more related to theories and ideas behind the technology (e.g. scientific ones). When the role of technology in society is discussed, social aspects should be considered. It is important that the citizens in our democratic society become aware of the positive and negative consequences of technology. It is also important to *cooperate with companies and institutions in society, as well as to understand the interaction between the society, technology, nature and human beings.*

The students often point out the unclear picture of technology teaching in school. *The aims* and framework, and the concept of the school subject technology, *ought to be explained for and discussed with the pupils.*

It is gratifying that pupils, who had been taught by teachers who were fully qualified to teach the subject, showed increased interest in technology and were motivated to choose a high level program which includes technology. More in-service training for teachers is considered necessary. There is a need to develop other, non- traditional, examinations. The use of reliable assessments will create many possibilities for the pupils to improve their technology knowledge. In sum, there is a need for more time to be spent understanding the didactic words " why, what, how and when" in the teacher training process, and in the school with regards to the school subject technology.

## References

ANDERSSON, B. (1994). Om kunskapande genom integration. *Na-spektrum*. Nr 10. Göteborg: Göteborgs universitet, IPD.

ANDERSSON, B. (1997). Teknikämnet i omvandling? *Na-spektrum*. Nr 20. Göteborg: Göteborgs universitet, IPD.

ANDERSSON, B. (1996). Konstruktivismen - ett sätt att se på lärande och kunnande. I T. GINNER & G. MATTSSON (Red.), *Teknik i skolan*. (s. 53-65). Lund: Studentlitteratur.

HERSCHBACH, D.R. (1995). Technology as Knowledge: Implications for Instruction. *Journals of Technology Education*. 7(1) Fall 1995.

MATTSSON, G. (2000). *Tekniktankar. En studie om vad skolämnet teknik innebär för lärarstudenter och lärare*.(Institutionen för pedagogik och didaktik, enheten för ämnesdidaktik, 2000:10). Göteborg: Göteborgs universitet.

LAYTON, E. (1974). Technology as Knowledge. *Technology and Culture*. 15(1), 31-41.

SOLOMON, J. (2000). Learning to be inventive: design, evaluation and selection in primary school technology. In J. Ziman (Ed), *Technological Innovation as an Evolutionary Process*. (pp. 190-202). Cambridge: Cambridge University Press.

VINCENTIi, W. G. (1984). Technological knowledge without science: The innovation of flush reveting in American airplanes. *Technology and Culture*. 25 (3) 540-576.

**Keywords:** school subject technology, teacher training, school pupils, university students' reflections about technology

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# A NEW PROJECT ON ASSESSMENT OF SECONDARY SCHOOL STUDENTS IN SCIENCE SUBJECTS IN THE CZECH REPUBLIC

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**Abstract**

The paper deals with the project aimed at setting and assessment of output competences for students of secondary schools (age category 16-20 years) in the area of science education, and gives a summary of the results reached so far. The starting point for setting output competences was to define the four main target categories common to biology, chemistry and physics, set the topics, and formulate specific objectives. After the verification of the proposal within the framework of experts' evaluation, catalogues of target competences for the area of biology, chemistry and physics were issued in October 2000. These are the fundamental documents for a common nationwide written part of the graduation examination in the above-mentioned subjects at secondary schools. This type of graduation examination will be introduced in the Czech Republic, for the first time as obligatory, in 2004.

Learning tasks created to verify the individual competences are, in contrast to the previous "knowledge-based tasks", i.e. tasks verifying the knowledge of facts, aimed mainly at the categories of comprehension, observation, performing experiments, and communicative skills (communication). The first series of these leaming tasks (20 tasks from biology and 20 tasks from chemistry) was designed and verified in practice with a group of 1496 students over the period January – April 2001. The results of this research and their analysis can be found in the final part of this paper.

## 1. Introduction

At present, all over the world, a great deal of attention is devoted to pedagogical assessment and its changes. The use of new methods of assessment is significant both in scientific and research area and in the educational practice. The Czech Republic is also heavily involved in these problems. One of the topical issues is the assessment of educational results at the individual educational levels and types of schools (4), with a particular emphasis on the problem of " What a secondary school graduate should know ".

Diversification of our school system at the beginning of the nineties resulted in a considerably large heterogeneity both in terms of content and process side of education. This brought about different final results as not only the objectives of education as a whole, but also educational objectives of the individual subjects are set in a very general way, and it is very difficult to find out the level they should meet. Therefore, at the end of the nineties, an interest in the assessment as well as in the development of assessing tools, both theoretical and practical, was raised within the educational system in the Czech Republic. This was supported by the two - out of eleven - recommendations formulated by the OECD board of examiners:

- to set and unify the level of graduation examination at secondary schools
- to design tools to assess the learning results of secondary school students

This paper tries, within a new project on assessment of secondary school students (2), to offer a solution to the problem of assessment of output competences and skills in biology and chemistry with the students taking their graduation examination. The new project follows the two major objectives. The first, and in our opinion the most decisive one, is to affect the learning process in science subjects by formulating concrete skills of target students. The second objective is, then, to unify the requirements that the students should meet, and to verify them.

The project was coordinated by the Centre for the reform of graduation examination – CERMAT. A team of experts from different institutions was appointed for each subject. The authors of the present paper headed the respective teams – Mrs Cizkova – biology (3), Mrs Ctrnactova – chemistry (7).

## 2. Methods

In the course of project development, methods of analysis and synthesis (17), theory of learning material acquisition (16) and development of learning tasks (5), empirical and analytical methods as well as statistic methods have been used.

It was found out that present science education in the Czech Republic is aimed mainly at formal memorizing of a large number of facts with a little emphasis on higher thinking operations (18). A prevailing mere reproduction of memorized knowledge leads to a rapid forgetting. The outputs of our research have been supported by the outputs of the TIMSS project. Therefore, with our target competences set for each subject, the emphasis has been laid on active mental and practical activities of the students. Practice-oriented competences and, first of all, skills have been preferred to verbal reproduction of knowledge.

Based on the analysis of specific benefits of science subjects – biology, chemistry and physics - for the secondary education of students (6, 13), the target competences that we consider as fundamental in science subjects have been set first. Target competences (1) represent structures of knowledge and skills that are characteristic for a given study subject and express its educational objectives. Target competences represent the subject as a whole. They are formulated as sets of activities/ operations/ that a student should master in certain situations. They are as follows:
A – acquisition of knowledge and comprehension
B – application of knowledge and problem solving
C – observation and performing experiments
D – communication

The second stage of our work was to set - for each subject - topics for graduation examination. These topics cover the whole scope of each subject and result from the present conception of secondary education in the Czech Republic and other European countries (11, 15).

In the third stage, specific objectives were formulated on the basis of methods of analysis and synthesis of learning materials and theory of learning materials acquisition (14). Specific objectives represent concrete requirements on the common part of the graduation examination. They were developed from target competences for the individual topics and formulated as output requirements on competences and skills of the students taking the common part of the graduation examination. The number of the respective topic and the letter of the respective target competence mark each specific objective.

All these components are listed and summarized in the catalogues for the common part of the graduation examination in science subjects.

In the forth stage, a set of study tasks was developed for each specific objective on the basis of the theory of learning tasks (9, 10, 12). These sets were verified on a statistically significant sample of students from secondary schools, and the results obtained were then analyzed.

## 3. Application and evaluation

These stages of our work were subsequently realized practically over the period of November 1990 - October 2001 .

Let us present, as an example, the development of target competences for biology (3) and chemistry (7).

**A – Acquisition of knowledge and comprehension**

Student is able to:

- in biology
  - describe biological phenomena and objects based on reality, model or picture
  - identify, with biological objects and phenomena, features that are substantial, general and specific
  - orientate himself/herself in natural systems of organisms and understand relationships between them
  - classify and categorize biological objects and phenomena according to their distinguishing features
  - explain biological phenomena and processes by means of common biological laws and theories
  - make conclusions from initial conditions by means of induction, deduction and other thinking operations
- in chemistry
  - describe basic chemical concepts and quantities used in chemistry
  - identify substantial, general and specific features of chemical substances and phenomena
  - analyze data on chemical substances and phenomena, compare them and arrange them on the basis of a certain criterion, and identify the relationships among them
  - classify chemical substances and chemical reactions on the basis of their general and specific features
  - explain a chemical phenomenon or reaction by means of common chemical laws and theories
  - make conclusions from the initial data and conditions by means of induction, deduction and other thinking operations

**B – Application of knowledge and problem solving**

Student is able to:

- in biology
  - use biological knowledge for solving biological tasks
  - apply theoretical and practical biological knowledge to solving concrete situations of everyday life
  - assess the effects of a phenomenon or human activity in terms of ecology, economy or health care
  - develop a positive approach to nature through his/her own attitudes and understand the rules of environmental protection
  - apply the knowledge acquired from other fields of study, first of all from chemistry, physics, geography and mathematics, to solving biological problems
  - substantiate the importance of latest biological knowledge for the society – health care, cultivation, different industries and other applied sciences
- in chemistry
  - use the acquired knowledge for solving chemical tasks
  - apply theoretical and practical chemical knowledge to solving concrete situations of everyday life
  - evaluate chemical substances, phenomena and reactions, assess the relationships among them, identify the courses and effects
  - assess the effects of substance properties and the course of chemical reactions in terms of everyday life, economy, protection and development of the environment, and health protection and safety
  - apply the knowledge acquired from mathematics, physics, biology and geography to solve a chemical task or problem
  - substantiate the importance of latest chemical knowledge for the society – new materials and production techniques, their use in health care, industry, agriculture, etc.

**C – Observation and performing experiments**

Student is able to:

- in biology
  - observe and objectively record the results of observations
  - illustrate observations through the use of simple drawings and schemes with descriptions
  - use basic biological procedures and techniques
  - perform a simple experiment by following the guidelines
  - propose and perform a simple experiment that demonstrates a certain phenomenon or gives answer to a certain problem
  - follow the ethical principles as well as the rules governing safety at work with biological material and technical equipment

- in chemistry
  - observe chemical substances and their changes, record the course and results of these observations
  - formulate conclusions from observations and explain them using common chemical knowledge
  - use basic chemical procedures in a chemical laboratory
  - perform a simple chemical experiment and evidence of selected elements and compounds by following the guidelines
  - propose and perform a simple experiment that demonstrates or proves a certain property, phenomenon or reaction
  - follow the rules of safety at work in a chemical laboratory

**D – Communication**

Student is able to:

- in biology
  - read and comprehend a specific text at the level of secondary school course books and process this text with the aim to produce a relevant output report
  - search for and interpret the information from the specific biological literature, e.g. from journals, atlases, using PC including the internet, video technique, etc.
  - make assessments and conclusions from data in tables and graphs
  - record empirical data in the form of table, graph, scheme or picture
  - write and interpret a relevant report on the biological experiment or observation
  - understand the substance and express his/her own opinion on the use of different biological methods and procedures in practice (biotechnology, genetic engineering, biological struggle, etc.)
- in chemistry
  - read and comprehend a chemical text at the level of secondary school course books and process this text with the aim to produce a relevant output report
  - search for and interpret the information from specific chemical and technical literature, e.g. from chemical tables, specific journals, information from mass media, internet, etc.
  - assess correctly the data obtained from tables, graphs, and schemes
  - record and assess empirical data, construct a table, graph or scheme
  - write and present a report about results of chemical experiment or observation
  - understand and express his/her own opinion on how to use different chemical procedures and methods in practice (application of chemistry in areas of human activity, pollution and purification of air, water and earth)

The second stage of our work was to set topics for graduation examination. These topics are the following:

- Biology
  1. General Biology, viruses, bacteria
  2. Biology of plants
  3. Biology of fungi
  4. Biology of animals
  5. Biology of humans
  6. Genetics
  7. Ecology and environmentalism
- Chemistry
  1. Basic concepts and quantities
  2. Composition and structure of elements and compounds
  3. Chemical reaction and its laws
  4. Inorganic Chemistry
  5. Organic Chemistry
  6. Natural substances and basics of Biochemistry

The targets presented have been diversified into the groups of specific targets under topics related to biology and chemistry. We have created two sets of specific targets - 480 biological specific targets and 510 chemical specific targets.

When the level of acquisition of specific targets was verified, a set of 20 biological and 20 chemical tasks (8) has been developed. Let us introduce the examples of these specific targets and tasks.

**5.3D Biology of humans - respiration and respiratory system**
**Specific target**: Student is able to evaluate a diagram showing the volumes of air making up vital lung capacity and total lung capacity

**Biological task**: From the following graph, determine the volume of air (in litres) that corresponds to the vital capacity of lungs with the patient undergoing medical examination.

**Solution**: 1,5 l

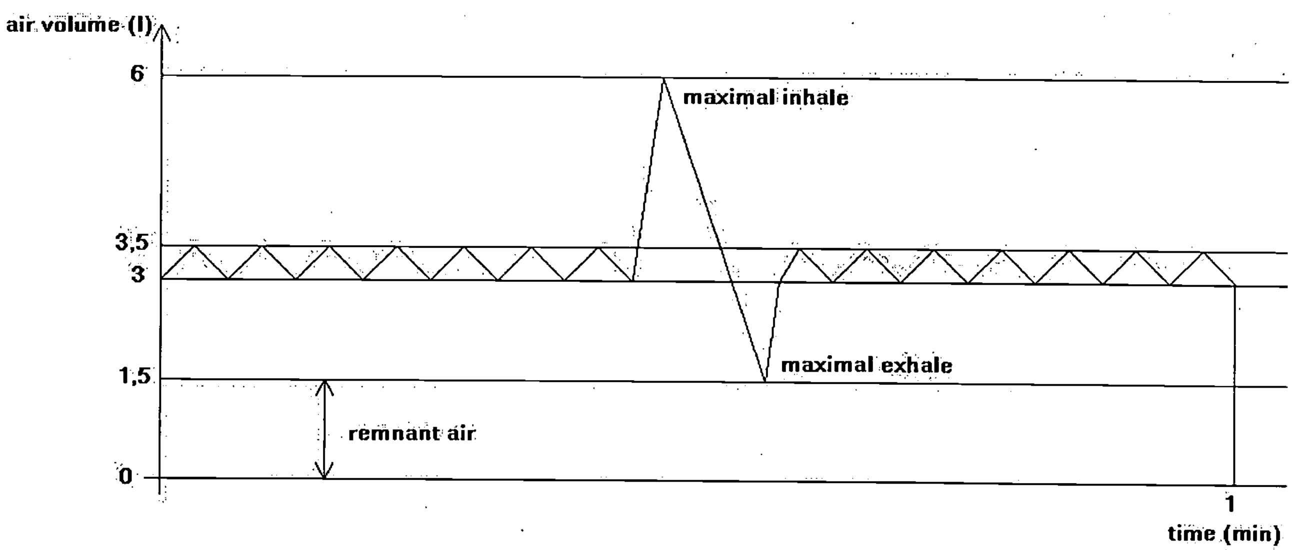
This task (No.13 from Graph 1) was correctly solved by 72 % of students and incorrectly solved (or not solved at all) by 28 % of students. The students, therefore, were quite successful in working with graphs and solving this task.

**1.5D Basic concepts and quantities - chemical reactions and equations**
**Specific target:** Student is able to write the course of the chemical reaction, given in the text, using a chemical equation.

**1.6B Basic concepts and quantities - basic chemical calculation**
**Specific target:** Student is able to solve the task with the use of relationships among basic chemical quantities.

**Chemical task:** In the space surrounding the Earth, satellites and spaceships move. Rockets have carried them up to the orbit. The basic movement of the rocket is initiated by the escape of hot gases through the jets. These gases are generated by combustion in the individual stages of the rocket. The Saturn 5 rockets that carried Apollo spaceships had three stages. The second and the third stage contained tanks with a total of 447 000 kg of liquefied oxygen and 55 875 kg of liquefied hydrogen. Write the equation of this reaction, its product, and its mass.

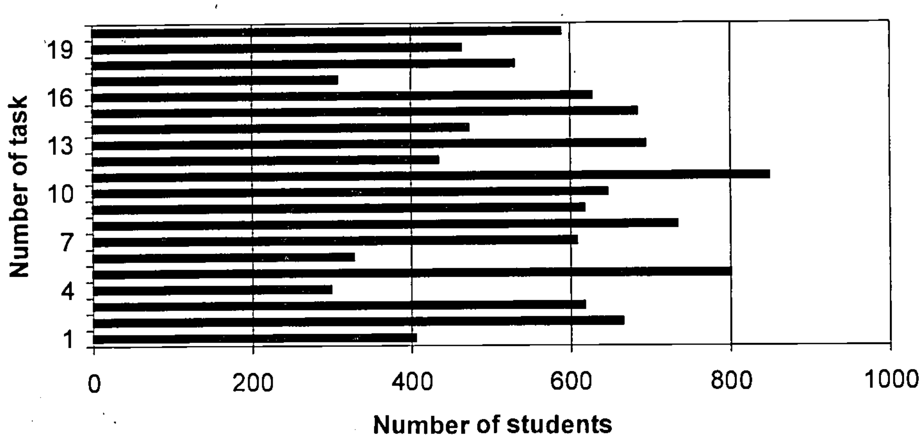
**Solution:** $2\ H_2 + O_2\ 2\ H_2O$, water vapour, 502 875 kg



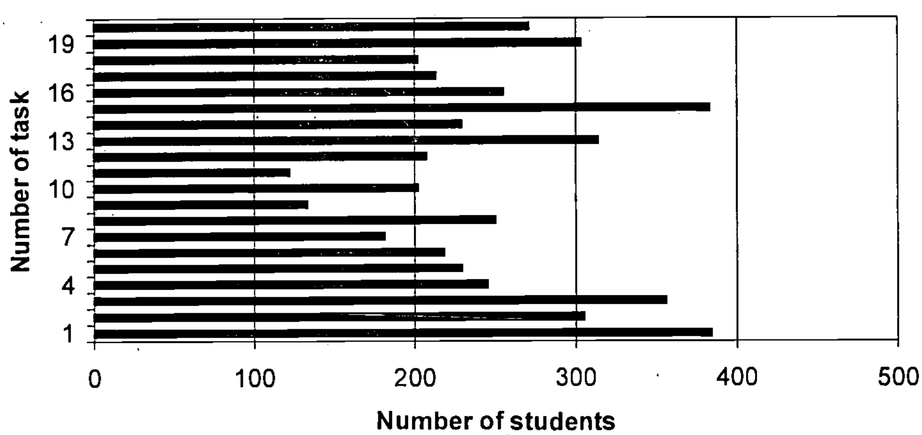
This task (No.7 from Graph 2) was correctly solved only by 32 % of students and incorrectly solved (or not solved at all) by 68 % of students. The students were relatively successful in writing the chemical equation, but much less successful in computing the mass of a product.

964 students in total solved a set of biological tasks while 532 students in total solved a set of chemical tasks. The results obtained are illustrated in the following graph 1 - results of the set of biological tasks, and graph 2 results of the set of chemical tasks.

**Graph 1 - Results of a set of Biological tasks**




**Graph 2 - Results of a set of Chemical tasks**




The graph 1 shows that the tasks 5, 8,11 and 13 were very easy (more than 70 % students solved them correctly), but tasks 4 and 17 were very difficult (only 30 % students solved them correctly). The latter required higher target competences. The graph 2 shows that the tasks 1 and 15 were very easy (more than 70 % students solved them correctly), but tasks 9 and 11 were very difficult (only 30 % students solved them correctly). The latter required higher target competences, too. Therefore, it is clear that it will take a lot of time and a lot of changes will be necessary in both teaching and learning approaches before the students acknowledge themselves with higher target competences. The new assessment project can provide the required results.

## Conclusion

The main output of the project is the publication entitled Catalogue of requirements on the common part of the graduation examination in biology and chemistry in 2004. It was developed by the teams of authors over the period of 1999 – 2000 and issued in October 2000. Over the period of January – April 2001, the first set of study tasks was developed and verified in practice. Based on the analysis of the results obtained, further study tasks are under development at present and these will also be verified in practice. Thus, gradually, a bank of learning tasks is developed for each subject of graduation examination.

One of the main benefits of the above - mentioned project, in terms of common issues related to the assessment of elementary and secondary school education, could be seen in the methodology of the development of assessment criteria that was designed and realized by our team, and that is based on the formulation of the objectives common to a certain area of education. Another important output of the project is the development of sets of tasks with the aim to verify the acquired competences.

## References

1. BLOOM, B. S., KRATHWOHL, D. R. (1956). Taxonomy of educational objectives. David McKay, New York.

2. CERMAT (2001). New graduation examination in Czech Republic. Institut for Educational Information, Tauris, Prague, 16 p.

3. ČÍŽKOVÁ, V. ET AL. (2000). Catalogue of requirements for the common part of secondary-school graduation examinations in the year 2004. Biology. Ministry of Education, Youth and Physical Education, Tauris, Prague,16 p.

4. ČÍŽKOVÁ, V. (2001). Evaluation of the Knowledge of the Natural Sciences amongst Pupils Leaving Elementary Schools. In: Science Education Research in the Knowledge Based Society - ESERA Proceedings, Thessaloniki, p.781 – 784.

5. ČTRNÁCTOVÁ, H. (1997). The theory and practise of project method of the educational tasks. Pedagogika, XLVII, no. 2, p. 138 - 149.

6. ČTRNÁCTOVÁ, H. (1997). Problems and perspectives of science education in the Czech Republic. In: Proceedings of 2nd IOSTE Symposium for central and east European countries. Lublin, p. 21 - 24.

7. ČTRNÁCTOVÁ, H. ET AL. (2000). Catalogue of requirements for the common part of secondary-school graduation examinations in the year 2004. Chemistry. Ministry of Education, Youth and Physical Education, Tauris, Prague,16 p.

8. ČTRNÁCTOVÁ, H., KROUTIL, J., MOKREJŠOVÁ, O., VASILESKÁ, M. (2001). A set of tasks for a common part of graduation examination - chemistry. Tauris, Prague, 108 p.

9. ČTRNÁCTOVÁ, H. (2001). Increasing the effectivity of Science education through interactive tasks. In: Science and technology education: Preparing future citizens - Proceedings of the 1st IOSTE Symposium in Southern Europe. Paralimni, p. 197 - 204.

10. ČTRNÁCTOVÁ, H. (2001). Acquisition of theoretical and practical skills by solving of educational tasks. In: Proceedings of the 6th European Conference on Research in Chemical Education and 2nd European Conference on Chemical Education. Universidade de Aveiro, Aveiro, 6 pp.

11. FRASER, B. C., TOBIN, K. G. (1998) International handbook on science education. Kluwer, Dordrecht.

12. FRIDMAN, L. M.(1977) Logical and Psychological Analysis of the Educational Tasks. Nauka, Moscow.

13. KOLÁŘOVÁ, R. ET AL.(1998). What should an elementary school pupil know about physics, chemistry and biology. Prometheus, Prague, 88 p.

14. NIEMIERKO, B.(1979). Taksonomia celów wychovania. Kwartalnik pedagogiczny, 24, n. 2, p. 67 –77.

15. SJOBERG, S. (1997) Scientific literacy and school science. In: Science, Technology and Citizenship. NIFU, Oslo, p. 9 - 28.

16. TOLLINGEROVÁ, D. (1986) The theory of eduational activity. SPN, Prague.

17. THOMAS, C. A. (1963) Programmed learning in perspective. The Adelphi Press Ltd., Barking.

18. ZOLLER, U. (2000) Innovative STES teaching towards scientific and technological literacy for all in new millenium. In: 3rd IOSTE Symposium for central and east European countries. Prague, p. 14 - 20.

**Keywords:** secondary schools education, Science subjects, target competences, assessment of education, learning tasks, a set of tasks, statistical analysis of data

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# THINKING SPATIALLY: CURRICULA K-16 AND PROFESSIONAL DEVELOPMENT FOR EDUCATORS

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**Abstract**

The study of spatial distributions and relationships has expanded to almost every discipline over the past 25 years. Geographic Information Science (GISc) has itself emerged as a new discipline. At North Carolina State University, seven colleges currently offer coursework in Geographic Information Systems (GIS), the application sub-discipline of GISc. Both graduate and undergraduate programs are offered. In 1996, the College of Education offered professional development activities for educators; participants learned about and have been introducing these concepts to the students in their classrooms in grades K-12, in nature centers, museums, and at other non-formal locations. In this paper, we will describe three different, yet connected, programs: 1) GIS certificate programs offered to undergraduate and graduate students at North Carolina State University, 2) a 5-step conceptual plan and methodology to introduce GIS to educators state-wide, and 3) a specific application and research study for science teachers in a professional development program. All three of these programs are interconnected with the goal of supporting individuals in their use of environmental data to solve problems.

A collaborative network has been developed over a period of years, of individuals from state government, university, corporations, and schools K-12. This network is expanding as more and more individuals take classes, workshops, and seek additional experiences. This network is vital to the growth of knowledge and technology application in universities, schools, non-formal organizations, and communities.

We are at the beginning of an explosion and expansion of the use of environmental data to solve problems – from the development of school bus routes, to the solution of crimes, environmental controls, city and open-space planning, flood and fire mapping, emergency management, and many more. It is important that all students learn how to use technology in their every-day lives and to be technologically prepared for the jobs of the future. We wish to share the work of this collaborative network developed over a period of years, of individuals from state government, university, corporations, and schools K-12. We seek your comments and look forward to your communications.

## Graduate and Undergraduate Programs in Geographic Information Systems

The ability to reason spatially is vital to the understanding of natural and cultural phenomena. Once exclusive to Geography Departments, the study of spatial distributions and relationships has expanded to almost every discipline. This is evidenced at North Carolina State University with over 30 departments active in varying applications of spatial analysis within their respective fields. The expansion has developed over the last 25 years to the point where a new discipline, Geographic Information Science (GISc), has emerged complete with its own academic and professional organizations and journals, a separate program office in the National Science Foundation, academic programs at over 50 universities, and a large job market.

North Carolina State University (NCSU) has been exceptionally active in this new scholarship field. Seven of our Colleges currently offer coursework in Geographic Information Systems (GIS), the application sub-discipline of GISc. NCSU's Libraries are a national leader in the provision of campus and community GIS data services and training, and our Instructional Technologies Program has one of the largest distribution networks of GIS software in the academic world.

NCSU's GIS program has now matured to the point where further expansion to meet the staggering student, research, and professional needs is warranted (e.g., projected professional shortfalls of 3,000 to 4,000 positions per year for the next 10 years). We will establish an internationally acclaimed Graduate GIS Certificate and GIS Minor program to compliment our traditional degree programs–a joint effort of 8 colleges, the NCSU Libraries, the Graduate School, and the IT program.

The program, which will be a new venture for graduate education at NCSU, centers on a 15-credit hour graduate level certificate available to both non-degree (i.e., certificate only) and graduate students enrolled in traditional disciplines. The program is supplemented by a 10-hour graduate minor available to degree program students only. Enrollments in the current GIS courses are running at about 250 students per year and this occurs with no advertising beyond word-of-mouth. Approximately 30 percent of the students in the beginning courses are non-degree, indicating a great opportunity to significantly expand university graduate enrollment with relatively little financial investment - to perhaps as much as the equivalent of 30 full-time graduate students per year.

This program coordinates with each of the university's goals. First, GIS by nature is multidisciplinary. It develops broad ranging partnerships across the university and beyond. We have received support and/or active participation in the program from over 30 different NCSU departments in 8 of our Colleges. We have extensive partnerships with federal agencies, GIS software and application firms, foundations, and an extensive network of K-12 assistance programs throughout the state. Second, our university business plan is impacted in that by implementing this program we stand to significantly increase graduate enrollment. Currently, one GIS course is offered entirely through the web and another has substantial web dependence, thus the program also will enhance NCSU's distance education presence. Finally, we have had successful trial programs with Pembroke University, North Carolina Central University, North Carolina Agriculture & Technology University, and several community colleges and have the potential to employ GIS as a mechanism to raise underrepresented populations on our campus.

Thanks to substantial investments by NCSU Colleges, Libraries and Graduate School, foundations, and a very successful research program, the infrastructure (software, hardware, and key personnel) is in place to support this program.

**Phase 1:** The initial phase will last three years and a full evaluation of program results will be developed and delivered during the spring of the third year along with recommendations for continuation and adjustments.

**Phase 2:** It is anticipated that the initial phase will be an overwhelming success. Additional faculty, technical support, and additional laboratory and support staff space will be required in this next phase.

We seek to establish a Graduate Certificate in Geographic Information Systems that will provide NCSU graduate students the opportunity to develop recognized academic credentials in Geographic Information Systems in addition to their major area of graduate study. In addition, we will provide non-degree graduate level students the opportunity to develop recognized advanced expertise in Geographic Information Systems.

We also seek to establish a Graduate Minor in Geographic Information Systems, by providing NCSU graduate students the opportunity to develop a recognized minor academic credential in Geographic Information Systems in conjunction with their major program of graduate study.

If you are interested in the specific academic requirements and coursework, please contact Dr. Hugh Devine.

### A Five-step Plan and Methodology to Introduce GIS to Educators State-wide

**GIS Consortium**. The North Carolina GIS Consortium formed in 1996 represents a dynamic partnership between state agencies, universities, GIS users in municipalities, and software companies. Central to the

Consortium is SCI-LINK, an educational initiative that links research scientists with teachers and students to bring cutting-edge environmental science directly to the classroom in the most pedagogically sound and engaging way. SCI-LINK represents NCSU's College of Education, College of Natural Resources, and the Center for Earth Observation. Other partners include the NC Center for Geographic Information Analysis, NC Department of Public Instruction, many entities in the NC Department of Environment & Natural Resources (DENR), including the Office of Environmental Education and its Divisions of Water Resources and of Water Quality, Urban and Regional Information Systems Association (URISA), and Environmental Systems Research Institute, Inc. (ESRI). The Director of the DENR Office of Environmental Education chairs our consortium's semi-annual meetings. Consortium members function as the Steering Committee for this project and will continue to provide professional expertise and resources to support the ongoing educational program.

**Non-point Source Pollution.** Polluted runoff in wetlands, a form of non-point source pollution, raises many serious environmental concerns related to water quality—community issues that are of great and growing importance to the health of the environment and to the people of North Carolina. How can we learn and teach about the vitally important environmental topic of non-point source pollution? How can we prepare teachers and students to extract information from different sources and employ a range of emerging technologies, while we simultaneously enable and empower each teacher to shape a classroom/site application plan that incorporates national, state, and local standards and frameworks? Our goal is to pilot a *model program* that integrates these multiple goals and strategies, utilizing emerging GIS technologies as tools to collect, access, and then to analyze environmental data for use in all curriculum areas, based on environmental education principles. Activities will include professional development opportunities for teachers, environmental monitoring, and research conducted by educators and students, and the "APlans" that educator-participants will develop for each educational site.

Non-point sources include lawn herbicides, pesticides, and fertilizers, oil residues from city streets, and agricultural runoff–any pollution that is general in nature, as distinguished from "point source" pollution from factories and waste treatment plants. Our state's increased urbanization, which has accompanied our 19.5 percent housing unit growth rate (6th nationally) and has led to more impervious surface area, thus generating more runoff that leads to increased flooding. Flooding can bring overflow from hog waste lagoons and sewage treatment plants and contaminate sources of drinking water. However, because it is often difficult to pinpoint the source of such non-point pollution, it is challenging for communities to address. The topic also presents unique challenges for those who prepare environmental educators, the educators themselves, and their students. The need for better integration of education about non-point source pollution has been recognized by our state government. Secretary Ross of the NC Department of Environment and Natural Resources has asked every division within the agency to include raising public awareness of polluted runoff as a major goal for 2002.

The environmental consequences related to wetlands and polluted runoff are central to our proposed model program. These environmental issues are of great and growing importance to North Carolina communities, as they have a direct impact on the health of the environment and of the people of North Carolina. In the graduated workshop series that we have been piloting and that we plan to transform into a model program, answers may be found to such questions as, "What is my ecological address at home? at school? In what river basin do I live? Where does my drinking water come from? Where does the water from the washing machine go? What are wetlands? How close am I to a flood plain? What happens to the water from a parking lot? If I were to look from a satellite, what does my schoolyard look like? What is a topographic map? Can I make one?"

**Education about the Environment.** This project focuses on building knowledge in education about the environment, new innovations in technology, and current scientific research. *From Pilot Study to Model Program* will build a critically needed capacity in North Carolina's education community to increase educators' knowledge about and interest in non-point source pollution; improve their access to environmental data collection, analysis, and display; and prepare them to develop integrated plans of application for use in their schools or at other educational sites. The model will become institutionalized over time, with each institution using applications for their locale.

We have piloted a series of graduated workshops that overcome barriers for teachers to master these technologies and integrated uses in the classroom, but have conducted this to meet short-term needs rather than build capacity for the entire state of North Carolina. We need to marshall our partnership resources to move these piloted workshops into a visionary plan to introduce environmental topics, the use of environmental data, and environmental education to a much broader audience, even beyond the state. This program takes into consideration the barriers teachers have encountered, the experience levels of teachers using technology, and the availability of classroom computers. We will test this model. We will rely on our formative and summative evaluation to help us make necessary changes and form final recommendations, so that other educational institutions will be provided with a practical, working model for dissemination. Master Teachers, former participants in this ongoing program will become Workshop Leaders.

The NC Education and Environment Roundtable developed a strategy that embraces "five proven educational practices: integrated interdisciplinary instruction; collaborative instruction; problem-based learning; student-centered, constructivist methods; and cooperative learning." This approach also reflects the *Guidelines for Excellence in Environmental Education* as proposed by the North American Association for Environmental Education. In North Carolina and in many other states, the envisioned model program can be a cornerstone in the design of learning and teaching programs focused on many environmental topics and has implications for the teaching of GIS and related technologies. In addition, environmental education as promoted through our project cultivates the teaching skills and learning habits necessary for deeper learning in many other subjects.

In addition, as is well-documented, technology can be a key enabler of inquiry learning, And studies have demonstrated that appropriate uses of technology can improve student achievement. In our project, different technologies are utilized to maximize understandings. Teachers can fulfill requirements for technology credit in new and different ways. And they can utilize these technologies for the state's new Earth/ Environmental Science requirement for high school graduation. For example, one student in a local high school who had had no hope of going further in school worked with one of our former participating teachers. He was so intrigued with ArcView as a Junior that he became highly proficient in the software applications and has just received a full scholarship to a local university upon graduation.

Week-end, two-day, and one-week workshops and follow-up sessions are components of the graduated model program. Consortium members will be important components of the workshops. Teachers, students, and non-formal educators will present their work at a range of meetings, including at their own sites, faculty and PTA meetings, and at NCSTA, NCEEAC, URISA, GIS Teacher Day (in conjunction with GIS Day), and other NC meetings. Presentations will also be made at national meetings sponsored by NSTA, NAAEE, ESRI, URISA, and others.

After evaluation and revision, the model will be disseminated throughout our state by the 16-campus UNC system's Mathematics and Science Education Network and by our other partners. However, we believe our model will have broader implications for national dissemination. In North Carolina and in many other states, the model program can be a cornerstone in the design of learning and teaching programs focused on the many different facets of polluted run-off. Each school, university, or non-formal site will be able to address the environmental topic of most concern in that region. A GIS Users Group will enable participants to communicate across the state to share their findings. A website will provide contact for calendars for future workshops, presentations, publications, and findings, and serve as a way to communicate and provide a network for educators.

We will continue announcing the workshops within our proposed model program through the SCI-LINK website, newsletter, and listserv (comprised of 1000+ individuals), the Environmental Education network, the NC Science Teachers Association newsletter and annual meeting, graduate classes, and other various means. (In North Carolina, we've found that word of mouth is most important.) Two individuals are already signed up for SCI-LINK Summer Workshops 2002, and we anticipate having a waiting list in 2002. With a few additional requirements, graduate, continuing education, environmental education, and technology credits are available for the participants.

Our project is structured to leverage our prior GIS workshops by identifying and cultivating master teachers from them as well as building on our knowledge of how this material is best learned—through a graduated series of workshops. Our intent is to capture, over a year, a group of teachers who are cycling through the more advanced workshops, while also recruiting and reaching teachers and other non-formal educators to attend entry-level workshops. The more advanced teachers (master teachers) will assist us in delivering the entry-level workshops.

Wake County is leading the pilots of the project, sponsoring two entry level (Step I) weekend workshops for teachers in Spring 2002 and two in Fall 2002. Participants from previous GIS workshops with strong track records will serve as Master Teachers. The Wake County Public School System (the 5th largest district in the U.S.) has a long-standing tradition of excellence. Over 100,000 students attend its 123 schools, with over 89 percent of its students going on to post-secondary education. According to Wake County Science Supervisor, Mike Tally, "this grant proposal is a *strategy* that will help us identify exemplary models of teacher preparation that, if successful, can be widely replicated. This on-going professional development model using GIS/GPS will improve the quality of mathematics and science teaching in kindergarten through grade 12." Evaluations and results from these workshops will serve as a vital component of the pilot project.

**The Model Program**. The Model Program is a graduated program. It involves a five-step workshop series. A skeletal overview of the workshops follows: Step I Workshop is an introduction to maps, spatial thinking, and non-point source pollution using ArcVoyager. Step II focuses on a specific school or other site and advances the ideas and concepts from Step I. Mapping a 10-meter site, monitoring various parameters (including cover, temperature, animals, plants, and run-off) using GPS, GLOBE protocols, and CityGreen provides knowledge of a specific area. Step III focuses on the community, with field trips to compare polluted run-off and other environmental factors. Agency personnel present research on specific sites. GPS units, data from the internet, and beginning use of ArcView is introduced. These workshops include project and inquiry-based learning, and all require use of critical thinking skills.

From our previous experience, we think most educators will take these three workshops within a year. Step IV and Step V workshops are more advanced. Most likely, educators will take these during a second year, after they have had the opportunity to utilize the experiences from the Steps I-III workshops in their classrooms/sites. We think that the graduated program is the most realistic strategy and will appeal to most educators. We believe a positive outcome for each participant is much more possible using this graduated approach. Only the evaluation and participant reactions will indicate this.

Using the new conceptual overview associated with principles of teaching and learning, we seek to facilitate the learning process using environmental data with these new technologies. This approach requires testing and evaluation of each workshop to develop a final model for future dissemination throughout the state. It is hoped that this will be successful, and that other states will want to make use of this model.

A required final component of each workshop is what we are terming the "APlan," which reflects the participant's integrated response to and use of all components of our program in their educational setting. Can each participant apply what they have learned in a workshop and carry it out in their own classroom/site? Using information, techniques, strategies, methods, resources, and outcomes of each Step workshop, educators must define objectives within their own curricula that they will meet when they return to their classroom/site. How will they teach in their classroom or in their nature center? These lesson plans must be aligned with the National Standards for Science Education, National Council of Teachers of Mathematics Standards, Technology Education Standards, EPA's Guidelines for Excellence in Environmental Education, and each state's frameworks. Timeline, methods, materials, and community must each be addressed in the APlan. How has each participant related their APlan to run-off pollution? To environmental education concepts? To technology? Are there anticipated problem areas? Each participant will present their APlan the last afternoon of the workshop and share it with others. During the Follow-up Day (about 3-4 months later), each participant will bring an evaluation of their individual APlan, sharing their student's reactions, feedback, and student work. The revised APlans will be put on the web to share with others.

Evaluation of the pilot program will 1) measure the project's effectiveness (summative), and 2) apply evaluation data gathered during the project to strengthen the program (formative). The evaluation will have both quantitative and qualitative components and will take place during and after all workshops as well as the Step I workshops. Evaluation will focus on pedagogical practices, workshop content, and participant understanding of content areas. Particular attention will be paid to the learning of new technologies by the participants.

After each workshop, a customized instrument will be administered to gather data about how participants felt about the content and teaching strategies used within the workshop. Information will also be collected, upon implementation of materials back in the classroom, about the workshop's usefulness. A standardized test will be administered thereafter to assess cross- comparisons of knowledge gained and the role of teachers' learning styles and differing backgrounds in how effectively they apply new information. A final part of the evaluation process will include interviews of randomly selected participants to receive feedback on the process and structure used during each workshop and recommendations for future workshops.

Contact Dr. Harriett Stubbs for more information about this project.

## Description of a Specific Application and Research Study for Science Teachers

Mapping Our School Site (MOSS) using Geographic Information Systems (GIS) is a project in which teachers and their students monitor a 10-meter by 10-meter site on their school campuses. The data collected is used to formulate and analyze the relationships between the abiotic and biotic components of the environment. Problem questions formulated by student research groups are analyzed using GIS, phenomena are modeled, and results are communicated visually. "MOSS is multi-disciplinary and embraces science, technology, biology, geography, and math. It allows students to work in cooperative groups and experience hands-on science." (Nain Singh, Carrington Middle School, Durham, NC) "MOSS helped show me how to engage students in inquiry-based learning." (Belinda Hogue, Anna Chestnut Middle School, Fayetteville, NC) In the MOSS project, the 3 X's of technology are experienced using GIS - eXplore, eXpress, and eXchange. These three fundamental skills are necessary for digital equity in the 21st century (Hardel, Idet, www.mamamedia.com).

In the MOSS project, teachers use a website to teach the unit (www.ncsu.edu/sci-link/studysite). Procedures for monitoring the components of the 10-meter by 10-meter study site, grading rubrics, GIS instructions, spreadsheets, and base map files are all downloadable from the website. "We are using the website as a guide and information management system." (DeeDee Whitaker, Southeast Guilford High School, Greensboro, NC) "Students can download the spreadsheets and enter data. There is a virtual wealth of information here such as an on-line picture insect identification guide." (Ginny Owens, Ligon GT Middle School, Raleigh, NC) Management strategies, alternative assessment examples, examples of problem questions and final maps from various school sites are also pictured on the site. A problem-solving section contains a verbal map and graphic organizer for formulating good problem questions and a guide for solving problems skillfully. Depending on the problem investigated, other data may need to be collected. This allows flexibility and a focus on specific curricular content such as soils, light, or air temperature.

There are many other environmental data collection procedures available such as those from GLOBE (www.globe.gov) or others contained in the curriculum. Each data collection point has a locational attribute. It is entered and saved in a data management program such as EXCEL and further analyzed using GIS. The geodatabases are visualized and results communicated. One problem question can be investigated by a group of students or several different questions can be investigated by many small groups. The project allows teachers to choose what is most important for their teaching and learning.

Teachers then use CityGreen (an extension to ArcView), GIS, and aerial photographs of their school to create an ecological analysis of their school site based on trees and tree canopy cover. CityGreen involves students collecting data on trees, buildings, impervious surfaces, grasslands, and shrubs. GIS formulates statistics on the school site and reports carbon sequestration and storage, pollution removal benefits, energy conservation, and tree growth models of their school site. Informed decisions can then be made regarding management of the outside environment. "It is as important for us to manage our green environment as our building environment.

We are planning a nature trail through our school campus. We have received grant money to plant trees removed due to building renovations." (Ginny Owens, Ligon GT Middle School, Raleigh, NC) "We can do tree-loss counts now due to the construction on our campus." (Sarah Hanawald, Greensboro Day School, Greensboro, NC) "My students have learned how to collect data, make observations, formulate hypotheses, solve problems, and ask questions through these projects." (Pat Schweiger, Leesville Middle School, Raleigh, NC) "My students have studied the impact of human development and the consequences of population density." (Val Vickers, Greensboro Day School, Greensboro, NC) "This project has shown me how to take science outside and relate it to the local environment. It has shown me how to integrate technology into the science curriculum in a new and better way." (Carolyn Moser, Leesville Middle School, Raleigh, NC)

Geographic Information Systems (GIS) is a powerful technology for schools. It is an interdisciplinary approach that enables teachers and students to become techno fluent by focusing on problem-solving using real world data. Technology skills are learned and practiced but the task itself is central with the technology as substrate. Teaching using GIS alters the environment for thinking, learning, and communicating. It enables teachers and students to demand and articulate their technology needs. Teachers in the MOSS program have received new computers, color printers, scanners, and plotters for their classrooms, some provided by their school systems and others donated by businesses and industries. Community partnerships with universities and Urban and Regional Information Systems Associations (URISA) have developed and continue to provide ongoing GIS technical support for the schools. School projects have been presented by teachers and their students at conferences in science (NCSTA, URISA), technology (GIS in Education, NCAECT), and education (National laptop schools). A video made of the MOSS project in one school was broadcast to over ten states as an example of effective technology use in science (STAR network, NCDPI). Finally, multiple school projects are beginning to evolve in which GIS is used to investigate a community environmental problem. Four schools in the Walnut Creek watershed, Raleigh, NC, are working to preserve a wetland; two high schools are monitoring water quality on the Deep River in Greensboro, NC. GIS has provided the framework for all of these projects and allows schools to teach through technology.

In the future, teachers and students in more schools would like to participate in the MOSS program. They want to develop networks with each other and compare their school sites with other school sites in different parts of the country, possibly the world. They are interested in preserving and monitoring their outside environment on a continuous basis and are becoming more active in the decisions made regarding the green space in and around their schools. GIS allows students to learn real world skills that they will be able to use to solve many types of problems in the future.

The website is: www.ncsu.edu/scilink/studysite

Contact Rita Hagevik for more information about this project.

## Conclusion

In this paper, three of us, one a university professor in natural resources and technology, one a professor in science education, and one a Ph.D. student in science education, each describe three different, yet connected, programs: 1) GIS certificate programs offered to undergraduate and graduate students at North Carolina State University, 2) a 5-step conceptual plan and methodology to introduce GIS to educators state-wide, and 3) a specific application and research study for science teachers in a professional development program.

All three of these programs are interconnected with the goal of supporting individuals in their use of environmental data to solve problems. For example, teachers may attend a workshop, they then return to their classrooms, apply and use environmental data with their students to solve problems. Teachers may return to the university to become part of the certificate program. The students of the teachers may then become undergraduates in the environmental degree programs at the university. A number of the graduates in the GIS certificate programs support the educational K-12 programs, such as: present in workshops and support teachers, provide maps for classroom use, serve as guest speakers in classrooms, load software, provide and find data for the teachers to use, and are a resource to educators.

A collaborative network has been developed over a period of years, of individuals from state government, university, corporations, and schools K-12. This network is expanding as more and more individuals take classes, workshops, and seek additional experiences. This network is vital to the growth of knowledge and technology application in universities, schools, non-formal organizations, and communities.

We are at the beginning of an explosion and expansion of the use of environmental data to solve problems – from the development of school bus routes, to the solution of crimes, to environmental controls, city and open-space planning, flood and fire mapping, and emergency management. It is important that all students learn how to use technology in their every-day lives and to be technologically prepared for the jobs of the future.

We seek your comments and look forward to your communications.

## References

Alibrandi, Marsha, Candy Beal, Anna Wilson, Ann Thompson & Rita Hagevik. Chapter in book, Improving Social Studies Teaching and Learning through School/University Collaborations, (in press).

Alibrandi, Marsha, Ann Thompson & Rita Hagevik. Chapter in book, GIS in Schools, "Historical Documentation of a Culture", ESRI Press, 2000.

Argentati, Carolyn, H.A. Devine, and Hal Meeks. "The Student-Directed, Information-Rich SDIR) Undergraduate Education Project," *CONNECT*, No. 26, Fall 1996, pp:7-9.

Devine, H.A. and Stephen O. Morris. "From Experimental Undergraduate Course to Graduate Degree Program: The Development of GIS Instruction at North Carolina State University", Proceedings of GISED98, Ypsilanti, MI, 1998, pp: 83-96.

Devine, H.A. and Deborah S. Savage. "On-line GIS Instruction at North Carolina State University's College of Forest Resources," Second Biennial Conference on University Education in Natural Resources, Logan, UT, 1998, pp: 167- 175.

Baron, P.K., Hugh A. Devine, and Carolyn Argentati. "A Comprehensive GIS Data System for Public Participation in Regional Planning in North Carolina: The Research Triangle Prototype", National Urban and Regional Information Systems Association Meeting, Charlotte, NC, 1998, pp: 234-252.

Devine, H.A. and Leslie L. Armstrong. "GIS in The National Park Service", The 10th Conference on Research and Resource Management in Parks and on Public Lands, Asheville, NC. 1999 (In press)

DuBay, Denis, and Harriett S. Stubbs. "Geographic Information Systems and Environmental Education". In Environmental Education for the Next Generation: Professional Development and Teacher Training, Selected Papers from the Twenty-fifth Annual Conference of the North American Association for Environmental Education, San Francisco Bay Area, Calif. November 1-5, 1996. NAAEE, Troy, Ohio. 1997.

Stubbs, Harriett S., Denis T. DuBay, Norman D. Anderson, Hugh A. Devine, and Rita A. Hagevik. 1999. Environmental Science Utilizing Geographic Information Systems (GIS). In Proceedings of a Conference, North American Association for Environmental Educators, Annual Conference, South Padre Island, TX. October 2000. 4pgs. CD-ROM. NAAEE, 410 Tarvin Rd., Rock Spring, GA 30739, USA.

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# DESIGNING AND ASSESSING INSTRUCTIONAL MATERIALS BASED ON GUIDED INQUIRY

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## Abstract

Using materials based on guided inquiry to engage students and educate them to meet current educational expectations is a new challenge for education generally and for teachers in particular. Teachers are leaders of the human interactions we define as the curriculum. Their commitment to the new approaches to education called for in mandates such as the National Science Education Standards and Project 2061 in the United States is essential if our society is to accomplish all of the goals we now set for science education, both in and beyond school. By rethinking the traditional concepts that have shaped schooling for more than a century, guided inquiry can redefine the roles of students and teachers alike.

Students are no longer passive vessels that teachers must labor to fill with knowledge; they are no longer raw material in a process that trains them to look to others not only for information, but also for judgments of its value. If science educators are to meet society's new demand for mastery learning on the part of all students, they first must engage students. If teachers are to engage students without draining their own creativity in the process, teachers themselves must first find the materials available to them engaging while also maintaining academic rigor. Such materials need to define, and approach, learning in a way that is starkly different from what conventional textbooks and worksheets do: this new kind of material should be organized around issues and principles that touch students' lives directly.

Guided inquiry is therefore defined and recommended as an approach to enhancing student learning in science. It is also identified as a powerful organizing principle for development of instructional materials in science. Engaging of students in their own learning is emphasized. Principles for the design and assessment of instructional materials in science are discussed. Recommended is an enhanced role for teachers in any materials development effort. Their role as academic leaders in their schools and communities is emphasized.


## Introduction

Development of quality instructional materials that engage students in their own learning is a complex process. This paper discusses the importance of guided inquiry and the involvement of teachers in the development process. Assessment is defined as an integral part of instruction that helps developers, teachers and especially the students to better understand what they have learned and what they want to learn.

## Guided inquiry as an organizing principle

The new social and economic demands for higher- order intellectual skills, coupled with our new understandings about the mechanisms of genuine learning, require a new approach to teaching and learning. That new approach has to move beyond attempts to improve the traditional lectures, textbooks, and worksheets. One way this new approach can be accomplished is by applying the concepts of guided inquiry. New definitions are emerging of what it means to educate and be educated. These definitions measure learning not by what students are able to recite or the books they have been assigned, but by what students are able to do. That means that "learning" can no longer be defined as taking courses and passing tests, but only as mastery of a subject or skill demonstrated by the ability to apply concepts and processes flexibly and accurately outside of the classroom. Performance assessments have been developed to meet the new learning goals *(Champagne & Newell, 1992; Messick, 1994; Shavelson, 1991*, NAS p. 101) New definitions of learning, in turn, call for a new understanding of what a "curriculum" is.

This will not be easy. The challenge, and the opportunity, that the new social and economic mandate poses to materials developers and teachers is to think in fundamentally different ways when creating learning experiences for students. It calls on them to surrender the notions of "instruction" and "lessons" and to think instead in terms of "questions" and "investigations". In that sense, materials developers and the teachers who collaborate with them are "learning engineers": they apply the latest research to create practical methods of helping students achieve not just grades, but the intellectual benchmarks that new national standards are establishing. To accomplish that, developers and teachers must begin acting less like lone inventors and more like applications teams. —They need to work collaboratively in a clearly organized multi-step process, sharing ideas, critiquing each other's efforts, and aiming for a steady flow of incremental improvements. Experience shows that the change is worth making-not only for the sake of students, but also to help teachers continue to find engagement and meaning in their own work.

Guided inquiry does not ignore or belittle the value of the information that textbooks, databases, and other repositories of facts have to offer. No one, student or adult can be expected to rebuild the entire structure of science or other disciplines for themselves. Educational research, and a century of experience, has shown us that facts must be given a meaning and context that enables students to assimilate the information into their personal structures of knowledge.

By rethinking the traditional concepts that have shaped schooling for more than a century, guided inquiry can redefine the roles of students and teachers alike. Students are no longer passive vessels that teachers must labor to fill with knowledge; they are no longer raw material in a process that trains them to look to others not only for information, but also for judgments of its value.

Guided inquiry helps teachers to stop being the all-knowing source of information and lets them become more of a facilitator" or learning coach, a person who helps students master the processes of learning for themselves. Equally important, through guided inquiry students can develop the skills of lifelong learning: the ability to frame problems, ferret out facts, test and assess the accuracy and relevance of those facts, articulate conclusions, and make reasoned, evidence-based decisions. These are crucial survival skills in a world awash in un refereed information, much of it being peddled by groups with partisan agendas to promote. Guided inquiry however is only one means to an end. The goal is higher quality learning experiences for students. Before discussing the nature of guided inquiry it is important to summarize what our expectations for student learning in science are.

## Designing Learning Experiences for Students

The scientific experiences that we design for students should be:
- Conceptually structured;
- Evidence-based;
- Materials-centered; and
- Guided inquiry-oriented.

By conceptually structured, is meant that the structure of an experience or inquiry is to be designed to be "transparent"—to reveal the knowledge we want students to confront through the activity, not to make the mechanical aspects of the activity itself the centerpiece. Each activity or investigation must forcefully convey substantive, specific principles, ideas, and facts within the context of scientific processes. Activity for its own sake can be a way to keep students entertained and busy, but it is as educationally pointless as the rote transfer of data.

Guided inquiry in science must be evidence-based because science is defined operationally as a process of gathering and evaluating physical evidence in order to answer questions and make decisions. Increasingly, being able to gather and evaluate scientific evidence is a survival skill as essential as reading. As citizens, voters, and consumers, we are being asked to make more and more decisions related to science and technology. Whether about global issues such as environmental protection or about personal questions such as the value of taking vitamin supplements, such decisions must be made on evidence collected and presented to us by others. Therefore, helping all students cultivate skills in judging evidence and the ways in which it has been gathered, and incorporating those skills into their personal lives, is key to ensuring that our society can respond to technical issues appropriately and confidently.

Classroom science must be materials-centered because science itself is. Scientific investigations gather and interpret quantifiable information about the material world. Being able to measure physical quantities and to observe external events are key skills in any scientific process, particularly in replicating tests and investigations to assess the accuracy of others' results. If they do not develop skills in using materials, students will not experience science.

Finally, our definitions tell us that students' learning experiences in science should be guided inquiry-oriented. Through guided inquiry, student's can experience the processes by which evidence is collected, tested, evaluated, and put to use. These elements of guided inquiry can be keys to achieving the National Science Education Standards' goal that students experience science and scientific processes so that the students later are able to use them to make personal decisions and increase their economic productivity (NAS, 1996, p.13).

**Historical Development of guided inquiry**

A course of learning that emphasizes knowledge within a framework of process skills—and that places both in the context of life beyond schools and classrooms—is needed to fulfill the new expectations for science education in our society.

But this is not news. The struggle to articulate these new definitions of teaching and learning began in the 1960s (summarized in" Piaget, Gruber, and Vonèche, 1977). The movement began in earnest in the early 1970s with a push for "hands-on" science study and activity-based learning ("summarized in" Stohr-Hunt, 1996] The hands-on movement was a crucial step in moving science education forward. But it lacked consistently effective instructional frameworks guiding students' attention from what they were doing to the scientific principles they were modeling

Seeking to forge the missing link, educators in the 1980s began to unite content with activities to foster "inquiry education" (see, for example, Welch, 1981 or Shulman, 1987). Students still conducted activities, but those activities were wedded to academic content—another crucial step forward. But, again, inquiry education has its weaknesses. Specifically, individual inquiries often lack a comprehensive direction or framework. Emerging from the tumult of educational change and "reform" of the 1980s, the National Science Education Standards in the United States embody that call (National Academy of Sciences [NAS], 1996 p.113). Indeed, as summarized below they do nothing less than mandate a completely new approach to science education and, therefore, science learning materials.

The National Science Education Standards envision change throughout the system. The science content standards encompass the following changes in emphases:

| LESS EMPHASIS ON | MORE EMPHASIS ON |
|---|---|
| Knowing scientific facts and information | Understanding scientific concepts and developing abilities of inquiry |
| Studying subject matter disciplines [physical, life, earth sciences] for their own sake | Learning subject matter disciplines in the context of inquiry, technology, science in personal and social perspectives, and history and nature of science |
| Separating science knowledge and science processes | Integrating all aspects of science content |
| Covering many science topics | Studying a few fundamental Science concepts |
| Implementing inquiry as a set of processes | Implementing inquiry as instructional strategies, abilities, and ideas to be learned |

If students are to find personal meaning—another word for relevance—in science as the new standards mandate, science education must move beyond the old definitions of inquiry learning. There must be a plan that guides students as they move from activity (or at least a reading that motivates them to ask questions) to information, then through the synthesis that leads to understanding, and, finally, relevance—meaning in the students' own lives (Linn and Hsi, 2000).

To chart that path, educators and materials developers need to expand the idea of inquiry to "guided inquiry" (as reviewed in Tafoya, Senal, and Knecht, 1980]

## A Working Definition of Guided Inquiry

In this paper guided inquiry is defined as the sequencing and integration of appropriate processes and information chosen through research, to fashion experiences for students. These experiences should lead students to:

- Confront scientific concepts and principles in the context of real-world problems or situations;
- Use data and evidence to reason their way through a particular problem or issue;
- Reach independent conclusions or decisions justified by the data and evidence.

The concept of "guided inquiry" gives equal weight to knowledge and skills, retaining a hands-on or activity-based focus that relies on strong content. Sequencing activities in a larger curricular plan or design enables educators to reach their curricular and instructional goals. Placing scientific ideas and processes in the context of actual issues—balancing the risks and benefits of industrial production, for example—can suddenly give formerly abstract concepts meaning within students' own lives, a key element in helping them master knowledge.

The task of teachers and materials developers in guided inquiry is twofold. First, they must define and structure those experiences to achieve specific, substantive educational goals that include the development of the higher-order skills the new educational standards call for. Second, they also must frame and structure those experiences in the most engaging and effective ways. The teacher's challenge is to "orchestrate the performance of the materials and their processes (the teachers' own performances as well as those of students) in a way that brings the ideas embodied in the materials to life in the mind of each student (Sarason, 1999). The materials best able to achieve that goal result from the intimate collaboration of materials developer and teacher—craftsperson and performing artist, if you will—each translating and enhancing the skills of the other.

## Engagement a Key to Quality Learning

If science educators are to meet society's new demand for mastery learning on the part of all students, they first must engage students. If teachers are to engage students without draining their own creativity in the process, teachers themselves must first find the materials available to them engaging while also maintaining academic rigor. Such materials need to define, and approach, learning in a way that is starkly different from what conventional textbooks and worksheets do: this new kind of material should be organized around issues and principles that touch students' lives directly. Materials for guided inquiry not only present science content in a new way, but they also necessarily must be created in a new way. Content experts alone can write traditional textbooks. Materials that engage students in guided inquiry can be effective only to the extent that they are designed and refined by a team of diverse specialists. Content experts, veteran classroom teachers, editors, illustrators, assessment specialists, and others, pooling their individual expertise can ensure that materials are as imaginatively stimulating as possible while remaining academically challenging. Teachers, to make it possible for all students to learn effectively and consistently, have to rely to a significant degree on the quality of the materials they use and the learning experiences for students that those materials structure. A dusty science book can too easily alienate students and render them apathetic or even hostile to a subject, regardless of what a teacher does (or does not do) (Mechling & Oliver, 1983; **cf.** Duschl, 1986;). An effectively designed student learning experience, structured through the use of the right materials and based on guide inquiry can grab students' attention, brings ideas to life, and fill a classroom and its teacher with new energy—

## Creating Materials for Guided Inquiry

The development teams' challenge is to create for every teacher materials that embody academic concepts and principles in a rigorous way and also empower teachers to use their full range of skills, imagination, and creativity. This combination of carefully designed materials and skilled teaching can help every student weave those concepts and principles, rich with meaning, into his or her practical understanding of the world.

Creating materials for guided inquiry demands a combination of widely diverse skills on a scale, and of an intimacy, almost unknown in conventional materials development. Ensuring the accuracy and currency of the facts, concepts, and methods that the materials will present is a job for content specialists. But education researchers, not content specialists, can best determine the compatibility of materials' structure and approach with what is known about the mind's mechanisms of effective and efficient learning. Writers and graphic designers, not researchers or content specialists usually are the most skilled at presenting substantive information clearly and easily in ways that hold students' interest. And, as these experts work together, at every stage working classroom teachers must analyze and question. "How would my students respond to this?" "Would this work for me and other teachers in the classroom?"

This degree and diversity of collaboration in development is rare in materials development.

## Teachers role in Guided Inquiry

Using materials based on guided inquiry to engage students and educate them to meet current educational expectations is a new challenge for education generally and for teachers in particular. Teachers are leaders of the human interactions we define as the curriculum. Their commitment to the new approaches to education called for in mandates such as the National Science Education Standards and Project 2061 [AAAS] in the United States is essential if our society is to accomplish all of the goals we now set for science education, both in and beyond school.

As teachers recognize the challenges to their profession that the new century lies down, they also will recognize the opportunities those challenges open to them. By joining with developers to create materials for guided inquiry, teachers can do more to ensure that their students achieve the new standards. By working with developers to implement guided inquiry in their classrooms, teachers can find the opportunities for professional growth and begin to accomplish the ideals that brought them into the profession in the first place.

Teachers—with their unique, front-line classroom experience must play a vital role in designing materials for guided inquiry. They also play the central role in implementing those materials effectively in classrooms. Because the classroom is the developer's laboratory as well as the ultimate destination for the materials that developers create, collaborations between classroom teachers and a development team must lie at the center of any good development project.

## "Curriculum" and the teacher's role in creating it

It might not seem obvious at first, but this collaboration between materials developer and classroom teacher is, in fact, a different way of defining the term "curriculum."

Many educators, consciously or not, define curriculum as the textbooks or other materials that are delivered by publishers and other materials producers. This view relegates the teacher to the role of a repeater station between the content specialist, who is broadcasting, and students, who become the equivalent of radio receivers. Instead, we would argue that materials are not a curriculum any more than a blueprint is a building or a violin is a tune.

Materials are a detailed plan that becomes "curriculum" only when a competent teacher uses them to shape and guide interactions with and among students. The curriculum itself is the opportunities (spontaneous as well as planned) for learning that arise from the meeting of minds between teacher and student through materials.

Materials developers can create, design, and produce learning materials, but no matter how well-conceived the materials are, their effectiveness depends on the human interactions between teacher and student as the two interpret together the materials' meanings and implications. This interaction, sparked by the materials, sets the stage for a guided inquiry into the materials' content that fosters a complex and essential engagement between student and teacher. That engagement, which can (and should) reflect all of the complex dimensions of human interactions, is the basis for what is meant in this paper by "curriculum". Thanks to the National Science Education Standards and 2061 those goals now emphasize students' abilities to carry scientific principles and processes beyond the classroom and use them in making decisions in their own lives. This novel definition of "curriculum" necessarily redefines the mission and role of the teacher. If the old view cast the teacher as an information transfer station, the new one casts her more in the mold of a performance artist or jazz musician.

While the old definition of curriculum views the teacher as a worker who follows instructions from administrators and textbook authors, the new definition views the teacher as a kind of entrepreneur—using the academic and human capital at hand to create and then seize the teachable moment.

If materials become effective curriculum only in the hands of a skilled and engaged teacher, then materials developers cannot succeed without teachers as full partners in creating interactive materials for guided inquiry. The teacher knows what is likely to work with students and other teachers, what likely will not, and why. Without the practical wisdom of working teachers, developers will not be able to create interactive materials that engage teachers and students while still accomplishing the new, skills-based educational goals of a 21st-century society.

### Assessment and evaluation

Gauging the positive impact of educational materials is difficult. What students learn (and how well) must be assessed. In guided inquiry, authentic learning is best measured by assessments that are both embedded and authentic.

Too often as educators, we assess what is easy to measure and easy to grade—increasingly by using a machine. As a result, conventional curricula focus on facts instead of on concepts and their application. But standardized, fact-based tests do not and cannot assess the processes and skills that our newest citizens and workers will need to know. They also cannot assess how well students are able to use what they have learned to improve their own lives and those of their communities. Of course, standardized tests have legitimate roles. They can signal long-term trends in students' mastery of facts. Given in high school, they also can predict first-year college success because so much of freshman instruction is conducted in large groups and assessed by fact-based tests that can be scored by machines. The fit is perfect but the shoe itself is wrong.

Needed are efforts to develop accurate, authentic means to assess guided inquiry-oriented, activity-based learning as described in this paper. In order to accomplish this we must trust the judgment of classroom teachers. If one wants to improve the condition of one's head, inside or out, one places oneself in the hands of a licensed professional—neurologist, psychiatrist, barber, cosmetologist—and accepts the professional's judgment, seeking second opinions only from other professionals. Only in education does our society assume that the judgment of front-line professionals must be routinely validated by third parties—in this case, by the makers of batch-processed tests. Authentic learning can be assessed accurately only by the teachers, the professionals who work with the students being assessed.

In guided inquiry, assessment should be the fraternal twin of instruction: the two should look as much alike as possible but be designed differently enough so that each fulfills its distinct purpose. These embedded assessments weave the tasks on which students are assessed into the learning activities, projects, and investigations that students conduct as routine elements of their learning. The activities designated as assessment tools are carefully crafted to resemble as closely as possible any other day-to-day activity. In contrast, standardized tests can interrupt learning as teachers and students "get ready" to take the test by practicing test-taking skills, drilling repeatedly on the same lists of facts, and so on.

Emphasized is that the approach to assessment, as to development, should be evolutionary rather than revolutionary. Authentic, embedded assessment is not intended to supplant fact-oriented tests. Knowledge of facts remains key to a knowledge of science or any field. The goal of these new assessment regimes is to augment the measurement of factual knowledge with measurements of students' evolving abilities to understand what those facts mean and how to apply them appropriately in making real-life decisions.

## Embedding authentic assessment in guided inquiry

As an example, consider an assessment event in the guided-inquiry course "Science and Sustainability"[SEPUP 2000] for high-school students. A theme of the course is energy use and its impact on issues of sustainability. Through a series of course activities, students examine the principles of energy transfer. In one investigation, students burn equal amounts of ethanol and kerosene (instead of gasoline, for safety reasons) to heat identical volumes of water. The students observe and record the change in temperature in each container of water as well as similarities and differences in how the two fuels burn. Then the students are posed a question: "Chemically, gasoline is very similar to kerosene. How could the results of these investigations affect your decision to buy fuel for your car that combines ethanol and gasoline?"

The question is an assessment item, graded against a five-point rubric that gauges a student's ability to gather and weigh evidence and to use that evidence to make trade-offs. (For example, students learn that ethanol burns cleaner than gasoline, but yields less energy per volume of fuel used.) This ability to weigh evidence and balance advantages and disadvantages of specific choices is not only one of five variables on which students are assessed during the course, but also is a task that will confront them daily in their lives beyond school.

## Conclusion

Designing instructional materials development around guided inquiry engages students in their own learning and provides an effective method for including the concepts and processes called for in current expectations for science education such as the National Science Education Standards in the United States. Teachers as the leaders of the development team in the classroom, which is the developer's laboratory, must play an integral part in all development efforts. The best development effort can only produce instructional materials that foster the human interactions among teacher and students that are defined as the "curriculum." Essential to quality learning for all students' is an embedded, authentic approach to assessment that helps students and their teachers monitor the student's growth and development as a result of instruction.

## Bibliography

American Association for the Advancement of Science. (1989). Science for all Americans: A project 2061 report on literacy goals in science, mathematics, and technology. Washington, DC.

Champagne, A.B., & Newell, S.T. (1992). Directions for research and development: Alternative methods of assessing scientific literacy. Journal of Research in Science Teaching 29 (8): 841-860.

Duschl, R. A. (1986, January). Textbooks and the teaching of fluid inquiry. School Science and Mathematics, 86(1), 27-32.

Hurd, P.D. (1999). Inventing Science Education for the New Millennium. New York: Teachers College Press.

Linn, M. C., & Hsi, S. (2000). Computers, teachers, and peers: Science learning partners. Hillsdale, NJ: Erlbaum.

Mechling, K. R., & Oliver, D. L. (1983, March). Activities, not textbooks: What research says about science programs. Principal, 62(4), 41-43.

Messick, S. (1994). The interplay of evidence and consequences in the validation of performance assessments. Educational Researcher, 23 (2): 13-23.

National Academy of Sciences—National Resource Council. (1996). National Science Education Standards. Washington, DC: National Academy Press.

Piaget, J., Gruber, H. E., and Vonèche, J. J. (1977). The Essential Piaget. New York: Basic Books.

Sarason, Seymour (1999). Teaching as a Performing Art. New York: Teachers College Press.

Science Education for Public Understanding Program. Chemicals, Health, Environment and Me (CHEM 2), Enhanced. (1997). Science and Sustainability [2000] Ronkonkoma, NY: LabAids.

Shavelson, R.J. (1991). Performance assessment in science. Applied Measurement in Education, 4 (4): 347-362.

Shulman, L.S. 1987 Knowledge and Teaching Foundations of the New Reform. Harvard Educational Review, 57 [1]: 1-22

Stohr-Hunt, P. M. (1996). An analysis of frequency of hands-On experience and science achievement. Journal of Research in Science Teaching, 33(1), 101-09.

Tafoya, E., Senal, D. W., and Knecht, P. (1980). Assessing inquiry potential: A tool for curriculum decision-makers. School Science and Mathematics, 80, 43-48.

Thier, H. D. with Daviss, B. [2001] Developing Inquiry-Based Science Materials—A Guide for Educators New York Teachers College Press

Welch, W. (1981). Inquiry in school science. In N. Harms & R. Yager (Eds.), What research says to the science teacher Vol. 3 (pp. 53-72). Washington, DC: National Science Teachers Association.

**Keywords:** Curriculum redefined, engagement of students, guided inquiry, instructional materials development, role of teachers.

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# 037 A STUDY OF THE STATE OF KNOWLEDGE THAT HIGHSCHOOL STUDENTS IN JAPAN HAVE ABOUT RADIOACTIVITY, AND THE USEFULNESS OF A NEW RADIOACTIVITY LESSON

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## Abstract

It is important for a present and a future highschool education to solve the following problems so as to accomplish the educational purposes of environmental education in highschools in Japan. I describe the problems to solve as follows. The first is the necessity of the research to investigate state of thinking of students. The second is the necessary performance of the recognition on the fundamental facts and units in the recent radioactive science. The third is the realization of experimental skills for detecting the radioactivity phenomena in nature. According to the results of this research for five years, almost all highschool students in Japan generally have a very poor understanding about an atomic energy and of nuclear phenomena. We teachers must give adequate teaching materials on atomic physics to students. We must help them attain an adequate recognition of radioactive phenomena by using several kinds of data and by doing simple experiments in radioactive science with them by means of the use of a pocket type diode radioactive scintillation counter.

## Introduction

Nowadays, we have a few radioactive lessons in highschools in Japan that serve as an important environmental lesson. Fifty years ago, in the modern history of Japan, we experienced the first atomic disaster in Hiroshima and Nagasaki in World War II. There is, therefore, a strong reaction against all the nuclear affairs (e.g. an atomic power plant, atomic bomb experiment etc.). But generally, nuclear physics now plays a great part in modern science in Japan, as well as in the world. Currently, atomic-nuclear science exists as a modern science, and a basic physics, which sustains a material science. Nowadays many scholars receive the physics Nobel Prize in the subject area of atomic science.

Therefore, the decline of nuclear physics education in school in Japan must be a weak point in physics study, and in the modern science education, in Japan. Furthermore, the techniques of an atomic power plant for generating electricity is necessary for supplying the great needs of electric energy in modern day Japan.

Today, in many countries they make a point out of the usefulness of the wind-powered energy-producing mill as a clean natural energy. But an energy share from this kind of power generation is less than one tenth of that of atomic power. Recently, the Germany government declared a demolishing of atomic power plants, but because of the German high needs of energy for industry use and home use it will make a plan to import electric energy from the nearest countries that have atomic power plant instead of generating electric energy itself.

High supply in return for high demands in advanced modern industrial countries like Japan, United States of America, Germany, France requires atomic power generation. But there are several kinds of problems in physics and environmental education regarding atomic energy in high school in Japan. One is that atomic techniques are restricted so as not to permit an accident of airplane and railway transportation, the other is difficulty in the good training in maneuvering of atomic power plant adequately.

In this paper, I will first present the results of research that investigates content and changes in accordance concerning the awareness of high school students about an atomic and a nuclear affair in nowadays Japan over ten years. Secondly, I will present the results of the students activity where they make use of a "semiconductor style scintillation counter" to detect radioactive rays that exist at background levels in not only in school, but also out of the school room. Thirdly, I will describe the reconstructed school curriculum, and the making of teaching materials (a theoretical and experimental textbook).

**1.Results of a research study analyzing the state of recognition of high school students on radioactivity phenomena**

The results of student answers are shown as tables 1-1 to 3-2 as follows:

1.On Energy and Environment (40 persons in total)(Oct.1997)

1-1.From which sources do you get news about energy and environmental problems?

| | | | |
|---|---|---|---|
| A (1) lessons in highschool | 21 persons | (7) museums | 0 |
| (2) family | 4 | (8) TV/radio | 28 |
| (3) friend | 0 | (9) newspapers | 13 |
| (4) assembly of citizens | 0 | (10) magazines | 4 |
| (5) PC information | 0 | (11) books | 4 |
| (6) pump of company | 0 | (12) everything | 0 |

1-2. What do you think of oil and a convenient everyday life?

| | |
|---|---|
| A (1) oil is full/ no problem | 6 |
| (2) decrease of consumption of oil | 22 |
| (3) new energy preparation is necessary | 11 |
| (4)oil will be decrease, environment pollution decrease | 0 |

1-3.What kind of energy source do you think will be best in the future?

| | | | |
|---|---|---|---|
| A (1) oil | 1 | (5) water power | 6 |
| (2) coal | 0 | (6) wind power | 2 |
| (3) natural gas | 0 | (7) under ground heat | 2 |
| (4) atomic power | 1 | (8) sunshine | 27 |

1-4.What do you think is the most important issue in the 21st century world?

| | | | |
|---|---|---|---|
| A.(1) increase in population size | 4 | (6) degradation of ecosystem | 4 |
| (2) lack of natural resources & energy | 12 | (7) increasing problem of waste materials | 4 |
| (3) lack of food | 3 | (8) widening of conflict in regions | 0 |
| (4) environmental pollution | 8 | (9) increase of unemployment | 1 |
| (5) natural hazard | 0 | (10) inflow of diasporas | 1 |

1-5.What do you think of a reaction against atomic power plants?

| | | | |
|---|---|---|---|
| A1.(1) increase in number | 3 | (2) decrease in number | 19 (man 8.woman4) |
| (3) maintain of present state | 12 (man8.woman4) | (4) others | 5 |

| | |
|---|---|
| A2.(1) the atomic disaster in Japan didn't happen | 2 |
| (2) unaccomplished techniques | 0 |
| (3) safety techniques don't accomplish | 13 |
| (4) new energy is available | 2 |
| (5) atomic power plants are dangerous | 13 |

1-6.What is the cause of heat generation in atomic power plants?

| | |
|---|---|
| A.(1) heat generation by the combination of U and O | 2 |
| (2) heat generation by degradation of U | 12 |
| (3) heat generation by collision between U and e | 6 |
| (4) heat generation by reaction between U and water | 6 |
| (5) heat generation by reaction between U and hydrogen | 12 |

1-7.What material do you think contains radioactivity?

| | | | |
|---|---|---|---|
| A.(1) human body | 15 | (4) plastics | 23 |
| (2) iron | 10 | (5) rock(granite ) | 15 |
| (3) water | 5 | | |

2. On radioactivity (205 persons in total)(Dec.1995)
2-1.How do you do research on radioactivity ?

| | |
|---|---|
| A (1) did research with interest | 2 |
| (2) didn't research with interest | 100 |
| (3) without interesting | 103 |

2-2.Which material is a radioactive substance ?

| | | | |
|---|---|---|---|
| A.(1) ultra violet ray | 74 | (6) neutron ray | 37 |
| (2) infra red ray | 55 | (7) X ray | 181 |
| (3) laser ray | 56 | (8) gamma ray | 29 |
| (4) electromagnetic wave | 16 | (9) beta ray | 40 |
| (5) cosmic ray | 54 | (10) alpha ray | 35 |

2-3.Where do you find radioactive rays?

| | | | |
|---|---|---|---|
| A.(1) X ray car | 171 | (8) cancer hospital | 115 |
| (2) TV | 32 | (9) waste nuclear materials deposit | 122 |
| (3) in air | 43 | (10) transformer plant | 16 |
| (4) electric luminescence tube | 30 | (11) camera | 15 |
| (5) underground | 26 | (12) food | 15 |
| (6) atomic power plant | 160 | (13) electronic oven | 45 |
| (7) dentist's | 54 | (14) acidic rain | 30 |

3.What kind of an image about radioactivity do you have? (124 persons )(Aug.1996)

| | |
|---|---|
| 3-1.(1) death, danger ,fear | 67 |
| (2) atomic bomb, nuclear weapon ,Hiroshima, Nagasaki | 55 |
| (3) cancer, abnormal state of gen. | 50 |
| (4) environmental pollution, reaction against atomic power plant | 8 |
| (5) useful but dangerous | 5 |
| negative image is 175 in total | |

| | |
|---|---|
| 3-2 (1) atomic power plant | 32 |
| (2) dangerous but useful | 5 |
| (3) cure of cancer | 5 |
| (4) energy source | 5 |
| (5) determination of geological age ,electronic oven | 3 |
| positive image is 50 in total | |

**Analysis of Results of Research**

According to the research data from 1995 and1997, only 1% of students in highschool in Japan did an experiment on radioactivity, but 49% are interested in these experiments.(2-1) Almost all students have had very poor experiences. It is recognized that it is not taught enough by teachers and textbook s and most information is gained radioactivity not from a text book (physics) but as mass communications data.(1-1) Therefore, a large number of students in Japan gave a wrong answer for adequate radioactive materials,(2-2) (UV, X-ray, laser is 20~30% in total. On the other hand, the number of right answers was less than 20%).On the radioactivity question there exists many wrong answers.(1-7) On the place where radioactive substances exist, almost all students indicate the place is an atomic power plant, but don't realize that radioactive substances are near themselves.(2-3,1-7) About hazards that come from radioactivity, almost all students answered an abnormality of gem, cancer. Concerning the applications of a radioactivity, they gave answers of its use for generating atomic power, its use as in helping the treatment of cancer, research into materials, but there existed even smaller numbers of answers concerning its use as a protection against a germination, or in the determination of geological age.

**2 Results of an experimental study by a semiconductor type radioactive scintillation counter (Nov.2000)**
In order to improve this poor educational state, we made an experimental research study about a radioactive ray by using a "handy type semiconductor scintillation counter" on November 2000 supported by the Radioactive Ray Measurement Society of Japan at Tokai district in Ibaragi prefecture.

### Results of experiment and contains of reaction from students

Intensity of rays were obtained under the unit of micro shibelt per hour firstly, then 24x365 times from data which shows the unit of micro shibelt per year is as follows.

A class (2nd grade, 36 persons, 31 woman 5)(Nov.2000)

| | In room | on ground | on sunny spot 20m height over ground |
|---|---|---|---|
| (9 times ave) | 0.057 | 0.021 | 0.030 |

B class (2nd grade, 36 persons, man 31, woman 5)(Nov.2000)

| | | |
|---|---|---|
| 0.062 | 0.018 | 0.029 |

C class (3 rd grade ,40 persons ,man 30, woman 10)(Nov.2000)

| | | |
|---|---|---|
| 0.055 | 0.020 | 0.037 |

D class (3 rd grade ,15 persons ,man 15)(Nov.2000)

| | | |
|---|---|---|
| 0.059 | 0.020 | 0.035 |

in snow (Jan.2001) 0.013(depth 1m) 0.021(0.3m)

### Reaction of students

According to our follow up after the research lesson, all the students had a positive experience in our radioactive programs and were impressed with a radioactive experiment action by a handy diode type counter, and the general radioactive phenomena from the data, an absorption from air, snow and from the concrete wall of school room. From the research after this lesson, there exists a remarkable development and improvement in the knowledge and skills in contrast to the pre-lesson state. Therefore, I am convinced that this radioactive program project must be a success.

### 3. Summary and Conclusion

From the ten years of research (1990-2000) about experiences concerning radioactivity for the students in my highschool and others their knowledge of radioactivity is quite poor. Nevertheless, Japan is a top class country and has a large number of atomic power plants and is the only country that has ever experienced an atomic disaster (in World War II). Therefore, in order to improve this state of knowledge, I present a newly made experiment lesson designed to teach about radioactivity. From the results of our experiments, we obtained very remarkable differences in the intensity of radioactivity in the classroom as detected on the tables, on the ground, and on sunny spot 20m height from the ground. Because of the large difference in ray intensity (maybe absorption by air) we concluded that these differences was caused by the concrete radiation from the room wall which is similar to that of a tunnel wall. Half value in snow to the value in open air will be caused by the snow absorption (containing water).

Judging from the follow-up research, the execution of a practical experiment undertaken using a handy and precise "scintillation counter" were found to be very useful as tools to improve lessons, in high school in Japan, on environmental and radioactive physics, and we encourage there use in the future.

### References

**Hohnert,G.H.,**(1990)Nucl.Eng.Des.,121(2):259-275

**McDonald,C.F.,**(1996)Gas Turbine recuperater renaissance,Heat Recovery Syst.CHP,10,1

**Lynch,G.F.,et al**(1986)Paper 4.2-2.30th Congress of the World Energy Conf.,Canada

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# DIDAKTIK ANALYSIS FOR THE SYSTEM EARTH PROJECT THE ANALYTICAL FOUNDATION OF THE SYSTEM EARTH PROJECT

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**Abstract**

The "System Earth" Project is an attempt to go from discipline-oriented science education to an interdisciplinary one within a modern geoscientific framework. It is a project to develop and test teaching materials for secondary schools which can be used to help students to obtain an improved understanding of earth systems and their complex interactions. Understanding and competence embrace knowledge of the structure and function of the continuous changing planet earth as well as participation in the discourse about sustainable development and the changes in the global environment. The development of the material is being carried out in close co-operation with educators and geoscience institutes. The following article outlines the general aims of the project and the criteria for the project-specific topics and methods. The development of materials is based on the research on students' conceptions and interests, and is accompanied by evaluation and implementation studies. First results of preliminary research are reported upon.

*The earth as a system* is a project for the development and testing of teaching materials for secondary schools which can be used to help students explore the earth as a system. As a thorough basic knowledge of science is required for such exploration, the materials are developed in close co-operation with geoscience organisations and research institutions, the interdisciplinary nature of whose approach requires an integrated response in terms of school subjects. This analysis sets out to explain and justify the research and development work required to fulfil this objective.

## 1. The steps of Didaktik analysis

The development work commences with the identification of the general aims of the project. The next step is to analyse the current framework of relevant research, essentially to establish what has been and is being researched and why. The third step is to examine the conditions for implementation of an interdisciplinary treatment of this topic in schools. On the basis of these three components, the stated aims, the scientific framework and school conditions, criteria for the selection of topics and methods can be set up and project-specific topics and approaches then chosen. The final step is to identify where research is needed in order to overcome problems with regard to implementation, topic selection or project-specific approaches. The analysis described here is based on the model of *Didaktische Analyse* proposed by Klafki (1980) and the *Didaktische Rekonstruktion* described by Kattmann and Duit (1997).

## 2. Development

### 2.1 The general aims of the project

Through Agenda 21, topics such as climate change, sea levels, volcanic eruptions and dwindling natural resources have become part of the public debate about sustainable development. The earth as a system Project thus sets out to enable students to understand and, where appropriate, participate in this discourse. Competence in this case includes a basic *understanding* of what the geosciences have revealed about the structure and function of our constantly changing planet and about the sustainable exploitation of its resources and the development of forecasting techniques and prevention strategies. For this to be achieved, interdisciplinary reflection is required. Competence also includes the *ability* to conduct basic ethical analysis and to make critical, rational judgements. In addition, the students need to be able to make their own practical contributions to the debate and obtain relevant information on their own. These goals, which are at a level above that of the subject material itself, can be applied to geoscience topics and classroom approaches. But first the scientific framework and the conditions for implementation need to be discussed.

**2.2 The scientific framework**

Geoscience is the study of the earth as a system, the study of the processes taking place within the earth and at its surface, which in particular influence the reactions between the subsystems of atmosphere, lithosphere, hydrosphere and biosphere. Research into the earth as a system draws on the methods of chemistry, biology and physics, on all scales of time and magnitude: from global observation of the planet from space to analysis of crystal lattices at the level of the atom, and from the geological ages in the formation of mountain ranges (millions of years) to the rapid fracturing processes during earthquakes (microseconds). In line with this diversity, a wide range of methods and techniques is employed, including satellites and space-supported measuring systems, as well as high-resolution processes for geophysical research at extreme depths. The methods also include laboratory experiments in which, for example, the pressure and temperature conditions of the earth's crust and mantle are simulated. The scientific exploration of our planet is pursued in order to "understand the earth as a system in all its parts, to discern global changes, to quantify endogenous and exogenous processes with their interactions and, on the basis of this understanding of the system and its processes, to develop strategies for securing natural resources and sustainable exploitation, using space above and below ground, storing waste, judging climatic and environmental development as well as anthropogenic influence on this development, and for protection against natural catastrophes and the minimisation of their consequences." (*Senatskommission*, 1999).

**2.3 Conditions for implementation of geoscience topics in schools**

The geosciences and science teaching are committed to the concept of sustainability. Thus the geosciences can deliver a significant chunk of the knowledge base on which the teaching of responsible attitudes and behaviour with the aim of sustainable development can build. As *biological, chemical and physical* processes inside and on the surface of the earth are to be explored, the three traditional school sciences are the first obvious settings for this teaching. As spatial-descriptive aspects also play a significant role, geography is a further relevant subject. A comprehensive basic understanding of the system can only be built up, however, if the interaction between elements within the system is dealt with from various points of view, but within a shared interdisciplinary context. For this reason, the topic lends itself to an integrated teaching approach, which is quite within the scope of the regional curricula in Germany. In recent years, interdisciplinary approaches have been promoted and supported at all levels. The multi-perspective approach of The earth as a system is also mirrored by the interdisciplinary approach of the geosciences. Major research projects focussing on the earth as a highly complex system generally involve biologists, chemists, geologists and physicists, a fact which facilitates an interdisciplinary approach in teaching, particularly as the knowledge emerging from geoscientific research forms a coherent whole.

**2.4 Selection criteria for topics and classroom approaches**

*2.4.1 OVERVIEW OF CRITERIA FOR TOPIC SELECTION AND CLASS ROOM APPROACHES*

A prerequisite for curriculum development is a well-prepared decision on the choice of content, and how this content will be communicated. To be legitimate, a decision of this kind must be made with reference to the general aims of the project (see 2.1). The project in this case aims, by means of interdisciplinary teaching, to develop a basic understanding of the earth as a system and thus create the scientific basis for developing judgmental skills with respect to sustainable development.

A basic *understanding* includes a conception of the earth as an energetic, open, dynamic system, which is in a state of constant change and whose biotic and abiotic subsystems form a complex network. It integrates description and explanation. As we pointed out above, the body of knowledge currently available, on the basis of which the students' understanding is to be developed, is interdisciplinary in essence, encompassing elements of biology, chemistry, geology and physics. When this knowledge is processed for application to teaching, criteria must be applied which ensure that the knowledge communicated retains its essentially networked character.

What *types* of content are required for an understanding of the type advocated here?

- *Basic concepts* and connecting *principles* link the contents of individual disciplines together in a *systematic context*, thus building up a cognitive structure of coherent knowledge.

- *Concepts of epistemology* are part of the basis of understanding and serve as a foundation for the assessment of the validity of scientific statements.
- *Ethical analysis and justification* of protective measures and sustainable exploitation of natural resources are used to develop normative skills. They serve the development of integrity to debate socio-political decisions for securing and exploiting natural resources sustainably. To promote an understanding of the earth as a system and rational debate of the use and protection of the earth's resources, specific aids and activities are called for. These are
- the use of computers to process scientific models and to gain access to information, e.g. through the Internet,
- direct communication with scientists.

These criteria will now be explored in more detail.

*2.4.2 CRITERIA FOR TOPIC SELECTION*

*2.4.2.1 Descriptive and explanatory selection criteria*

**Basic contents.** Drawing on Bruner (1960) we understand basic concepts as general concepts which are necessary for a comprehensive understanding of a discipline and its particular thought structures. For this project, those basic concepts found in several earth science disciplines are particularly significant, as their understanding is a prerequisite for networked reflection. The ability to think in terms of networks often remains beyond students' reach because they have an inadequate understanding of basic scientific concepts, even within the school subjects. Particular effort is required if transfer is to be achieved and connections made beyond the individual subjects.

**Referential framework of system theory**. The most general referential framework for the communication of basic understanding of the earth as a system is system theory, the following aspects of which are particularly relevant to the selection and processing of topics in this context.

- Distinguishing system from system environment;
- Identification of relevant elements of a system:
- Identification of general characteristics of a system, e.g. non-linearity, non-reversibility, self organisation.

*2.4.2.2 Epistemological criteria for topic selection*

The understanding of the earth as a system can be facilitated by insight into the origins of knowledge about elements and interactions within this system. For example, the appraisal of model formation through *theory of science* can help towards a critical appraisal of models used in geoscience, such as for climate or lithographical development. An introduction to selected research *methods of science*, such as earth monitoring by satellite or bore analysis, demonstrates how complex and cost-intensive the exploration of the earth is. In addition, dealing with various scientific methods familiarises the students with the various scales which geoscientists use to describe their findings (see 2.2). The ability to move between scales is of particular significance in the understanding of the geosciences, as they deal with processes ranging from those of the solar system to processes at molecular level. And no less important are the scientific controversies covered in the *history of science,* showing the students the critical, rational attitude of researchers towards scientific theories and findings.

*2.4.2.3 Normative criteria for topic selection*

In general this involves the criteria for exploitation and protection of the earth. More specifically it involves the strategies mentioned under 2.2 above, as formulated by the Senate Commission for Joint Geoscientific Research within the German Research Council (*Senatskommission für geowissenschaftliche Gemeinschaftsforschung der Deutschen Forschungsgemeinschaft*: 1999). The concept of sustainable development continues to provide a viable basis for content selection (Rost 2002). Knowledge about the exploitation and protection of the earth's resources and about sustainable development provide a basis for ethical analysis and justification and thus support the development of discernment.

*2.4.3 CRITERIA FOR THE SELECTION OF CLASSROOM APPROACHES*

The criteria for the selection of methods and aids encompass aspects of epistemology and certain metacognitive skills, which are particularly important in view of the overall aims of the project. The epistemological criteria for topic selection cited under 2.4.2 serve equally well in the selection of methods, thus the following refers only to metacognitive criteria.

The project provides for computer use and communication with scientists with the aim of helping the students acquire metacognitive skills in connection with the subject matter. These skills were the criteria guiding the choice of approach.

Metacognitive skills relate to knowledge about learning, memory and other cognitive functions and their control. In this context, two types of knowledge are discerned (Hasselborn 1998, following Cavanaugh 1989): *Systematic knowledge* relates to cognitive functions and the influences they are exposed to. This includes, for example, knowledge about how to learn in order to remember new information. *Epistemic knowledge* encompasses judgement of the extent of one's own knowledge or lack of knowledge, as well as knowledge about strategies of acquiring and applying knowledge. An example here is knowledge about further sources of information and how to use them. The *control component* of metacognition encompasses skills such as planning, control and monitoring of cognitive functions. These include the ability to recognise that I have not understood a portion of text, the ability to rectify this, and to recognise one-sided arguments as such.

The complex interdisciplinary topic we are dealing with requires specific strategies of knowledge acquisition and, particularly, an awareness of relevant information sources and how to use them, in other words the acquisition of *epistemic knowledge*. As a strategy of knowledge acquisition in connection with the earth as a system, the interactive use of scientific models at the computer is important, as well as the acquisition of information through the Internet.

As descriptive and explicative knowledge in this area is interlaced with values and norms (e.g. "exploitation", "protection"), critical and rational judgement must be promoted. This includes the ability to avoid one-sided argumentation. The acquisition of such skills as a part of the *control component* of metacognition is particularly promoted by communication with scientists.

**2.5 Selected topics for materials development**

Guided by the general aims, the materials are to facilitate the acquisition of a basic knowledge of the earth as a system and the promotion of rational debate on issues concerning its exploitation and protection. To this end, basic concepts and connecting principles are to be dealt with within a coherent system, and concepts of epistemology, ethical analysis and justification communicated. Topics were selected and ordered according to these criteria. In addition, materials were chosen which provided an introduction to the field as a whole.

*2.5.1 INTRODUCTORY MATERIALS*

The introductory materials provide phenomenon-focussed access to the concept of the earth as a system. They are primarily designed as motivational and organisational aids, offering an overall view to awaken interest, inviting wonder and empathy, an affective bonding with the system. The intention is to show that our own existence and that of life in general depends on the earth being the way it is, and that the system can be profoundly influenced by human intervention.

*2.5.2 MATERIALS TO PROMOTE UNDERSTANDING OF THE EARTH AS A SYSTEM*

These materials lead into the complexity of the system as a whole. They take into account the fact that complex systems consist of a large number of interrelated components and are frequently open to environmental influences, and also the fact that the mostly non-linear interaction of the parts can generate new system properties which are hard to predict, but which do conform to certain general structuring principles. The structuring principles and the promotion of thought in complex systems are accessed primarily in a top-down approach which highlights examples of the relevant principles. The genesis of knowledge is a further focus of topic selection. The modules to be developed in this context can be subsumed under the heading "System earth/life – a complex dynamic system".
Modules: Earth as a dynamic system; development of life on earth; views of the world, pictures of the world.

*2.5.3 MATERIALS ON EXPLOITATION AND PROTECTION OF THE EARTH*

In a bottom-up approach, selected subsystems are observed so that specific methods of geoscience can be explored and the subsystems themselves to be placed in relation to the system as a whole. In this way, a deeper understanding of the overall system mentioned under 2.5.2 above can be achieved. The materials also emphasise the issues of exploitation and protection in relation to the ongoing general debate in society. The question of climate change is specifically addressed.

a) The first topic area deals with substance cycles. The materials look at dynamic processes influenced to a considerable degree by human activity. As this includes the removal of substances from and the emission of substances into natural systems, the concepts of exploitation and protection are central.
Module: Cycles of non-metallic substances (e.g. carbon); heavy metal cycles.
b) The second topic area deals with the exploitation and maintenance of food and energy sources. By removing minerals, energy sources and biomass from the earth's system, and by emitting waste, sewage and exhaust gases, humankind intervenes, in places on a massive scale, in the natural metabolism of the planet, affecting its dynamics both inside and out. Working through the modules, the students should be able to address the issues associated with sustainable utilisation of resources and waste disposal. In keeping with this topic, environmental biotechnology is also dealt with.
Modules: Securing natural resources as a foundation of social development; Exploitation of alternative energy sources such as geothermic energy, biotechnology; Soil as food source; The sea as food source.
c) The third topic area deals with the causes of natural phenomena and the associated issues of public protection (prevention/early warning systems/reaction strategies). The natural phenomena are also considered within a cultural and historical context.
Modules: Earthquakes; floods; volcanic eruptions; climate change; natural phenomena in a cultural and historical perspective.

**2.6 Project-specific methods of work**

Systematic knowledge, epistemic knowledge and the control component of metacognition thus serve as criteria for the selection of project-specific approaches, specifically computer use and communication with scientists (see 2.4.3).

a) Using the computer to process scientific models and for independent Internet research
The geosciences develop models of the earth's subsystems. Once processed for teaching, these models can be introduced into advanced secondary classrooms and, with the support of new media, used interactively by the learners (simulations, etc.). A CD-ROM and DVD are to be developed for this purpose. Independent work with scientific models promotes the development of epistemic concepts. Videos based on authentic film material from research institutions can be a valuable aid. In complex learning environments, such as the Internet and interactive simulations provide, the learners are stimulated to be active and self-guided in building up their store of knowledge (de Jong & Njoo 1992). On the other hand, complex learning environments can also overtax the learners' attention capacity. Thus appropriate pedagogical support is vital to facilitate the acquisition of applicable knowledge (Stark et al. 1995, 1997; Leutner 1993). The learners can, for example, be given tasks guiding them towards focussed fact-finding or questions highlighting essential aspects of content (Peeck 1993). Leutner (1993) shows that background information (basic information) made permanently available to the learners, i.e. which they call up as they require when working on simulations, can help towards the accrual of topic-specific knowledge. This could take the form of basic texts, either specially written for the project or taken from the Internet.
b) Direct communication with scientists
Communication with the scientific community can be achieved in various ways, a typical selection of which are as follows.
Scientists can be invited to the school to talk about their subject. The students prepare themselves thoroughly in advance of the visit and are given ample opportunity to engage in discussion with the visitors. Groups or classes can visit research institutions or universities to find out about new scientific developments. Students majoring in one or more of the relevant sciences can be put in touch with a member of a research institution who will provide scientific advice to support the students in their work for

their assignments and – if necessary – arrange for the use of the institution's equipment.
Senior secondary students can be given the opportunity for work experience at research institutions and to attend trial courses or lectures at universities.
Communication with scientists allows students to deepen their understanding of the earth as a system, not least with respect to the genesis of knowledge in the geosciences. It allows them practise rational discussion of the exploitation and protection of the planet. This supports the dialogue between the research community and the public, which is needed to promote a reasoned attitude on the part of the public towards science, research and technology, as, among other things, the decision to invest in research etc. is dependent on the respective social and political environment (cf. *Stifterverband* 1999, 58ff).

## 3. Research

The research addresses obstacles to implementation which the new approach can encounter, preconditions for learning on the part of the students, and requirements in relation to the aids and approaches, including media. The preconditions for learning include pre-instruction conceptions which the students have about the topics, as well as their level of interest. A further question is the effect of the teaching on learning and interest. An evaluation is to be carried out. The following sections outline the research into preconditions for learning.

### 3.1 Study of students' conceptions about the global biogeochemical carbon cycle

#### *3.1.1 JUSTIFICATION AND THEORETICAL BACKGROUND*

The geosciences have developed into an interdisciplinary branch of research based on a view of our planet as a system. This helps to improve our understanding of structures and processes, which is essential as a basis for the development of sustainable concepts of conservation and environmentally sound exploitation of the earth's resources. The interdependent elements of the system and the dynamic processes which drive them generate a high degree of complexity, making it difficult to represent the natural world in terms of simple logical relationships. In the classroom, however, complex interrelationships are often reduced to simple cause-and-effect structures. Despite its significance, systematic thinking in geoscientific contexts is hardly established in schools.

We understand learning as a process by which knowledge is actively constructed on a foundation of existing concepts (students' conceptions; see Duit 1995; Gerstenmaier & Mandl 1995). The pre-instruction notions students have with respect to the nature of the earth as a system, which need to be processed and fed into the development of teaching materials, have not yet been widely researched (see Ben-Zvi-Assaraf & Orion 2001; Gudovitch & Orion 2001; Orion & Eylon 2001). The studies available show in essence that students do not comprehend the dynamic nature of the earth and describe processes in terms of static concepts. For this reason, we are investigating students' conceptions of the characteristic properties of this natural system. In a pre-study we characterised pre-instruction conceptions of the global carbon cycle. It represents a complex system combining biological, chemical, geological and physical processes and thus serves as an ideal model to illustrate the interactions between the earth's subsystems – lithosphere, atmosphere, hydrosphere and biosphere. At the centre of the pre-study were special properties of the system such as non-linearity and irreversibility. These aspects of systematic thinking (Ossimitz 2000) are particularly hard to understand. Usually, more time is spent on analysing differences between natural systems than on recognising their general structuring principles. On the basis of the pre-study, teaching and learning experiments are being developed which contain instructions on multiple, flexible knowledge representation in line with the Cognitive Flexibility Theory (Spiro et al. 1987; Gerstenmaier & Mandl 1995). The results will be useful for the development of teaching material on the global biogeochemical carbon cycle within the general theme of the System Earth Project.

#### *3.1.2 RESEARCH QUESTIONS*

What concepts do students associate with the term "the earth as a system"?
What subject-specific conceptions do students have about the global carbon cycle?
What aspects of systematic thinking do students use in connection with the global carbon cycle?

*3.1.3 DESIGN AND METHOD*

**Association test.** 165 students in years 11 to 13 wrote down ten terms which they could think of in connection with "the earth as a system". The responses were categorised using concepts of system theory and evaluated with respect to the underlying conception of system.

**Detailed study of five students**. Five students from years 12 and 13 were questioned in more detail to elicit their conceptions of the global carbon cycle. The design drew on various qualitative and quantitative research instruments.

*Estimating and drawing*

The subjects were asked to estimate global carbon distribution in percentage terms (air, sea, organisms, rocks, fossil fuels, other). Then they were asked to draw a diagram representing the transport of carbon between the lithosphere, atmosphere, hydrosphere and biosphere. The subjects were given the opportunity to read up on definitions of the four spheres. For estimating and drawing they were given ten minutes.

*Interview*

In part-structured interviews (45 minutes), the subjects were questioned about their conceptions of the structure and dynamics of carbon transport between the lithosphere, atmosphere, hydrosphere and biosphere.

*Questionnaire*

The subjects were asked to fill in a questionnaire based on the knowledge of biology, chemistry, geology and physics considered essential for the understanding of the carbon cycle. They were given 20 minutes.

*3.1.4 SELECTED RESULTS*

**Association test.** The terms given by the students indicate a general understanding of the earth as a system. Detailed knowledge of the structure and dynamics of the spheres and their interaction was not ascertainable, however. There was also a lack of a concept of geological time with respect to the development of the earth and its subsystems.

**Detailed study of five students**. The pre-study shows that the students do not estimate the global distribution of carbon in a realistic order of magnitude. The atmosphere and biosphere are vastly overestimated as reservoirs of carbon in relation to the lithosphere and hydrosphere.

In addition, the students have difficulty comprehending carbon transport as a cyclical process. A few subjects described a linear process from the lithosphere to the atmosphere. The former is seen as an inexhaustible source of carbon and the atmosphere as an unrestricted carbon sink. The hydrosphere is not taken into account at all. Two students described a cycle reduced to the processes of photosynthesis and cell respiration, in other words the interaction between animal and plant organisms. The cyclical process they described is, however, not represented as a relationship between organisms and the atmosphere. The students in the detailed study have no conception of the dynamic properties which have determined the transformation of the carbon cycle in the course of earth's history. The development of the earth as a system is explained in terms of linear processes. Non-linearity is not recognised.

The questions in the knowledge test were answered surprisingly well. The biological, chemical, geological and physical concepts seen as fundamental for work within the context of the global carbon cycle seemed to be relatively well represented. In the contextual interview, however, they were not used in a scientific sense.

**3.2 Study of students' interest in the earth as a system**

*3.2.1 JUSTIFICATION AND THEORETICAL BACKGROUND*

Knowledge about students' interest is fundamental to work on the development and evaluation of teaching materials. Interest is defined in the literature either as a lasting disposition of an individual independent of situation (e.g. Todt 1978; Prenzel, Krapp, Schiefele 1986) or as a quality which is dependent on situation (e.g. Hidi, Andersen 1992). Häußler and Hoffmann (1998) argue that lasting, interest independent of situation can develop out of situational interest. They distinguish three dimensions of situation-related interest: interest in a specific item, interest a specific context connected with the content, and interest in a specific learning activity to pursue context-bound content.

### *3.2.2 RESEARCH QUESTIONS*

To what extent are students interested in certain geoscientific contents if these are taught within specific contexts? To what extent are students interested in certain activities when dealing with the earth as a system?

### *3.2.3 DESIGN AND METHOD*

A questionnaire was developed for a pilot study of years 11 to 13 and administered in three *Bundesländer* (states) in Germany (Bavaria, North Rhine-Westphalia, Schleswig-Holstein) to a total of 163 female students and 172 male students. The questionnaire comprised 88 items in a systematic combination of 11 fields and eight contexts. Data about the students' interest in various activities was obtained separately. In addition, the students were questioned about their school and out-of-school activities involving geoscientific topics (see Activities).

**Fields**

| | | | |
|---|---|---|---|
| G1 | Subsystems of the earth | | |
| G2 | Carbon cycle | G6 | Gas hydrates |
| G3 | Rocks and minerals | G8 | Drinking water |
| G4 | Fossil fuels | G9 | Earthquakes |
| G5 | Soil | G10 | Climate changes |
| G7 | Sea | G11 | Changes in biodiversity |

**Contexts**

| | |
|---|---|
| K1 | Individual |
| K2 | Society |
| K3 | Norms and values |
| K4 | System theory |
| K5 | Geosciences |
| K7 | Scientific method |

**Activities**

| | |
|---|---|
| T1 | Listening to a lecture by the teacher |
| T2 | Evaluating scientific date |
| T3 | Collecting data on a field trip |
| T4 | Making independent suppositions |
| T5 | Asking geoscientists questions |

### *3.2.4 SELECTED RESULTS*

On a general level, first results show on average a medium interest in almost all contents. The lowest interest is in Rocks and Minerals and a relatively high interest in Earthquakes. Regarding contexts, Individual, Society as well as Values and Norms are of relatively high interest. When analysing the data in more detail it becomes obvious that students' interest in a special content changes significantly with the context it is associated with. For example, students' interest in learning more about the carbon cycle is much higher in combination with the context Individual (health) than with its geoscientific dimension. Further, the students show different interest in the same context depending on the contents it is combined with. For example the context Geoscientific Methodology is highly interesting in association with Earthquakes and less interesting combined with Soil.

The students were much more interested in scientific factual knowledge with regard to the Subsystems Earth and Drinking Water than in system theory based knowledge. Concerning the Carbon Cycle, Soil, Climate Change and Change of Biodiversity they showed greater interest in system theory-oriented information. As to the other contents they were equally interested in both dimensions.

From the students' point of view, the 11 selected areas concerning System Earth were mainly covered in geography lessons, less in biology and almost not at all in chemistry or physics lessons.

More detailed results on the structure of students' interest in the area of System Earth as well as the relation between students' interest and traditional teaching of these contents at school will be presented. Gender oriented differences will be discussed.

## References

BEN-ZVI - ASSARAF, O. & Orion, N. (2001): Studying the Water Cycle in an Environmental Context. The "Blue Planet" Program (paper presented at the NARST).

CAVANAUGH, J.C. 1989: The importance of anwareness in memory aging, in: L.W. Poon, D.C. Rubin & B.H. Wilson (Eds.): Every day cognition in adulthood and late life (416-436). Cambridge: Cambridge University Press.

DE JONG, T. & Njoo, M. (1992): Learning and instruction with computer simulations: Learning processes involved. In: De Corte, E., Linn, M.C., Mandl, H., Verschaffel, L.: Computer based learning environments and problem solving. NATO ASI Series, Series F: Computer and systems sciences, Berlin: Springer, Vol. 84, 411-428.

DUIT, R. (1995): Zur Rolle der Konstruktivistischen Sichtweise in der Naturwissenschaftlichen Lehr- und Lernforschung. *Zeitschrift für Pädagogik* 41(6): 905-923.

GERSTENMAIER, J. & Mandl, H. (1995): Wissenserwerb unter konstruktivistischer Perspektive. *Zeitschrift für Pädagogik* 41(6): 867-888.

GUDOVITCH, Y. & Orion, N. (2001): The carbon cycle and the earth systems. Studying the carbon cycle in multidisciplinary environmental context. Department of Science Teaching, Weizmann Institute of Science Rehovot, Israel.

HASSELHORN, M. (1998): Metakognition, in: D.H. Rost: Handwörterbuch Pädagogische Psychologie. Weinheim: Beltz, Psychologie Verlags Union.

HÄUSSLER, P., & Hoffmann, L. (1998): Qualitative differences in students' interest in physics, and the dependence on gender and age. In L. Hoffmann, A. Krapp, K.A. Renninger & J. Baumert (Eds.), Interest and learning (280-288) Proceedings on the Seeon Conference on Interest and Gender (1998). Kiel: IPN.

HIDI, S., & Andersen, V. (1992): Situational interest and its impact on reading and expository writing. In K.A. Renninger; S. Hidi, & A. Krapp (Eds.), *The Role of Interest in Learnign and Development* (215-238). Hillsdale/NJ: Erlbaum.

KALI, Y., Orion, N. & Eylon, B.-S. (2001): The Effect of Knowledge Integration Activities on Students' Perception of the Earth's Crust as a Cyclic System, Department of Science Teaching, Weizmann Institute of Science Rehovot, Israel (submitted to the *Journal of Research in Science Teaching*).

KATTMANN, U., Duit, R., Gropengießer, H. & Komorek, M. 1997: Das Modell der Didaktischen Rekonstruktion. Ein Rahmen für naturwissenschafts-didaktische Forschung und Entwicklung. ZfDN 3 (3), 3-18.

KLAFKI, W. (1980): Die bildungstheoretische Didaktik. Westermann Pädagog. Beiträge 32 (1), 32-37.

LEUTNER, D. (1993): Guided discovery learning with computer based simulation games: Effects of adaptive and non adaptive instructional support. Learning and Instruction 3(2): 113-132.

PEECK, J. (1993): Increasing picture effects in learning from illustrated text. Learning and Instruction 3(3): 227-238.

PEECK, J. (1994): Enhancing graphic effects in instructional texts: Influencing learning activities. In: Comprehension of graphics. W. Schnotz , R.W. Kulhavy. Amsterdam, Netherlands, North-Holland/Elsevier Science Publishers: 291-301.

PRENZEL, M., Krapp, A., & Schiefele, H. (1986): Grundzüge einer pädagogischen Interessentheorie. *Zeitschrift für Pädagogik, 32,* 163-173.

RIEBER, L.P. (1990): Using Computer Animated Graphics in Science Instruction With Children. Journal of Educational Psychology 82(1): 135-140.

ROST, J. (2002): Umweltbildung – Bildung für eine nachhaltige Entwicklung: Was macht den Unterschied (in press).

SENATSKOMMISSION für geowissenschaftliche Gemeinschaftsforschung der Deutschen Forschungsgemeinschaft (1999): Geotechnologien. Das System Erde. Vom Prozessverständnis zum Erdmanagement. GFZ: Potsdam.

STARK, R., Graf, M., Renkl, A., Gruber, H. & Mandl, H. (1995): Förderung von Handlungskompetenz durch geleitetes Problemlösen und multiple Lernkontexte. Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie 27(4): 289-312.

STARK, R., Gruber, H., Renkl, A. & Mandl, H. (1997): "Wenn um mich herum alles drunter und drüber geht, fühle ich mich so richtig wohl." Ambiguitätstoleranz und Transfererfolg. Psychologie in Erziehung und Unterricht 44(3): 204-215.

STIFTERVERBAND FÜR DIE DEUTSCHE WISSENSCHAFT (1999) (Hg.): Dialog Wissenschaft und Gesellschaft. Essen.

TODT, E. (1978): Das Interesse. Bern: Huber.

WEIDENMANN, B. (1989): When good pictures fail: An information processing approach to the effect of illustrations. In: Knowledge acquisition from text and pictures. H. Mandl , J.R. Levin. Amsterdam, Netherlands, North-Holland: 157-170.

**Keywords:** Earth System education, didaktical analysis, student's preconception, student's interest, interdisciplinary studies

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# SCHOOL-BASED CURRICULUM DEVELOPMENT: A PROPOSAL FOR IMPROVING GIRLS' PERFORMANCE IN SMT

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**Abstract**

The paper discusses the process and logistical experiences of developing science, technology and mathematics (SMT) curricula materials at the primary and secondary school levels in Uganda. The author developed the approach as part of the Female Education in Mathematics and Science in Africa (FEMSA) project. FEMSA is an Africa regional project that aims at improving girls' access, participation and performance in SMT at the primary and secondary school levels in Africa. At the time of writing this paper, FEMSA was being implemented in 11 African countries, including Uganda.

To date the most common approach to curriculum development is the centralized approach involving subject experts at the higher levels to develop curricula content at a national curriculum development center. This paper describes the efforts made to involve practicing schoolteachers in school-based curriculum development under the FEMSA-Uganda project. Based on these experiences, the author proposes improvements to the process, which are likely to have a greater impact on learners, particularly the girls, in terms of motivating them, increasing their interest, participation and hence improving their performance in SMT at the primary and secondary school levels in Africa.

## Introduction

Uganda was among the 4 countries that piloted the FEMSA project for two years (1996-97), the others being Cameroon, Ghana, and Tanzania. During this phase, each country carried out research that identified the problems that girls experience in the teaching/learning of SMT at the primary and secondary school levels. The FEMSA-Uganda research identified many problems, which included the economic and social-cultural barriers, the negative attitudes of parents, teachers and the general society towards girls' education, the poor curricula and the gender-biased curricula materials. The problems were similar to those identified in other countries under the same project, and the overall FEMSA project findings have been widely disseminated in Africa and beyond (Ebout Mfou et al, 1998; O'Connor 1998, Mulemwa 1999 & 2000) and discussed at different forums such as the GASAT –Africa regional meeting of 1997, the GASAT international meeting of 1999, and the IOSTE meeting of 1999.

During the second phase of the FEMSA project, the countries participating increased to a total of 12 and each country tried to implement strategies and interventions to address the problems identified according to their own priorities. In Uganda, a multi-faceted approach was taken to try and address the identified problems. The different strategies and activities to improve girls' participation in SMT therefore targeted the key stakeholders. These are, the teachers; the parents; the students both boys and the girls themselves; the general communities surrounding the schools; the policy makers and implementers; and the general public at large. In this paper one of the strategies targeted at the teachers as the key to the improvement of girls' participation and performance in SMT is discussed. This is the development of gender-inclusive instructional materials to complement and supplement the existing school curricula materials.

## Why The Strategy Of Materials Development?

The problems identified by the FEMSA-Uganda research (Mulemwa 1997) included the gender-biased curricula including methods and instructional materials that "left the girls out" and the negative attitudes of teachers towards girls' education in SMT. Most teachers were not aware of the gender issues in education and in SMT education (SMTE) in particular and hence they unknowingly exacerbated the problems that girls experience in the learning of SMT. The strategy of school-based curriculum development was therefore implemented as a strategy to train teachers in the basic analysis and development of "girl-friendly" SMT content materials that can be used to supplementary the existing curricula materials. The strategy aimed at increasing girls' interest in and access to SMT through the use of relevant and gender-inclusive curricula content, and hence improving girls' active participation and performance in SMT at the school level.

## The Objectives Of The Strategy

The specific objectives of the strategy were to:

1. Develop materials that reflected examples from all the learners' experiences particularly those of girls;
2. Sensitize teachers on the need and importance of gender-sensitive and gender-inclusive curricula materials and methodology;
3. Train SMT teachers in the skills of materials development;
4. Demonstrate the process of School-based curricula development for possible mainstreaming;
5. Develop some gender-responsive materials for use in the classroom; and,
6. Build capacity in gender analysis and materials development, particularly for the women.

## The Process Of Materials' Development – An Overview

The process is quite long and includes the following major stages.

1. Training workshops to sensitize, train and acquire the necessary basic knowledge and skills in gender analysis;
2. Group and individual work to develop gender-inclusive and girl-friendly materials.
3. Workshops to review draft materials as they get produces, coupled with more training as necessary;
4. Re-casting the reviewed materials;
5. Reviewing of materials by other experts external to the core group;
6. Piloting the materials in schools;
7. Finalizing the materials to incorporate the feed back from the piloting exercise;
8. Producing the final materials;
9. Disseminating the final products to key stake holders;
10. Start on the activities for mainstreaming the materials.

## The School-Based Materials Development Activity

The materials development activity was implemented at 2 levels, namely, the national and the school levels. However, in this paper only the school-based level activities are discussed. There were 11 primary schools and 1 secondary school, all FEMSA-Uganda schools, which actively participated in this activity. The outline below mainly refers to the primary school level where the process seemed to work better. These primary schools had also been given Carpentry Kits by the project, in response to another identified problem of lack of school furniture. They had not only produced the furniture they needed, but also used the kits to produce some teaching/learning aid such as protractors, blackboard compasses, meter rules pulleys, clock-faces, calendars etc. These were incorporated into the materials' development activity. The activity had two specific phases, namely, the preparatory and the materials development phases.

**The Preparatory Phase**

The first phase of the strategy was the preparatory work, which basically included:

- Sensitization in gender issues and problems in education and SMT education in particular, and the introduction of the approach to the school authorities and the teachers through several seminars by the author who was also the coordinator of the overall programme;
- The development of guidelines for training of teachers and those for guiding the step-wise development of the materials, by the coordinator; and,
- Training of the SMT teachers in basic gender analysis techniques and skills in materials development. During the training workshops, the teachers were also given skills in setting quality test items and in some schools.

**The Development Phase**

This phase consisted of the following step-wise activities by the teachers:

- The identification of topics that are difficult to teach (learn);
- Developing materials in subject-specific or interdisciplinary groups depending on the materials to be produced. They were however often encouraged to work in mixed groups because of the need to acquire competency in both mathematics and science at the primary school level, and the need to integrate subjects;
- Organization of workshops for the teachers to work on the difficult topics with an experienced teacher, using a minds-on and hands-on approach as much as possible;
- More work by the teachers to finalize the topics discussed in the workshops and write them up as modules following and agreed format;
- The revision and correction of the draft materials by a more experience facilitator outside the school, but who is also an experienced primary teacher;
- Organization of follow-up workshops where the facilitator discusses the corrections and suggestions given, and offers more training as necessary;
- Revision of the materials according to the advice of the facilitator;
- The review of the drafts produced by another expert outside the whole process; and then the process continued as outlined above in the overview.

There were a few problems encountered the major one being the constraint of time and the lack of incentives for the teachers to do the work. Despite these problems however, the teachers greatly appreciate the activity because it clarified their own understanding of the subject matter, and they could immediately use the materials produced in their teaching. Consequently, they found time out of their very busy schedules and developed some modules. At the time of writing this paper, these materials were ready for step 5 of the process as indicated in the overview, namely, the external review by experts outside the development process, before they are piloted. The process did not find out concretely how the teachers used the draft materials in actual classroom situations as they developed them, and hence the instructional methods employed to teach the new content were not a focus at this stage. It was however realized that the gender sensitivity of the teachers seemed to have improved as they developed gender-inclusive content, which uses locally available materials as far as possible.

## The Proposed Improvements

Having initiated the FEMSA project in Uganda in 1995 and working as the National Coordinator of the FEMSA-Uganda project for over 4 years, the author stopped working directly with the project in May 2001. However, given the personal interest in girls' education, particularly in SMTE, the author has taken time to reflect on the FEMSA-Uganda activities, and specifically the school-based curricula development activities as discussed above. In the remaining part of this paper, proposals to improve this process are discussed. It is believed that if implemented, the proposals would greatly enhance the effectiveness of the school-based curriculum development process in increasing all learners' participation in SMT, particularly the girls, and hence improve their performance even more. The proposals focus on 3 areas, namely, the involvement of the pupils, particularly the girls in the process of curriculum development; emphasizing and developing the "reflective process" of the teachers; and the active involvement of the school authorities and the parents and the surrounding community in the process.

## The Active Involvement Of The Pupils

The pupils can be involved in the whole process of curriculum development at the school level. If this involvement is planned and hence deliberately and systematically implemented, the girls in particular would be given a relatively new experience which should arouse their curiosity and interest, allow them active practical experience of SMT outside the classroom, and hopefully improve their performance in SMT. The involvement of the pupils can be at three different levels as discussed below.

### 1. Identification of the Difficult Topics

As outlined above, the process of school-based curriculum development starts with the identification of the topics that are difficult to teach, by the teacher, with the reasons why this is so. The proposal here is that, the pupils too, should carry out a similar exercise. The FEMSA project in Uganda however found out that the pupils particularly at the primary school level could hardly articulate the reasons why particular topics were very difficult (Mulemwa 1997). They therefore need assistance and step-wise guidance at first, to learn and feel confidence in pinpointing what they do not know and diagnosing the reasons for their lack of understanding. It should be noted here that in a different research study (Mulemwa 1995) the teachers too, found a similar exercise difficult, although the underlying reasons were quite different. They too had to be assisted to gain confidence in admitting what they did not know and then they comfortably continued the process.

In identifying the difficult topics and the reasons for the difficulties experienced, the pupils should be assisted by someone they can trust. In my experience, this should not be their teacher or a member of the school administration, because then they may either be intimidated into silence and/or fear repercussions. This is because quite often the reasons involve poor teaching methods by the teachers, and rushing through content with hardly any time to reflect and ask questions, let alone practical work to facilitate learning. However, with time and if both the teachers and the pupils are comfortable, then they can work on this identification together. This would be the most ideal situation, but the teachers would have to drastically change their "know it all attitude" and develop confidence in the pupils to raise their learning problems without being penalized as being critical of or rude to the teachers.

The role of the facilitator in this process is therefore to train the learners in taking responsibility for their own learning, by analyzing their own learning styles and problems and articulating these issues as clearly as possible. The different ways of identifying the difficult topics or areas, and the reasons why, include the use of questionnaires, discussion groups and diagnostic tests by the teachers. Given that most people fear to expose their ignorance, the questionnaire would be the best method. Unfortunately, many pupils do not articulate well enough on their own for the data collected to be very useful (Mulemwa, 1997). On the other hand, very few have the guts to admit "ignorance" in a group. Therefore it is better to use a combination of all methods. This can be augmented by tests, which are specifically constructed to diagnose the learning difficulties of pupils and problematic content areas. Such a multi-pronged approach should yield useful result in terms of not only the difficult topics, but also more importantly, a comprehensive list of reasons for the difficulties experienced.

### 2. The Drafting Stage

Having identified and prioritized the difficult topics, the teachers start on the development of complementary and supplementary gender-inclusive materials, identifying teaching/learning aids and materials that could be utilized with the new content. The pupils too, can be actively involved at this stage. In fact the students are in a good position to contribute to the gender aspects of materials development by sharing their experiences, interests and fears with the teachers. The can pupils' participation in several ways. After identifying possible specimen, the teacher can get the pupils to collect some things like used bottles, pieces of wood for improvisation, insects, seeds, leaves and the like, from their environment, and in the process learn more about them. They can draw diagrams of some of the specimens for possible use in the classroom. Such diagrams include those showing the different parts of the body, of seeds or leaves and the like. The learners will automatically learn some SMT facts; make useful observations as they draw the specimens; and this would form the basis for questions, problems and issues for appropriate discussions in class. With some guidance and appropriate instructions from the teachers, pupils can further design and/or construct or make some teaching/learning aids, such as a First Aid carrier "bed" in science, models of different shapes in mathematics, models of pulleys and carts for S&T, as well as charts and diagrams of different processes and things as indicated above.

**3. Piloting the Draft Curricula Materials**
The supplementary and complementary curriculum content and teaching/learning aids developed have to be piloted to find out their effectiveness in an actual classroom-teaching environment. This process would be made a lot easier, more interesting and hence more beneficial to the learners, if they were actively involved in the development of these materials as outlined above. The teachers can then critically but constructively use the work of the pupils to discuss the content. This in itself would be very motivating to the pupils, and particularly so if the best diagrams or other aids constructed, or write up of a process, could be rewarded. The reward does not have to cost anything, as it can take the form of judicious praise in class, pinning the winning chart or diagram on the notice board or a having good piece of work displayed in the classroom or school. The pupils are then likely to be more eager to participate in the next set of curriculum development activities after a positive experience as outlined above.

## Developing The Reflective Process Of The Teachers

A good teaching process should be spiral in nature, where by the teacher prepares for a lesson, teaches it, and then reflects on it consciously to learn from both the positive and negative aspects of it, so that the next lesson can be better. Unfortunately, the teachers in many African classrooms are so overwhelmed by the prevailing circumstances that they hardly have time to consciously reflect properly on what they are doing and why they are doing it. This can be attributed to several causes. First, the poor salaries and other conditions of service mean that the teachers have to supplement their incomes through other work and hence have little time to prepare professionally for lessons. Therefore, any additional activity such as working with pupils on the development of teaching/learning aids, which presents a lot of extra work, is understandably avoided. Secondly, the teacher's work is also made more difficult by the large class sizes, coupled with poor resources. Lastly, the most common method of teaching is the Lecture type method (Ebout Mfou et al, 1998). The teachers therefore lack the experience and confidence to use more creative methods like the project or fieldwork in the classrooms, and yet these are methods that would enable a teacher to reflect more purposefully as they prepare to teach using them. What is being proposed here is the emphasis of a deliberate reflective process on the part of the teachers as they prepare curricula materials in the process discussed earlier. While this process occurs even subconsciously to some extent as one develops the materials, it needs to be emphasized at three distinct stages, namely, at the stage of identifying the difficult topics, the development of the draft materials with the learners, and as the materials get piloted in the classroom.

**1. Identifying the Difficult Topics**
A research study carried out in Uganda (Mulemwa 1995) showed that secondary school teachers generally find it very difficult to admit what they do not know with regards to what they are supposed to teach at the school level. This is not only because of the fear of being labeled as ignorant, but it is probably also due to a more deeply embedded and hence unconscious expectation and attitude that "the teacher knows or must know it all". In this research, the objective was to identify what the teachers found difficult to teach. However, all of them always started by identifying what "the students found difficult to understand" and squarely put the blame for the lack of understanding on the students. Moreover, the teachers were not easily forthcoming in pinpointing the exact source of the problem once the topics had been identified. It was only through deliberately guided small group discussions that teachers slowly admitted to finding difficulties in teaching

some topics. During such discussions, some teachers confused concepts as well, thus unknowingly, but clearly showing their lack of understanding of these concepts, such as a "mole" being used synonymously as a "molecule" in chemistry. When they eventually admitted to some lack of confidence in teaching any topic, the major reason given was often the lack of textbooks and materials for use with the topic. They did not easily admit that their lack of understanding of the concepts and theories involved in most of the identified topics could be making the identification of appropriate teaching/learning aids very difficult let alone those for improvisation.

We had similar experiences at first, in the FEMSA –Uganda project with primary level teachers as we tried to identify difficult topics for addressing in the school-based curricula development activity. This is why the proposal for a more deep and reflective process at this level is being advanced here. An effective reflective process would require a detailed analysis of what the study of each topic calls for. This is first of all in terms of the key theories, concepts and principles that one needs to know and to build on in order to facilitate the understand of the new topic, as well as those that should be taught as part of the topic. Such a detailed analysis helps to pinpoint the area of difficulty and hence the identification of appropriate illustrative examples, methods and aids that can help to teach the content more effectively. The reflective process on the part of the teacher is deepened and becomes even more useful if the teacher also work with the students, guiding them in their own analysis of the problem areas as already indicated above. In this process, the teacher would further clarify the difficult areas, concepts and principles.

The difficult topics identified by the teachers are likely to be very similar to those identified by the students because students can hardly be expected to understand topics that the teachers themselves find difficult to teach. It is such topics that should be addressed first in developing curricula materials.

**2. Developing the Draft Materials**

Developing materials is a long and time-consuming activity, and the proposed reflective process would make it even longer. However, the products should be much more suitable to the learners in facilitating their understanding, and in the long run, both the teachers and the students would find the teaching/learning process easier. At this stage, the teachers need to focus on the reasons identified as making the topic difficult both from the point of view of the teachers, and from that of the students. The reflection is deepened if the teachers engage the students in the collection and preparation of some teaching/learning aids. As indicated earlier, the teachers need to guide the students on what is likely to be needed and hence collected and/or made. Examples of this include the close observation of the life cycles such as those of a tadpole, or butterfly from egg to the adult species; seed dispersal, germination or flower pollination; making models of farm implements like wheelbarrows and rakes, or pulleys; collecting data such as age, height or population aspects and presenting it in the form of graphs and pie charts. The teacher has to develop some guidelines for the students to follow as they collect and prepare possible specimens and/or make other aids. This would effectively constitute assignments to the students such that by the time the topic gets discussed in class, the students would have had some experience with it and it would be more familiar to them. The teacher can for example ask the pupils to write up how and where they got or found each of the specimens they collect; design a flow chart or diagrammatically represent local process such as the making of bread or local beverages. Students will then have to do some research and hence acquire basic research skills and knew knowledge.

It is important to note here that the process as discussed above of necessity employs the more creative methods like the project method, discussion and fieldwork. Both the teachers and the students would therefore be experiencing and training in the skills of "learning how to learn". These skills are vital in the world today because as Costa and Liebmann (1997, p. xxii) stated, "*—knowledge doubles in less than 5 years and is projected to double every 73 days by the year 2020*". They continue to say that, "*it is no longer feasible to anticipate the future information requirements of individuals. We must look differently, and with greater depths, at what learning is of most worth*". They further went on to say that, "*we need to nurture skills, operations and dispositions that will enable individuals to solve problems when answers are not readily known. Educators need to embark on* *radical reforms that shift away from content to process and to value the collective intelligence of the group, as well as the intelligence of each learner".* This quotation captures the essence of the need to train learners in the skills of "learning how to learn", and the reflective process above on the part of the teacher can be used to inculcate such skills in a non-threatening atmosphere, as students would be carrying out the work outside a classroom situation. The students would further have to work together, consulting and cooperating with others, and hence learn to value collective knowledge. This would predispose them to "cooperative learning" in the classroom. This is an approach that is almost totally absent in the African classrooms, and yet it offers an appropriate alternative learning style, particularly for the African girl child. As Okebukola (1996, p. 33) put it, *"Cooperative learning is predisposing to the African socio-cultural orientation, facilities limitation and acquisition of knowledge, skills and attitudes in science and technology".* Moreover, it also emphasized the importance and *"value of the collective intelligence of a group"* as pointed out by Costa and Liebmann (1997p. xxii), which is very desirable today.

As the students discuss the progress of their assignments, the reflective teacher should be able to identify "alternative conceptions" and/or "mis-conceptions" of the students, and perhaps their own too. When these are known, then the lessons can be prepared in such a way that the mis-conceptions are challenged, hence assisting the students to re-construct their knowledge in a more scientifically acceptable way.

**3. Piloting the Materials**

The curricula content and all materials developed have to be tried out in a classroom situation to validate their effectiveness. The lessons should be livelier, if the students too, participated in the development of some materials as discussed above. In continuing with the reflective process, the teacher should endeavour to use the students' materials as much as possible and help the students to critically examine and discuss those selected as the most appropriate for use in the lessons. If properly used and with constructive criticism, even those students whose materials are not so good would be motivated to improve on them, while those whose materials are good could be encouraged to help others so that they too could improve even more in the process. The use of students' materials in the classroom is a very good motivator for them. The good materials like drawings, diagrams, write-ups, specimens or constructed materials could be appropriately displayed and/or exhibited. The students would then be even more motivated and willing to engage in the development of more materials.

As indicated above, the use of method such as fieldwork, the project, discussion, and individualized assignment for carrying would be inevitable. These are methods that facilitate the acquisition and development of the higher-level abilities of analysis, synthesis and evaluation. They further involve personal initiative and creativity. Consequently, the psychomotor skills and attitudes towards SMT are likely to improve in addition to the higher cognitive abilities, and hence participation and performance in SMT. The methods also involve collective responsibility and are bound to impact profoundly on the individual learners, helping them to clarify their personal interest or dislike of SMT subjects. Whatever the personal interest turns out to be however, the learners would have learnt the skills of "cooperative learning" and working together to achieve a common goal, and the skills and attitudes necessary in "learning how to learn".

As the materials get piloted, both the teachers and the students would identify more "fuzzy" areas and the process of refining and developing more materials would continue. Once the teachers and the students gain the confidence of admitting that they don't know, the analytical skills of identifying what they don't understand, and the skills and attitude of trying to devise means and ways of alleviating the problem and hence research, then the process of "learning how to learn" would have been institutionalized. It should be underscored here that the methods above, which employ the cooperative learning style might be more attractive and hence effective to the girl child than the individualistic and competitive lecture method learning style.

### Involving The School Authorities And The Community

The process of school-based curriculum development, which actively involves the pupils and the teachers as discussed above cannot be successful without the support of both the school authorities and the community. This support, especially that of the parents of the school and the general surrounding community is vital if the process is to be sustainable.

**The Role of the School Authorities**

The school authorities can offer support to the school-based curriculum development process in several ways. First and foremost, the teachers need to be sensitized to the problem of gender biases in education and SMT in particular, and trained in gender analysis and materials development. This must be planned such that regular workshops and seminars are organized for the teachers, employing appropriate facilitators, as opposed to a once-in-a-while workshop. The school authorities need to recognize the great shift in mind-sets that is required by this approach and therefore be prepared to offer supportive training to the teachers for quite some time. The FEMSA-Uganda experience showed teachers get greatly encouraged when the school authorities also participate in some of the training and/or the materials development activities. This is quite beneficial to the authorities too, not only because they equally need such training, but also because they can forge a closer working relationship with the teachers through these activities. They further get equipped with the knowledge and understanding of the issues and what needs to be done, and are therefore likely to be more effective in mobilizing support for the process and for the school.

It is vital that the school authorities allow the teachers time to engage in the activity without encroaching too much on the teachers' free time. For example, a lot o work can be done within the normal school working days without the learners loosing out, instead of taking up all the weekends. However, this requires proper planning and timetabling on the part of the school administration. The school authorities should provide the necessary stationery and other materials needed for the activities, while encouraging improvisation and the use of locally available materials as much as possible. They should further organize regular sensitization meetings and workshops for the parents and general community, on the need and value of education, particularly for the girl child in SMT. The community needs to be educated on the goals of a good education, highlighting the importance of the strategy of school-based curriculum development as crucial in achieving such goals. This sensitization is necessary in order to ease the mobilization of resources and general support for the process. Last but very important, the school authorities should endeavour to provide some incentive for the teachers, in terms of refreshments or meals as necessary, or even a small allowance where possible.

**The Role of the Parents and the Community**

A well-sensitized community can offer a lot of support the school in general and the curriculum development process in particular. First, the parents have to allow their children particularly the daughters, time to participate in the curriculum development activities at the school, especially if they take place after the usual school hours and/or on weekends. They also have to give them time at home for these activities. They could assist, guide and facilitate them in the school assignments that have to be done at home, such as project work, depending on their own potentials. The community, particularly the parents can even directly participate in the process of curriculum development through the practical assistance they give to the learners. As noted by Mulemwa (2001) they *"can help in the provision of SMT teaching/learning aids such as specimens, local materials like bottles, tins, and wood for improvisation, and their own home facilities like carpentry and metal workshops, gardens and farms for demonstrations and even practice and application of school SMT concepts and ideas. Furthermore, appropriately qualified and/or experienced members of the community can be oriented to assist teachers in either teaching or demonstrating particular skills and imparting values".* Otherwise, the parents and the community also provide a safe and encouraging environment particularly for the girl child, to explore and develop interest and skills in SMT. They can further contribute resources to facilitate the process and offer incentives to the teachers and the learners, thus complementing the efforts of the school authorities.

**Concluding Discussion**

During the period of 1992-1994, the author was exposed to, and participated a little in the work of teacher educators in Alberta, Canada through the University of Alberta, department of Science Education, on their efforts in "teaching thinking" (Alberta Education 1990 a) and "research" (Alberta Education, 1990 b) to learners. These educators had developed science material and models designed to help students grow in their abilities to gather, process and share information, a process that requires critical thinking skills. They had further developed materials to teach thinking skills and to develop students' research skills, at school levels. While the process called for a lot of hard work, initiative and creativity on the part of the teacher because it involved hands-on and minds-on work, the students enjoyed it very much and participated very actively. This experience spurred the author to carry out a research study with her own classes on "helping learners to take more responsibility for their own learning", in 1995-1996. The learners were post-graduate Diploma in Education Chemistry Methods students at Makerere University. The gist of this study was that students had to critically examine each lecture given, in terms of the appropriateness and effectiveness of the instructional methods and aids employed by the lecturer in facilitating their own learning of the content of the lecture. In doing so, they had also to identify any other barriers to their learning and suggest improvements.

The unpublished research work (Mulemwa 1996) clearly revealed and demonstrated several findings that are very informative for the teaching/learning process. First, the learners did not want to carry out the extra work of critically reflecting on the teaching/learning process, since it was not to contribute towards their examinations. The researcher, as a lecturer had to insist on having it done and had the reflections of the students discussed seriously before each new lecture. Secondly, the students found difficulties in identifying and in diagnosing their own learning so as to identify any problems. Thirdly but very critical, the students feared victimization by the lecturer (who was also the researcher) if they gave reasons that directly or indirectly reflected on her negatively, such as poor preparation and instructional methods. In fact, the lecturer/researcher had to design exercises where the students' critical reflection could not but yield negative criticism, if they were honest, so as to develop their confidence in giving constructive criticism. Fourthly, the research demonstrated that having gained confidence in identifying the problems and the causes, constructive criticism was not easy, because one had to suggest a way forward in terms of better alternatives or ideas. Lastly, but most important, the overall finding was that, towards the end of the one-year course, the students had gained the skills and confidence and were beginning to even suggest ideas of what could be done, as the lecture proceeded, rather than waiting to do so at the end. For example, during one double lecture, students requested that the lecturer changes the topic or method because they had had a big party the night before and most of them were finding it difficult to keep awake. This request clearly demonstrated the confidence the students had eventually acquired in sharing their learning problems with the lecturer/researcher. Their request was of course granted, but after a brief discussion of the implications of both their own discipline in social matters and the suggestions of how else the rest of the lecture could be conducted to their benefit. The unfortunate thing was that, having taken almost a year to inculcate the self-confidence and skills for self-reflection and critical analysis of ones learning process, there was no time with these students to proceed to the next stage, which is where the whole process was aimed at. This was for the Lecturer/researcher to capitalize on their newfound confidence and employ methods that called more on their own initiative and creativity.

This research however gave clear indications that it is possible to achieve the objective of empowering learners to take responsibility and hence active participation in their own learning. Consequently, it should be relatively easier to achieve such an objective at school level because of two reasons. First, one has a lot more time to work with the learner and develop the necessary confidence and skills till they are well assimilated. Secondly and even more important, the learners are still young and quite flexible at that level and can hence be easily trained and influenced into any desirable way of thinking. In concluding this paper therefore, let me summarize the advantages of the school-based curriculum development process proposed above as a way of highlighting its importance and effectiveness in encouraging and improving the access, participation and performance of the girls in particular, in SMT at the school level and beyond. The advantages are as follows:

1. The approach encourages the active participation of the learners in seeking knowledge and exposes the learners to specific SMT processes and experiences, which help them to develop interest in SMT. This is particularly important for the girl child who is otherwise often denied such explorative and investigative experiences because of the cultural norms. The parents are more willing to allow such experience for the girls when it is part of the learning process at school.
2. The process potentially allows the learner to actively and extensively interact and get support from the two most important categories of people who also impact profoundly on any learner (Mulemwa 2001), namely, the parents and the teachers.
3. The learner is developed holistically, in terms of all the cognitive abilities, the psychomotor skills and the affective domain or attitudes.
4. The approach develops not only the science skills, but also the process skills, since the processes are emphasized as one reflects on what needs to be done and how. The major advantage here is the development of the skills of "learning how to learn" which are vital in the rapidly changing world.
5. The approach employs a cooperative learning style, with collaboration and consultations among and between the teachers and their students. It therefore inculcates the need to complement each other's efforts, the importance of group knowledge and collective responsibility, among teachers and students. This learning style reflects the more traditional learning approach in many African cultures. It may therefore greatly improve on the acquisition of the desire knowledge, attitudes and skills, particularly by the girl child because it presents an approach to learning that is quite familiar to her, given her social-cultural training. It also offers an alternative learning style.
6. The approach assists learner and teachers alike to develop interest in SMT as well as problem solving skills, which is an important and desirable utilitarian outcome of SMT education.
7. If the training is done effectively, then some teachers would emerge from the school as leaders, who can be trained as trainers so as to sustain the process with minimal costs. The approach therefore presents an effective mode of curriculum development, which is also very cost-effective in terms of sustainability. This is a very crucial aspect in Africa where the need for revising the curricula is great, yet the resources are very limited.
8. Equally important is the fact that the products of the process are immediately utilized at the school level, where they are targeted, rather than take years to get there, as in the usual centralized approach to curriculum development.
9. As the teachers carry out the materials development activity using the process outlined above, they not only design gender-inclusive content, which uses locally available materials as far as possible, but also inevitably employ gender-inclusive instructional methods. Consequently, they practice the use of the methods and appreciate the power of these methods in increasing interest and understanding in the learning of SMT.
10. The approach tends to close the widening gap between the educated and the communities.

The approach as presented requires a lot of sensitization and commitment of the school authorities and teachers. It requires a lot of time and initiative as well as strategic and systematic planning and collaboration between the teachers, the school authorities and the community, especially the parents. It further requires a coordinator who believes in the effectiveness of the approach so that they can have the patience and intrinsic motivation to facilitate its implementation to a successful conclusion. The coordinator must have the capacity and ability to direct the course of this process, monitor and offer supportive supervision to the teachers, as well as be a good advocate for the process and its products so as to ensure their mainstreaming at the appropriate time. Otherwise, the long-term sustainability of the approach greatly depends on the active involvement and support of the school authorities and the communities.

In Africa, the collaboration of schools with their surrounding communities is becoming very important because these communities are increasingly being called upon to support and complement the efforts of governments in the provision of education, particularly basic education. For example, at the Commonwealth Countries Expert Group meeting of 1998 (Commonwealth. Secretariat, 1998, p. 15), it was found that 6 of the 12 countries that were represented had definite and direct parental involvement in schools through contribution of resources. Therefore, the systematic and regular sensitisation of the communities about the importance of education in SMTE is vital. When a good relationship exists between the school and community, then the school prospers academically and otherwise. This involvement takes the form of participation in school programmes; being role models or instructors; encouraging, supporting and enforcing discipline at school, at home and in the community; and contributing resources to improve the social welfare and academic performance of students, teachers and the school in general. Even more specifically, the parents and other members of the community can participate in the process of school-based curriculum development and implementation through the provision of teaching/learning materials and facilities like their gardens and workshops for teaching and demonstration purposes. As Mulemwa (2001) pointed out,*"The involvement of communities in school curricula in this particular way is extremely desirable in Africa because it brings out the vital message of the immediate utility of the school SMT curricula content being taught, and stops the alienation of the school, and most importantly of the learners, from the community"*. The learners, particularly the girl child would then be assisted to access, enjoy and participate more actively in the learning of SMT. They would then persist and work hard to achieve good performance and in particular, more girls would be able to pursue SMT studies to higher levels, and hence increase their numbers in the SMT-based jobs and careers.

## References

1. ALBERTA EDUCATION (1990 a), "Teaching Thinking skills. Enhancing Learning: A Resource Book for Schools ECS to Grade 12". Alberta Education Curriculum Support Branch.

2. ALBERTA EDUCATION (1990 b), "Focus on Research. A guide to developing students' research skills". Alberta Education Curriculum Support Branch.

3. COMMONWEALTH SECRETARIAT (February 1998) "Popularising Scientific and Technological Culture in African Commonwealth Countries. A Report of an Expert Group Meeting prepared by Prof. Olugbemiro J. Jegede.

4. COSTA A.L., & LIEBMANN, R. M., (Eds) (1997) "The Process-Centered School: Sustaining a Renaissance Community". Corwin Press, Inc.

5. EBOUTOU MFOU, R., MASANJA, V., MULEMWA, J. N., &QUAISIE, G. (1998) Country Profile Reports in *Female Education in Mathematics and Science in Africa, (FEMSA)*. These reports have been serialized into over 10 small "Dissemination Reports" and published by the "Forum for African Women Educationalists (FAWE).

6. MULEMWA, J. N. (2001), "A Triangular Framework for Improving Girls' Participation in SMTE at the School Level in Africa". An invited Discussion paper to the FEMSA/AFCLIST workshop on, "Developing a Systematic Framework for Gender Interventions within the Education System in Africa"; 6-8 December 2001, Nairobi, Kenya.

7. MULEMWA, J. N. (2000), "Projects, Programmes and Research Networks" pp. 185-211; A chapter in the UNESCO series on *"Innovations in Science and Technology Education*" Vol. VII, Part III: Gender, Science and Technology and Vocational Education Projects, Programmes and Research Networks in Sub-Saharan Africa. Some Case Studies. Edited by Edgar Jenkins

8. MULEMWA, J. N., (1999) "The State and Challenges of Gender Equity in Science Education in Africa". A chapter in *"Using the Local Resource Base to Teach Science and Technology: Lessons from Africa", pp.19-53*; Edited by Mike Savage and Prem Naidoo, ISBN 1-947 445-63-4.

9. MULEMWA, J. N., (1997), *Female Education in Mathematics and Science in Africa FEMSA: The Uganda country Profile Report.*

10. MULEMWA, J. N. (1996), "Encouraging Students to Take More Responsibility for Ones Own Learning"; An un published research Study done at the Department of Science and Technical Education, Makerere University.

11. MULEMWA, J. N. (1995), "A Mini-pilot Needs Assessment Project, for an In-service Training Programme for Science Teachers in Uganda"; Un published results of a research study, funded by NORAD.

12. OKEBUKOLA, P. (1995), "Developing and Implementing a Science and Technology Education Programme for All in Africa". A chapter in *"Towards Scientific and Technological Literacy For All In Africa"*. Publ. UNESCO – Dakar, 1995

**Key Words:** Materials' development; gender sensitivity and gender-inclusive; active participation; reflective teacher; difficult topics; instructional methods; cooperative learning; teaching/learning process; teaching/learning aids; cognitive abilities; psychomotor skills; attitudes; teachers; students; school authorities; parents; community;

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# K-12 INSTRUCTION IN THE UNITED STATES: INTEGRATING NATIONAL STANDARDS FOR SCIENCE AND WRITING THROUGH EMERGING TECHNOLOGIES

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**Abstract**

The objective of this paper is to show how science, writing and technology can be successfully integrated to maximize learning for all students. A recent research study infusing the writing process into hands-on science lessons will be discussed, along with recommendations on the use of technology to support instruction in the areas of science and writing. Technology will be presented both as an extension of science through the use of Science-Technology-Society investigations and as a tool for teaching and learning. Strategies for supporting all learners in science, writing and technology will be emphasized. An overview of the state of technology today in the United States will be presented, as well as the U.S. National Educational Standards for Science, Writing and Technology.

Technologies support learning in a variety of ways. The connecting of U.S. classrooms to the Internet and expansion of numbers of computers accessible by students and teachers has led to increased access to information, online learning environments and tools to support collaboration and communication. Word processing and desktop publishing have made writing engaging and easy to edit, and students publish professional looking products. The development of digital technology has expanded the use of video, photography and simulations supporting active learning environments. These emerging technologies address multiple learning styles and active participation leading to knowledge construction and increased understanding of science. Other technologies such as videoconferencing and virtual environments are leading to new thinking about how students can connect to experts, peers and teachers.

The authors will describe examples of how technology, science and writing have been used in effective learning environments in K-12 education. These examples can be modified to fit the specific needs of teachers and learners. The researchers are currently implementing science model projects that will be included in the presentation.

## Introduction

Science and technology go hand-in-hand. It is hard to imagine science without technology, or teaching science without a focus on technology. National standards in the United States call for the use of technology to support learning. The National Science Education Standards include technology as an important component of science teaching. This focus addresses the need to prepare students for their future in which more than 60% of jobs will require advanced skills in technology (U.S. Department of Education, 1998). The partnership of hands-on science, constructivist pedagogy and technology-supported activities can lead to improved student achievement and accountability for continuous improvement (CEO Forum, 2001). Using technology in science not only helps make science relevant to everyday life, it can also assist students in gaining greater understanding of science concepts. But how are we using technology in the science classroom? Is technology being used to help children develop their knowledge and expertise in content areas such as science? How might teachers accomplish this, and at the same time, work with students to improve their writing skills?

Our purpose is to demonstrate how science teaching, writing skill development, and the use of technology can be integrated in the K-12 classroom for the purpose of optimum learning in science and improvement in writing skills. The paper is divided into three major areas: science education, writing instruction and educational technology. In the final part of the paper, we discuss the relationship among the components and how all three may be integrated to positively influence teaching and learning.

First, we will introduce the National Science Education Standards and briefly discuss the standards that are related to science teaching, science content and science education programs. In this section, technology will be introduced as an extension of science instruction through Science-Technology-Society investigations. The second part of the paper describes a "snapshot" of writing as a part of K-12 classes. We have included the writing process as a focus because of the importance of literacy in today's classrooms and because of the additional opportunities that writing offers as a way to learn science. We present National Standards for the English Language Arts that include writing. Examples of writing activities to infuse in science classes are provided.

Next, we have included a description of educational technology use in U.S. classrooms. The National Educational Technology Standards are summarized, and are followed by a discussion of how technology supports constructivist teaching and learning practices. Examples of how technology is used as a tool for science instruction are described. Finally, we bring the three areas of science, writing and technology together, and discuss how integration in constructivist classrooms is important to prepare students for their futures.

## Science Education

### The National Science Education (NSE) Standards

The NSES standards (http://search.nap.edu/readingroom/books/nses/html/) present a vision of a scientifically literate populace. They outline what students need to know, understand, and be able to do to be scientifically literate at different grade levels. They describe an educational system in which all students demonstrate high levels of performance, in which teachers are empowered to make decisions for effective learning, in which interlocking communities of teachers and students are focused on learning science, and in which supportive educational programs and systems nurture achievement.

The intent of the NSE Standards can be expressed in a single phrase: Science standards for all students. Different students will achieve understanding in different ways, and different students will achieve different degrees of depth and breadth of understanding depending on interest, ability, and context. But all students can develop the knowledge and skills described in the Standards, even as some students go well beyond these levels. The National Science Education Standards are presented in six categories:

- Standards for science teaching
- Standards for professional development for teachers of science
- Standards for assessment in science education
- Standards for science content
- Standards for science education programs
- Standards for science education systems

This paper focuses on science, writing and use of technology in individual classrooms and learning situations. Therefore, NSE Standards related to science teaching, science content, and science education programs are most relevant. Overviews of the standards are presented below.

### Science Teaching Standards.

The science teaching standards describe what teachers of science at all grade levels should know and be able to do. They are divided into six areas:

- The planning of inquiry-based science programs
- The actions taken to guide and facilitate student learning
- The assessments made of teaching and student learning
- The development of environments that enable students to learn science
- The creation of communities of science learners
- The planning and development of the school science program

Effective teaching is at the heart of science education, which is why the science teaching standards are presented first. Good teachers of science create environments in which they and their students work together as active learners. They are continually expanding theoretical and practical knowledge about science, learning, and science teaching. They use assessments of students and of their own teaching to plan and conduct their teaching. They build strong, sustained relationships with students that are grounded in their knowledge of students' similarities and differences and they are active as members of science-learning communities.

**Science Content Standards.**
The science content standards outline what students should know, understand, and be able to do in the natural sciences over the course of K-12 education. They are divided into eight categories:
- Unifying concepts and processes in science.
- Science as inquiry.
- Physical science.
- Life science.
- Earth and space science.
- Science and technology.
- Science in personal and social perspective.
- History and nature of science.

Each content standard states that the content is to be understood or certain abilities are to be developed. The standards refer to broad areas of content, such as objects in the sky, the interdependence of organisms, or the nature of scientific knowledge.

**Science Education Program Standards.**
The science education program standards describe the conditions necessary for quality school science programs. They focus on six areas:
- The consistency of the science program with the other standards and across grade levels.
- The inclusion of all content standards in a variety of curricula that are developmentally appropriate, interesting, relevant to student's lives, organized around inquiry, and connected with other school subjects.
- The coordination of the science program with mathematics education.
- The provision of appropriate and sufficient resources to all students.
- The provision of equitable opportunities for all students to learn the standards.
- The development of communities that encourage, support, and sustain teachers.

Program standards deal with issues at the school and district level that relate to opportunities for students to learn and opportunities for teachers to teach science. The first three standards address individuals and groups responsible for the design, development, selection, and adaptation of science programs—including teachers, curriculum directors, administrators, publishers, and school committees. The last three standards describe the conditions necessary if science programs are to provide appropriate opportunities for all students to learn science.

**Science-Technology-Society**
A Science and Technology Standard is included in the content standards of the National Science Education Standards to show the relationship between the two fields. The science and technology standard establishes connections between the natural and designed worlds and provides students with opportunities to develop decision-making abilities. It is not a standard for technology education; rather, it emphasizes abilities associated with the process of design and fundamental understandings about the enterprise of science and its various linkages with technology (http://www.nap.edu/readingroom/books/nses/html/6a.html#sts).

Science-Technology-Society (STS) is an interdisciplinary approach to teaching science that integrates the studies of science, technology and society in thematic or project strategies. STS focuses on the influence of each of these subjects on each other, and it helps students understand what science and technology are and the role they play in our lives. STS presents scientific problems for students to solve that are based on issues that are relevant to them. STS topics may include various ecological and environmental issues, energy, health, population, resources and other topics that citizens should understand in order to be active and responsible members of our society who are willing to take actions for improving their lives and world.

STS is grounded in constructivism, as students begin to understand the science concepts and processes because they are relevant to daily lives. In STS investigations, children identify relevant issues, and participate in deciding what they need to know and do as they research explanations and answers (Martin, 2000). Children and teachers are co-inquirers as they collaborate in deciding what should be studied, how to proceed, and how they will get involved. New questions and problems are encountered along the way.

## Writing Instruction

### Writing Across the Curriculum

Many K-12 schools in the U.S. currently emphasize writing across the curriculum. Some elementary schools have daily writing prompts that all teachers use as catalysts for students to practice and improve their writing. In states such as California and Texas that have many English language learners, literacy is the major focus of instruction in elementary schools. Reading and writing are highlighted in every class in every grade level. Some universities, such as the institution of the authors of this paper, have a universal writing requirement; every class has a writing component. The authors of this paper have identified writing as a way to learn science and as an important component of constructivist classrooms. Ways to infuse writing activities into hands-on science classes are presented.

### National Standards for the English Language Arts

Writing is a major focus in U.S. classrooms, both as a component of literacy and as a way to learn and demonstrate knowledge. The writing process is now being taught in all grade levels, so that students graduate from high school with confidence and competence in the writing process. Below are the National Standards for the English Language Arts (http://www.ncte.org/standards/) that include standards in writing. The vision guiding these standards is that all students must have the opportunities and resources to develop the language skills they need to pursue life's goals and to participate fully as informed, productive members of society. These standards assume that literacy growth begins before children enter school as they experience and experiment with literacy activities—reading and writing, and associating spoken words with their graphic representations. The standards encourage the development of curriculum and instruction that make productive use of the emerging literacy abilities that children bring to school.

1. Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts. They draw on their prior experience, their interactions with other readers and writers, their knowledge of word meaning and of other texts, their word identification strategies, and their understanding of textual features.
2. Students adjust their use of spoken, written, and visual language to communicate effectively with a variety of audiences and for different purposes.
3. Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.
4. Students apply knowledge of language structure, language conventions, media techniques, figurative language, and genre to create, critique, and discuss print and non-print texts.
5. Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.
6. Students use a variety of technological and information resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.
7. Students develop an understanding of and respect for diversity in language use, patterns, and dialects across cultures, ethnic groups, geographic regions, and social roles.
8. Students whose first language is not English make use of their first language to develop competency in the English language arts and to develop understanding of content across the curriculum.
9. Students participate as knowledgeable, reflective, creative, and critical members of a variety of literacy communities.
10. Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

**Infusing Writing Activities in Science Instruction**

Writing is considered an important part of the science curriculum. Clear communication of thoughts and ideas is imperative in science (Ediger, 1994/1995). Writing has been shown to aid students in learning and reflecting during science instruction. Writing-to-learn is a viable constructivist process and compliments inquiry science teaching methodologies. Writing can provide new avenues for students to understand science, and should not simply be used to assess past learning (Hand, Prain & Vance, 1999).

A research project on the integration of writing processes with science instruction was conducted last year by one of the authors of this paper. The study investigated student achievement in science and writing, when hands-on science lessons were infused with extensive writing activities in a 6th grade classroom. In the study, student achievement in a class in which writing was linked to hands-on science was compared to student achievement in a class experiencing hands-on science without the integration of extensive writing assignments. The research included pre-testing, post-testing and performance-based assessments in science and writing. Results showed that it is beneficial to integrate science teaching and writing processes; the integration helps students in their understanding of science concepts and in their writing skill development. Different types of writing were included in the science lessons in the study. Examples of these and other writing activities are described in the remainder of this section.

Scarnati and Weller (1992) suggest that narration, description, explanation, and persuasion are the four basic methods of writing, and should be a student's main purpose in writing. Scarnati and Weller believed that there is "no better subject in which to practice these skills than science." By reporting on science activities, and keeping observations, students are in a situation in which a need for different writing forms exists. Students can keep experience charts, outline content, create concept maps, do book reports, keep journals and logs, write poetry, and produce writings at the beginning and end of classes in order to write as a way to learn science.

Keeping a science laboratory notebook is a viable way for students to practice and extend their writing abilities. Instead of completing data sheets in which they fill in information, students write out the complete investigations in sentence and paragraph format. They write out the scientific questions, their predictions, methodologies, results and conclusions. Rather than filling in charts, they design charts to record numerical results. The write descriptions and interpretations, and draw diagrams and pictures illustrating the procedures and results. Journal writing can also be used in science class, and may include learning goals, progress records, as well as summaries of content and further questions. Journal writing can be used to clarify understanding and to promote student-teacher communication. Children may keep journals on particular projects or units of study. Journals can be used to document change over time and experiences in fieldwork. Journal writing encourages students to observe and think like scientists.

Children of all ages can design a science project, and write and present a proposal which explains the question or project they are proposing, the materials and references needed, and the procedure they will follow. They can do the project and then write up the results and conclusions. Students can design creative inventions, creative applications of science concepts to real-world life, and physical and language metaphors to explain science concepts and process skills. They can also create their own science books by designing, writing and illustrating their understandings of topics in science. This makes science learning relevant to their own lives. They can share their books with other students.

Writing poetry can enhance young people's study of science. Teachers can read poetry aloud to students, in order to help them find their own way of expressing their awareness and understanding of science concepts and issues. Additionally, students can write an autobiography of themselves as scientists. Teachers will become aware of students' previous science experiences and how they felt about them.

Teachers can pose questions at the beginning of class that raise students' thinking to higher levels. The teacher may ask an open-end question, one that is opinion-based, and corresponds to what is being studied. Students can write the answer and share their answers. Students can produce learning logs at the end of class, and write a paragraph summarizing the day's lesson. They may list questions that the lesson made them want to ask.

They might write a quick-write paragraph describing what they learned. Students can complete exit cards on which they describe what happened in class that day. They can be asked to summarize, in one clear sentence, the main idea of the class on note cards. The next class, the authors of several of the cards can be asked to reproduce them on the board at the beginning of class. The class can discuss the sentences and compare thoughts on the previous lesson.

Focused free writing can be used to stir creativity. Students can write on a specific topic as quickly as possible, without worrying about grammar, punctuation, or style. Once individuals write a few lines, they will continue writing for five to fifteen minutes. Free writing can be used to generate ideas on a new topic, to review before a test, to create ideas before a discussion, and to find out students' knowledge on a topic. Students can make up their own who/what/when/where/why/how questions about a topic. Teams of students can then randomly select and answer questions in writing.

Educational technology will be the focus of the following section. The National Educational Technology Standards will be summarized, and examples of ways to infuse emerging technologies into science teaching and learning will be discussed. In the final section, we will discuss the integration of the three areas of science, writing and educational technology into K-12 classes.

## Educational Technology

### Technology Use in U.S. Classrooms

In 2000, 77% of classrooms in the US had computers connected to the Internet. The national average for students per instructional computer with access to the Internet was seven (CEO Forum, 2001).

This amazing statistic is evidence of the fact that most U.S. classrooms now include technology resources. Technology tools can include computers and a wide variety of equipment linking the computer to information. Video equipment is evolving as a key component of technology, which addresses a variety of applications expanding our use of technology in educational environments. Networking and infrastructure have connected computers to the Internet and a wide variety of tools have evolved to support communication through the use of chat rooms, threaded discussions, listservs, and interactive world wide web environments.

Teachers are beginning to use technology in the United States and to see the value of technology skills for preparing their students for future careers. A survey of teachers in early 2000 indicated that: 76% use computers daily for planning and/or instruction; 63% used the Internet for instruction and 77% had an email account (CEO Forum, 2001). Three ways teachers interact with students in the classroom include instructional approaches (web resources); interaction between faculty and students (virtual discussions) related to course content; and advice and counseling through email, cell phones, pagers and web tools. Teacher training has been expanded to include technology in pre-service experiences as well as ongoing professional development offered through school districts, county offices of education and higher education institutions.

According to a report from the CEO Forum (2001), digital content changes the learning process, allowing for greater levels of collaboration, inquiry, analysis and creativity. Technology can be used in schools for research, to solve problems, to analyze data, to collaborate and correspond with experts and to become content producers. Technology studies have shown that students who use technology for their schoolwork write better and perform better on tests. "Studies have shown that students who employed simulations, microcomputer-based laboratories, and video to connect science instruction to real-world problems outperformed students who employed traditional instructional methods alone" (CEO Forum, 2001). The explosion of digital technology has created a revolution similar to the "hands-on" movement of the 1960's and affecting science teacher education more than any curricular or instructional innovation in the past" (Flick & Bell, 2000).

### National Educational Technology Standards

The International Society for Technology in Education (ISTE, 2000) has developed National Educational Technology Standards (NETS) for Students (http://www.iste.org). In order for students to be prepared for a society with a technology base, it is important for students to develop skills in several areas:

1. Basic operations and concepts
    - Students demonstrate a sound understanding of the nature and operation of technology systems.
    - Students are proficient in the use of technology.
2. Social, ethical, and human issues
    - Students understand the ethical, cultural, and societal issues related to technology.
    - Students practice responsible use of technology systems, information, and software.
    - Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity.
3. Technology productivity tools
    - Students use technology tools to enhance learning, increase productivity, and promote creativity.
    - Students use productivity tools to collaborate in constructing technology-enhanced models, preparing publications, and producing other creative works.
4. Technology communications tools
    - Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences.
    - Students use a variety of media and formats to communicate information and ideas effectively to multip0le audiences.
5. Technology research tools
    - Students use technology to locate, evaluate, and collect information from a variety of sources.
    - Students use technology tools to process data and report results.
    - Students evaluate and select new information resources and technology innovations based on the appropriateness to specific tasks.
6. Technology problem-solving and decision-making tools
    - Students use technology resources for solving problems and making informed decisions.
    - Students employ technology in the development of strategies for solving problems in the real world.

Without a sequence of technology throughout the grades levels, it is impossible for teachers to plan for technology projects. Many students do not have technology at home and do not have an opportunity to expand their skills and have an equal opportunity to be prepared for college or professional careers. The issues of the digital divide are a concern for addressing equity in educational opportunities.

**Educational Technology and Constructivism**
In constructivist science classrooms, teachers and students learn side by side as they explore information, materials and resources. Tools are important for knowledge building; they help students gather data, organize information, share information and demonstrate their learning through writing. Emerging technologies provide many tools that support learning. The connecting of U.S. classrooms to the Internet and expansion of numbers of computers accessible by students and teachers has led to increased access to information, online learning environments and tools to support collaboration and communication. The development of digital technology has expanded the use of video, photography and simulations supporting active learning environments and addressing multiple learning styles and active participation leading to knowledge construction and increased understanding of science. Other technologies such as videoconferencing and virtual environments are leading to new thinking about how students can connect to experts, peers and teachers.

**Examples of Technology Use to Support Science Teaching**
Guidelines developed through the National Technology Leadership Initiative have been proposed to provide assistance in designing instruction and to guide applications of technology to support science teacher education reform (Flick & Bell, 2000). These guidelines include the following:
1. Technology should be introduced in the context of science content.
2. Technology should address worthwhile science with appropriate pedagogy.
3. Technology instruction in science should take advantage of the unique features of technology.
4. Technology should make scientific views more accessible.
5. Technology instruction should develop students' understanding of the relationship between technology and science.

In the paragraphs that follow, activities that support the guidelines and that infuse educational technology into science education are discussed.

Word processing and desktop publishing applications. Students can use word processing programs for written reports, essays, descriptions, and other writing forms. Mind-mapping software assists students in organizing their thoughts, brainstorming, and developing an outline. Children who use word processors exhibit higher quality and greater quantity of writing. Desktop publishing programs are word processing applications that allow children to put together newsletters, information pamphlets and similar products, with a professional appearance.

Tutorials and drill and practice software. Computer-based tutorials contain information that could be presented with a textbook, but may be more motivating than a text. These tutorials help students review information that they have not mastered, provide reinforcement of a skill, or provide additional time with a skill or concept. Drill and practice programs provide repeated practice and feedback to help students reach objectives. They focus on learning objectives, state the questions so that students know exactly what to do, give immediate feedback, and provide remediation.

Database management. Databases are systems that store and organize information. Students can use databases to generate and answer questions, formulate and test hypotheses and critically evaluate the results of inquiries. Through the computer, children can access commercial databases and information services, do collaborative research with others locally or around the word, get the latest weather and other science-related data. Students can also create their own database; this requires gathering information, analyzing it, categorizing it, and organizing it.

*Spreadsheet applications.* A spreadsheet is a ledger sheet into which data can be entered and stored. Numbers, words and a combination may be entered. Each cell has a reference based on its column and row. Numerical data from a spreadsheet may be converted into a graph. Data is represented in a form that makes it easy for pupils to see relationships between variables and to ask questions to be answered by referring to the spreadsheet. The spreadsheet and graphs are objects that help students analyze and understand their data.

*Multimedia presentations.* Students can create their own presentations to teach each other about concepts and processes. Students can be creative and demonstrate their understanding of a topic in unique ways to meet the learning objectives. The presentations can be saved and used for future reference or posted on the Internet for global sharing.

*Video.* Commercial and public television stations offer carefully designed instructional videos that are telecast during school hours so that schools can receive them and use them in appropriate classrooms (Martin, 2000). The Public Broadcasting System (PBS) regularly airs programs on science and nature; the Learning Channel airs programs on scientific topics; and the Weather Channel broadcasts daily 10-minute explanations of weather phenomena and offers documentary videos for use in classrooms. Students can produce their own videos demonstrating scientific concepts. They can be in charge of planning, directing and filming video clips explaining their scientific understandings to their peers.

*Threaded discussions.* Technology collaboration tools provided by the Internet include synchronous and asynchronous opportunities for discussions. Students can join discussions through listservs, bulletin boards, newsgroups, and computer-chat conferences about science topics.

*Videoconferencing.* Through the use of sound and video, classrooms are connected for the purpose of sharing knowledge, discussing perspectives, and asking questions. This tool can support the exchange of information between students or between student and mentor. Other technologies should be used in combination with this tool.

*Interactive video technology.* Interactive video technology (videodisks or compact disks) combines video pictures, microcomputer graphics, and text to present phenomena that otherwise would be inaccessible. This allows students to visualize chemical reactions or natural disasters like tornadoes that would otherwise be too hazardous, time-consuming, or expensive for students to observe. Examples of the use of video technology are for students to observe the eye of a hurricane or the colorful and violent reactions between dangerous chemicals.

*Microcomputer-based laboratories.* Microcomputer-based laboratories allow students to use computers as laboratory tools. The use of electronic probes and sensors allows students to use the computer to collect data and then import the information into a word processing system. They can collect accurate scientific data and complete multiple trials in a timely manner. Interfaced electronic probes can detect temperature, voltage, light intensity, sound, distance, dissolved oxygen, or pH while the computer digitally records and graphs the data. Students can observe graphs being produced as an experiment is being conducted, and they can obtain immediate graphs and see trends. This allows them to focus on the concepts they are exploring, spend more time analyzing their results, and ask new questions.

*Computer simulations.* The use of simulation programs support students in their understanding of experiences that may be difficult to create in the classroom environment. Computer simulations allow students to explore and manipulate ideas in artificial environments that minimize extraneous details and make it easier to study interactions among variables. Simulation experiences are an example of replication of what is used in the outside world. Astronauts are trained in space travel using simulation programs. Scientists often use simulations to investigate the inner workings of the human body. When is a simulation valid and when is the actual hands-on experiment necessary? Veterinarian students in a university setting posed this question. In some cases it is important to experience the lab dissection of the frog or other animal, but in other cases the animated simulation allows students to understand the workings of muscles and tendons supporting the extension of the human body through physical exertion. In some cases the ethical and moral questions are raised about the use of live animals when a simulation can replicate the experiment and understanding in the same way.

Model-building programs. Computer model-building programs allow students to visualize and form mental models of abstract concepts. The teacher helps students move from a hands-on experience in the lab to the computer program and back again, encouraging them to see the relations between concrete objects they are manipulating and abstract computer programs. An example model-building program is one that allows students to "see" density. Students choose from different kinds of materials of various densities to build objects of different sizes. Density is shown on the screen by the number of dots per square inch.

Internet. Online technologies can support restructured learning environments through network connections. Existing classroom computers can be linked to cameras and cables connecting them with remote stations through the Internet and/or dedicated phone lines. Teachers are no longer the sole experts as students can access information from outside experts and collaborate with peers from distant geographic locations (Hayden, 1999). These connections can support a video broadcast or a threaded discussion from opposite sides of the earth. These conversations can lead to better understanding and support the acquisition of knowledge. Students can take virtual field trips and explore science events as they happen. At the NASA website, students engage in live web casts introducing astrobiologists' fieldwork study of microbial mats. Students then interact with active astrobiologists in a forum as they compare and contrast their own investigation methods with those of scientists studying microbial mats in Baja, California. Students conclude with a third follow-up web cast on the results and conclusions of both investigations. (http://quest.arc.nasa.gov/projects/astrobiology/fieldwork/index.html)

Telecommunications networking. Students can communicate with scientists who are working in specific fields. Teachers can contact scientists and engineers in at local institutions, or they can arrange for the collaborations through the many projects designed to set up partnerships. In San Diego, the San Diego Science Alliance (http://www.sdsa.org/) has a database of scientists and engineers who work with K-12 students and teachers to assist in improved science education for all.

Portable keyboards and palm pilots. New technologies are often small and portable allowing their use during field trips, labs and from home to school. Eighty percent of what students use computers for in the classroom is writing. Portable keyboards can be an economic supplement to computers. They can be used for writing and brainstorming and then connected to the computer for transfer of files to more sophisticated software programs for multimedia and desktop publishing.

## Integrating Science, Writing and Technology

We have provided numerous ways to integrate science and writing, as well as science and technology. All of the methods for writing in science class can be enhanced by use of computer technology. In addition, the examples in the previous section on ways to infuse technology into science teaching and learning involve writing. Many of the examples for using technology in science class involve students accessing and then using information; the ways in which they use and process the information all involve writing.

Research has shown that students write more when using computers, as compared to writing with pen and paper (or word processing equipment, including typewriters). They enjoy their writing more and are more motivated to write when using technology. Teachers report that writing has always been a difficult process for students; many young people balk when asked to revise and re-do because it has been such a cumbersome process. However, technology opens up a whole new and positive experience for students as they learn and practice writing. They don't mind editing if they can do it on the computer. It is easier to visualize the whole paper on a computer, easier to play with ideas, and easier to edit on the computer.

Students think about their writing much more when they write on the computer. This is especially true in telecommunications. Even when using email, students consider their spelling, punctuation and grammar. They pay more attention to what they write and how they write because they are concerned with the impression they make with the people that read their writing. Writing becomes important because it represents them. When participating in threaded discussions, young people know that a variety of people will be reading what they write and they care about what the readers think of them. They want to make a positive impression and, thus, they do their best in their writing.

The future of technology is hard to predict, but it is clear that it will continue to change the way students learn and share information. Science and writing are both areas of our school curriculum that have taken full advantage of the benefits of technology. The typewriter evolved into the word processor and desktop publisher. The science laboratory has become digital and students' natural interest in technology and creativity has led to enhanced experiences reflecting the real world of scientific discovery. Wireless technology has started to become familiar at school sites and, as it becomes commonplace, will open up whole new avenues for teaching and learning. What we must do is make sure that all students are able to benefit from these technologies and have an equal opportunity to benefit from the integration into K-12 classrooms. Working with teachers to develop model projects will assist in this transition.

## References

CEO FORUM. (2001). Key building blocks for student achievement in the 21st century (Year 4 report). (2001, June). Retrieved on November 12, 2001 from the World Wide Web at: http://www.ceoforum.org/

EDIGER, M. (1994/1995). Writing in the science curriculum. *Catalyst.* 38 (2), 6-41.

FLICK, L., & Bell, R. (2000). Preparing tomorrow's science teachers to use technology: Guidelines for Science educators. *Contemporary Issues in Technology and Teacher Education* Retrieved on December 5, 2001 from the World Wide Web at: http://www.citejournal.org/vol1/iss1/currentissues/science/article1.htm

HAND, B., Prain, V. & Vance, K. (1999). Writing to learn. *Science Scope.* October 1999, 21-23.

HAYDEN, K. L. (1999). *Videoconferencing in k-12 education: A delphi study of characteristics and critical strategies to support constructivist learning experiences* (Doctoral dissertation, Pepperdine University, 1999).

INTERNATIONAL SOCIETY for TECHNOLOGY in EDUCATION (ISTE). (2000). *National educational technology standards for students: Connecting curriculum & technology*. Oregon, ISTE.

MARTIN, D. J. (2000). *Elementary science methods. A constructivist approach*. Belmont, CA: Wadsworth/Thomson Learning.

SCARNATI, J.T. & WELLER, C.J. (1992). Write stuff. *Science and Children*. 30 (4), 28-29.

US DEPARTMENT OF EDUCATION. (1998) *Technology innovation challenge grants*. [Brochure]. Office of Assistant Secretary for Educational Research and Improvement.

**Keywords**: constructivism, science, standards, teaching, technology, writing

041

# AGROCHEMISTRY: AN INSTITUTIONAL PROJECT OF THE UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO, FOR THE ELEMENTARY AND THE HIGH SCHOOL EDUCATION.

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## Abstract

This project's intended to initiate children and young adults into the knowledge of natural sciences, and has the purpose to explore the area of human knowledge in general, and chemistry applied to agriculture in particular, using the soil as a resource to reach it and taking advantage of the great childlike curiosity and amusement capability that a seed germination and the growing of the plant generate in children.

Taking into consideration that it's necessary to prepare tomorrow's scientists, the question's *what would be the best way to integrate a pedagogical statement and didactic strategy to teach the natural sciences while allowing students to record, measure, think, understand, analyze, integrate, criticize, and be creative?* Trying to put this into practice, we are presenting a general program which includes articulate and well-organized units to work on a soil parcel which constitutes the integrating unit of the program. For these purposes, soil use's the basic resource, and it closely related to different fields of knowledge, pretending at last, to conforme in children an unforgettable interest for the study of sciences.

In order to achieve the goals, a wide variety of experimental activities along with specific tasks on the parcel are suggested. Each student works at his/her own pace, and is given explanations of the work and observations done on the parcel. In this form, at the end of the program, students are able to come to the conclusion that the soil's the plant's support and the main supplier. Also, the program's related to other fields of knowledge such as mathematics (areas, seed density, yield.), geography (weather, soil, orography, .), history, biology, etc. Team work, discussions and integration of observations are of top priority to construct knowledge. However, individual capacities aren't overlooked and they're integrated to the collective work, since we're convinced that a great part of educational problems isn't due to an important lack of knowledge but to a deficient development of attitudes and the capability to do things together.

## Introduction

The essential and renewable resources keeping, within the foods production that guarantees the supplies to the population needs, constitutes a top priority and represents a national sovereignty matter, and a worldwide concern to the Latin American countries. Due to that, the development of sciences, in general, must comply with the specific needs from our own country development and at the same time, the science is looking for solving indispensable problems that represent how to solve a national priority, we are making and developing a science and not only arguing over or fitting foreign investigations to our own country, which are developed within other nations' needs.

That is why we must aware people –from kids to old men- over the necessity of developing a science which complies with a specific project for our nation, it is an undeferable task and it is the answer to the necessity of an educative project in which the majority of the people must have a scientific culture formed through and education started at home and strengthened by the national educative system, which begins in the kindergarten and should last for all their whole life.

This educative system will let them not just demand, but create and impel a country's project which considers as much the resources preservation as foods keeping and production, this is equally essential for us in order to achieve the elementary competence and guarantee an economical independence. On the contrary, to this statement and immersed into the new millennium, actually Mexico does not produce the basic and enough foods for its population's national diet; furthermore, it is not able to export and get a favorable economical balance, and in the other hand, it confronts a great diversity of serious problems, outstanding two problems from all of them closely related and equally essential:

1) Environment degradation and pollution
2) Enough quality and quantity of food production

So, although it is valid to get developed within the area we have a particular interest (since there is freedom to do it, this project is trying to get the attention of those who develop science over the necessity of abounding in soil knowledge as a physicalchemistry means, indispensable for plants growing and foods production, as well as the fact that, in a country whose soil is every day more damaged by erosion, salinity, sodicity and pollution, this natural resource comes to degradation day by day. So, the quality and quantity of foods produced will be lower each day, damaging society, and mankind would be finally in danger.

Responsability falls on professional, parents and citizens, but mainly on us, since we are the ones who have, or at least should have, a bigger conscience and knowledge about the things that should be done, and we cannot be left out of our country problems. Consequently, it is necessary to integrate multidisciplinary teams of scientists, in which pedologists, chemist, physicist, phycalchemists, agricultural engineers, biologists, etc., work together on the general sciences area and the Soil and Chemistry Science specially.

Those scientists teams must be created today in the kindergarten and the elementary school, achieving, through the link and integration of the different knowledge areas, to form a citizen who analyzes, discusses, proposes, lives and executes his own knowledge performance for the social and individual welfare. At this respect, *what would be the best way to integrate a pedagogical statement and didactic strategy to teach these natural sciences while allowing students to record, measure, think, understand, analyze, integrate, criticize, and be creative by himself?* (Reyes-Sánchez, 2000).

Trying to put this into practice, we have established a science teaching program for the elementary school, which must include, integrate and conjugate the physicalchemical phenomenon knowledge which involve the soil as a mean of plants production within the agricultural science development; we are trying to make it in an analytical, systematic, clear, precise and suitable way in accordance to the students' age; this will generate uncompleted knowledge on children, knowledge which are still under study, although this does not mean they are not correct or scientific, this program would encourage them not only to study but favoring them to acquire the wish of discovering, acquiring and linking new knowledge in a critical and positive way, and at the same time, an early discovering of their wishes and tendencies in front of the knowledge areas and science perspectives which have not been explored at this educational level.

## General Objective

Form an educative project about soil science for the elementary, high school and junior high levels, which look at this one as a physicalchemical means for plants development and their interrelation with the agriculture in perfect balance within the nature.

This project would allow us to initiate children and young men within these sciences knowledge, such as the ecological handling of this natural resources, trying to generate, during an early age, an important learning as well as a far-reaching interest on knowledge areas which concern to all of the nations.

## Methods and materials

This educative proposal was built under various methods perspective. In the first part, the main areas of the science knowledge are defined through the historical analysis of the social, economical and political development of Mexico, just for the project conformation as much as to initiate the kids on the job; as well as lacks and actual need of its population, just to come to the conclusion that these problems: pollution, environment degradation and foods production, constitute some of the most serious ones and their solution implicates the soil as a resource.

Once defined the knowledge areas the project would embark upon, it was formed a general program which will be worked, organized and integrated under the scientific methodology around the agricultural parcel job, and by means of this one we pretend to guide children to touch the natural ciences which is integrated and linked to the other sciences. In this way they will be able to associate and absorb some of their ideas and involve their feelings, sensations and specific job personal experiences through their daily effort on the agricultural parcel, fixing to these ones a great aggregated value by means of the same performance and allowing them through their senses statement, (taste sense must be supervised by professor) to hold them by joining and enhancing them with the written, spoken, logical and mathematical language, etc., as well as with geography, history, etc., and associating them with knowledge acquired in the classroom. In order to achieve all of this, they will direct and extend them by means of a joint of experiments that have been designed for that purpose. This proposal was made to work with children from kindergarten to high school, under a pedagogical statement which comes from the same knowledge and appropriation across the execution of Celestine Freinet's daily work. (Freinet, 1984 and Carbonell, 1980)

A general program was formed and we are working on it by means of joint and organized units regarding to the agricultural parcel as an integrated unit, using the soil as a resource in order to get it, correlating it with several areas of knowledge and taking advantage of the immeasurable curiosity and astonishment the germination of a seed and the growth of a plant bring about in children

In order to achieve this goal, many experimental activities are carried out, planned and designed, at the same time that children **evaluate:** surface availability, what, when, and how to sow, etc.; **plans:** extents, outline and lot direction, rotation of crops....; **organizes:** labors schedule, activities responsible...; **watch and record:** what kind of organisms do we find in our soil?, do all kind of seed sown grow in the same way?, do they become ripe at the same time?, do we obtain the same yielding?, are they morphologically equal?, are they attacked by the same plagues?...; **quantize:** dry and wet weights, humidity %, yielding...; **investigate:** why do crops shape?, how are plagues controlled?...; **discuss:** do we sow in a direct way or by transplanting?, do we fertilize?...; **analyze:** how are the cycles interacting with the plant and soil, which they graphically and descriptively learn in the theoric courses ($H_2O$ and C, N, O cycles)?; why are not all of the soils productive?. There is not a defined edge, the limit would be the interest children show and the teachers' capability; this program must be obviously adapted to children's age and educative level.

This program is developed in connection with two main themes and two experimental phases come from it; these phases are carried out by students in the classroom and parcel during the academic year. For this purpose they are supported by their own investigations at home, that is: books, specialized sciences magazines and newspapers, videos, educative T.V. programs, as well as the one carried out in the school library and the daily, critical and positive analysis which will influence the child daily life, that will be led and impelled, at the beginning, by counselors, but later on they will be only supported and oversaw while learning from them and storing his several ideas.

During the first unit development, we will have children understand how the soil is composed by two phases: organic and inorganic, as well as which are the components of each one of them and what is their performance to support and feed plants. In the second unit, we will try again and reinforce the colloid concept and flocculation; at the same time we will introduce acidity, basicity and pH concepts, relating them with soil pollution.

Cultivations proposed to work on the agricultural parcel are not very fragile and short cycle, adapted to the academic year: carrot, pumpkin, radish, lettuce, cabbage, etc.

This program is complemented with themes that can be investigated by the students and/or explained by teacher, according to the academic level, academic rhythm and themes they are studying at that moment, as well as the commitment the teachers have at this respect.

Following, there are two examples which belong to Prehispanic systems on soil -as a resource- handling and preserving.
1. Erosion: Prehispanic terraces in Nochistlán, Oaxaca, México.
2. Handling and Preservation: Chinampas in Xochimilco, México City.

In this way, interrelation among many areas of the curriculum comes true by properly choosing the themes children will have to investigate, ask, inform about and visit: What were the Mesoamerican cultures who built them? What age did they live?, How did they work and live?, What knowledge did they have?, How were they organized?, How was their production?, What kind of soils did they have?, How did they classify soils?, which cultural and preservative practices did they establish?; and finally they will present their job, write their reports, work their wall journal out, carry out field investigations, etc., and be proud of their origins, which are present in their actual knowledge and roots: as an example of the experimental activities.

## Results

We will expose at the congress and at your consideration a sequence of activities which have different difficult grades in comprehension and execution; following we expose a sequence of activities which have different difficult grades in comprehension and execution:

1. Qualitative experience: Child must watch soil in order to distinguish the different particles there are in it, he must touch dry and wet soil playing with his little hands and talking -in his own words- about the differences he perceive.
   Objective: The child must distinguish "by touch" the different particles of the soil and its different capability to keep water, as a consequence of its chemical composition.
   **Sandy:** the water slips between his little hands.
   **Muddy:** it keeps water but is "soapy" by touch, he can mold it but it cracks.
   **Clayish:** it keeps water, can be molded, does not get crack, and he can print his fingerprint.
2. Quantitative Experience: children will fill in a disposable bottle, which was cut at the middle and perforated in the bottom, with sandy soil, and another one with clayish soil; they will fill in each bottle with a specific quantity of water and will wait until water will be distilled. The water distilled will be picked up in a cup in order to measure volumes and time of draining; at last, they will measure and compare times and volumes obtained from draining in both cases.
   Objective: Children must clearly watch and relate the different kind of soils which have different capabilities to keep the water the plant will absorb later on.
3. Quantitative experience: We will show children how to mix various common substance like salt, sugar, starch, etc., and soil within disposable bottles filled in with the same quantity of water; some of them will get dissolve with different facility and quantity, as well as not all of them will get dissolve.
   Objective: Initiate children into the solubility concept and sow the idea about different sized particles existence: ions and colloidal particles.
4. Qualitative and quantitative experience: 50 g of soil will be mixed in a test tube with approximately 900 ml of water and later on, more water will be added up to the measurement point; the mix will be shaked and children will realize that the more we shake the mix, the less the soil gets dissolve, soil gets disperse and their particles are easily watched back-lighted.
   Objective: Initiate children into the dispersions, homogeneous and non-homogeneous mixes and different sized particles concepts.
5. Quantitative experience: We will compare the previous mix to another one made with salt in the same proportion, persisting on showing children how the salt gets dissolve without shaking, while soil gets disperse but not dissolve. Following, both test tubes are placed together and children will be invited to watch them back lighted.
   Objective: Watch how colloidal particles can be seen back-lighted while ionic ones cannot.

Materials used on this project are affordable and the most of them come from recycle. Chemist reagents are home made, proper to home economy and the school, they are harmless for children, which let them not only to repeat experiences at home but generate their own ideas at that respect.

Finally, childs throughout the course of the activities, make their own records about their reserarchs and prepare with the correspondent results, tables and charts showing the volumes of filtered water, and the time filtration tooks in each kind of soil; which substances were dissolved and which ones were not, as well as not all of them were.

Team work, discussions and integration of observations are of top priority to construct knowledge. However, individual capacities aren't overlooked and they're integrated to the collective work, since we're convinced that a great part of educational problems isn't due to an important lack of knowledge but to a deficient development of attitudes and the capability to do things together. (Reyes-Sánchez, 2000).

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## Conclusion

Each soil is different and if we learn about its porpertys, we could know wich kind of plants is more appropiated for each soil.

## Discussion

We belong to a generation who has the possibility to make decisions about what to teach, how and to whom. In a collective way, and as scientist engaged with the impact of a Soil and Chemistry sciences teaching, today we've the chance to decide if we will continue to confine this kind of teaching to professional and specialization levels, or if we assume a personal commitment of being creative and teaching knowledge and high technology not only to higher levels but to children and young people who are blank pages to write on, making grow in them a real interest for these topics, getting them to become enthusiastic about it, and making them fall in love with the scientific work; *creating together a new paradigm in teaching the natural sciences: a teaching project where the interpretation of human facts meets with the explanation of scientific facts while they both face each other dialectically to construct a child's learning.* (Reyes-Sánchez, 2000)

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## Literature

1 Carbonell, J.,(1980). La Pedagogía entra a la granja. Cuadernos de Pedagogía. (62), 12-15. Barcelona,España.

2 Carbonell, J., (1980). El trabajo manual en la escuela. Cuadernos de Pedagogía. (62), 6-11. Barcelona, España.1980.

3 Freinet, C., (1984). La enseñanza de las Ciencias. Ed. LAIA. Barcelona, España.

4 Reyes-Sánchez L. B., (1997). Agrochemistry for children: Soil floculation-defloculation, a pH effect, and greenhouse effect. Memoirs of Fifth Chemical Congress of North America. Cancún, México.

5 Reyes-Sánchez L. B. *et al.*, (1988) Agrochemistry: Le sol soutien et dépense pour la végétation. Mémoire du 16e Congrès Mondial de Science du Sol. Montpellier, France.

6 Reyes-Sánchez L. B., (2000). Marbles, worms, clays and stories around the construction of a new paradigm in teaching the Soil Science. Simposio de Innovaciones educativas en la enseñanza de la Ciencia del Suelo. **Invited conference.** Memorias del XXX Congreso Mexicano de la Ciencia del Suelo. Sociedad Mexicana de la Ciencia del Suelo. Veracruz, México.

7 Reyes-Sánchez L. B., (2000) Agrochemistry: An Educative Project. **Invited conference.** XXIV Congreso de la Federación Latinomericana de Química. Lima, Perú.

8 Reyes-Sánchez L. B., (2002) Soil, support and provision for the plants: A researching project for the elementary and the high school education. **Oral conference.** XVIIe Congrès Mondial de Science du Sol. Bangkok, Thailand.

**Key words:** Soil, Education, Constructivism, Conservation, Resources.

042

# FOSTERING BOTH CREATIVITY AND CARE IN SCIENCE AND TECHNOLOGY EDUCATION

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**Abstract**

The need to incorporate an interdisciplinary theme of care in science and technology education has never been more important. This paper explores how sustainability issues fit within an ecotechnological curriculum model complemented by postformal thinking processes.

Sustainability in its broadest sense consists of both ecological and socio-political dimensions (Robinson et. al, 1996). Sustainability is a normative ethical principle, not a scientific concept as such, and since it has both necessary and desirable characteristics, there is no single version of a sustainable system. In other words, sustainability as a concept is open to broad interpretation, discussion and negotiation, precisely the kind of concept that lends itself to developing an interdisciplinary theme of care for science and technology curricula. Moving toward sustainable systems of production and consumption will require that students attend to the care of others and the environment in new and innovative ways.

## The Need for Ingenuity

Few people would disagree that we live in an increasingly complex and turbulent world. The technological, social, economic, and ecological systems in which we live, work and depend upon exist in a state of dynamic flux. For many this means that young people must be prepared for a life of 'permanent innovation' and ingenuity. Homer-Dixon (2000), defines ingenuity as ideas applied to solve practical technical and social problems, they need not necessarily be new or innovative ideas but more importantly ideas which are *useful*. The demands placed upon natural systems worldwide due to increasing population and consumption levels, requires escalating levels of ingenuity in order to find practical and sustainable solutions to these problems. According to Homer-Dixon, if requirements exceed the supply of available ingenuity, an '*ingenuity gap*' ensues (Figure1). The social and ecological consequences of an ingenuity gap can ultimately lead to social breakdown and ecological life support system collapse.

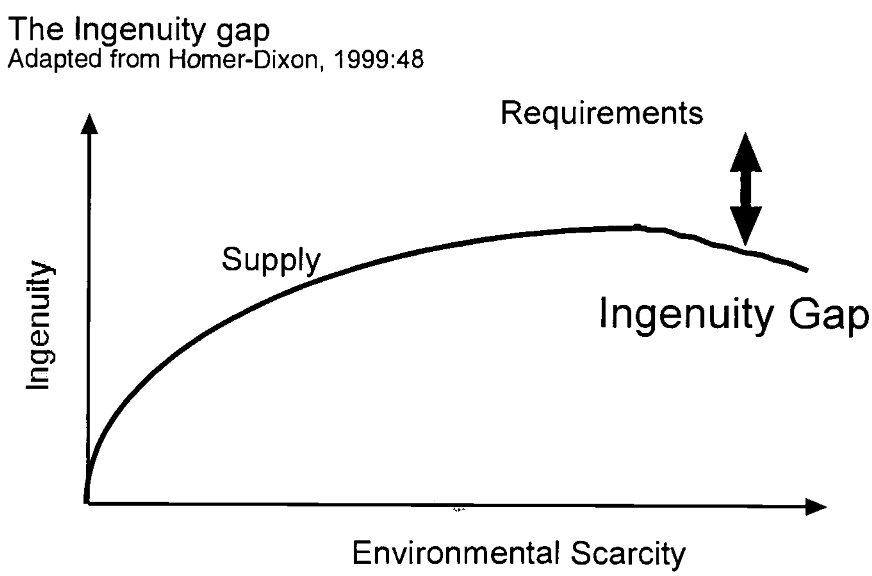



**Figure 1.**

The key point is that the need for social and technical innovation will never be greater than in the near future. An important role for educators will be to showcase examples of creativity and innovation which decrease our material and energy demands on the planet and provide a positive and affirming example of how science technology and social innovation can improve our quality of life without detriment to the natural capital of the planet.

In diminishing or neglecting the need for transformative social change that is required *concurrently* with scientific and technological change, instrumental forms of science and technology education will contribute to the ingenuity gap. The ingenuity gap is not to be confused with 'economic productivity' or GDP measures which reflect a narrow technicist understanding of the human economy. The need for scientific, technological and social innovation to reduce our collective *ecological footprint* has never been greater. It is projected that during the century and a half from 1900 to 2050, a period of barely two lifetimes, humanity's annual impact on the planet's natural environment is projected to multiply over *forty-fold!*

There is a broad and growing consensus that fundamental and substantial changes on a societal and a personal level will be necessary to achieve any measure of long term environmental, social and economic sustainability (UNEP, 1999; Suzuki, 1998). Our collective inheritance , the *'natural capital'* embodied in the systems that purify our air, replenish our soils and underpin our food systems are in serious trouble. Hawken succinctly captures the crux of the problem facing society today:

> *The biosphere represents our source of wealth. It is the capital which we draw down to support our lives. Whenever we pollute or degrade that system with toxins or waste we are destroying our natural capital and reducing our ability to sustain our civilization. It is that simple (Hawken, 1993).*

Environmental degradation is not a necessary outcome of economic development, rather it results from a set of historically contingent choices for technology, production processes and consumption patterns.

Any number of our technological systems of production-consumption operate in what could be termed an 'open-loop' mode, that is without any effective feedback mechanisms which would restrain their growth, consumption of natural resources or production of waste. In effect these systems operate in a *'runaway mode'*, where for example, the ecological consequences (costs) of raw material extraction, production and pollution generation are not tied directly to product marketplace cost. Accelerated product consumption is not connected to market feedback mechanisms which attenuate consumption. Science and technology education has an important responsibility in helping young people understand the systemic nature of these unsustainable processes and to provide opportunities where they can collaborate on devising alternate systems.

Technicist forms of education does little to enlighten young people about the systemic nature of being or the nature by which technology shapes our perception of the world. Technologies are broadly and almost exclusively understood in terms which suggest narrow purposiveness. Other dimensions of technological practice - affective, affiliative and spiritual - are ignored.

On the other hand, single-minded purposive consciousness is celebrated and financially rewarded in many facets of western culture. We seem enthralled by what the media tell us is 'bold entrepreneurialism,' 'prescient risk-taking' and 'decisive leadership behaviour' in designing and applying technology. The social and ecological fall out, both anticipated and unanticipated, is readily and quickly dismissed as a necessary 'cost' of progress. Frank and Cook (1995) have documented the ascent of the *'winner-take-all'* society in which more and more people compete for ever fewer and larger 'prizes' in society. The fallout from hypercompetitive winner-take-all markets is ever escalating income inequity, economic waste and impoverishment of cultural life.

Developing a caring attitude when using science and technology entails accepting some humility with respect to how little we actually know about natural ecosystems and how ineffective our efforts to 'manage' them often are. Students need to develop a critical attitude toward technological triumphalism or omnipotence that informs much popular science and technology writing. Developing critical and imaginative capacities in young people through science and technology education will be essential if more sustainable lifestyles and livelihoods are to be achieved.

While the Newtonian worldview of a mechanical billiard ball universe consisting of independent atomistic building blocks is fading, we still lack habit patterns to conceptualize a vision of interrelatedness that we can live by. We stick to what we believe to be the 'tried and true' and familiar model of how the world works, we tend to overlook much of the overwhelming evidence that our mechanistic model is profoundly dysfunctional. Education has an important role in helping young people develop an alternative metaphoric consciousness concerning science and technology, one which will allow them to glimpse broader realities and embrace alternative possibilities to shaping the world. Perhaps what is most needed in technological education is a new gift of perspective and immediacy, one which acknowledges fully the complex interdependencies and interconnectedness which exist between our technological systems and the biosphere. Many forms of education have been largely concerned with what Daly (1977:8) has termed 'intermediate ends and means' (Figure 2.).

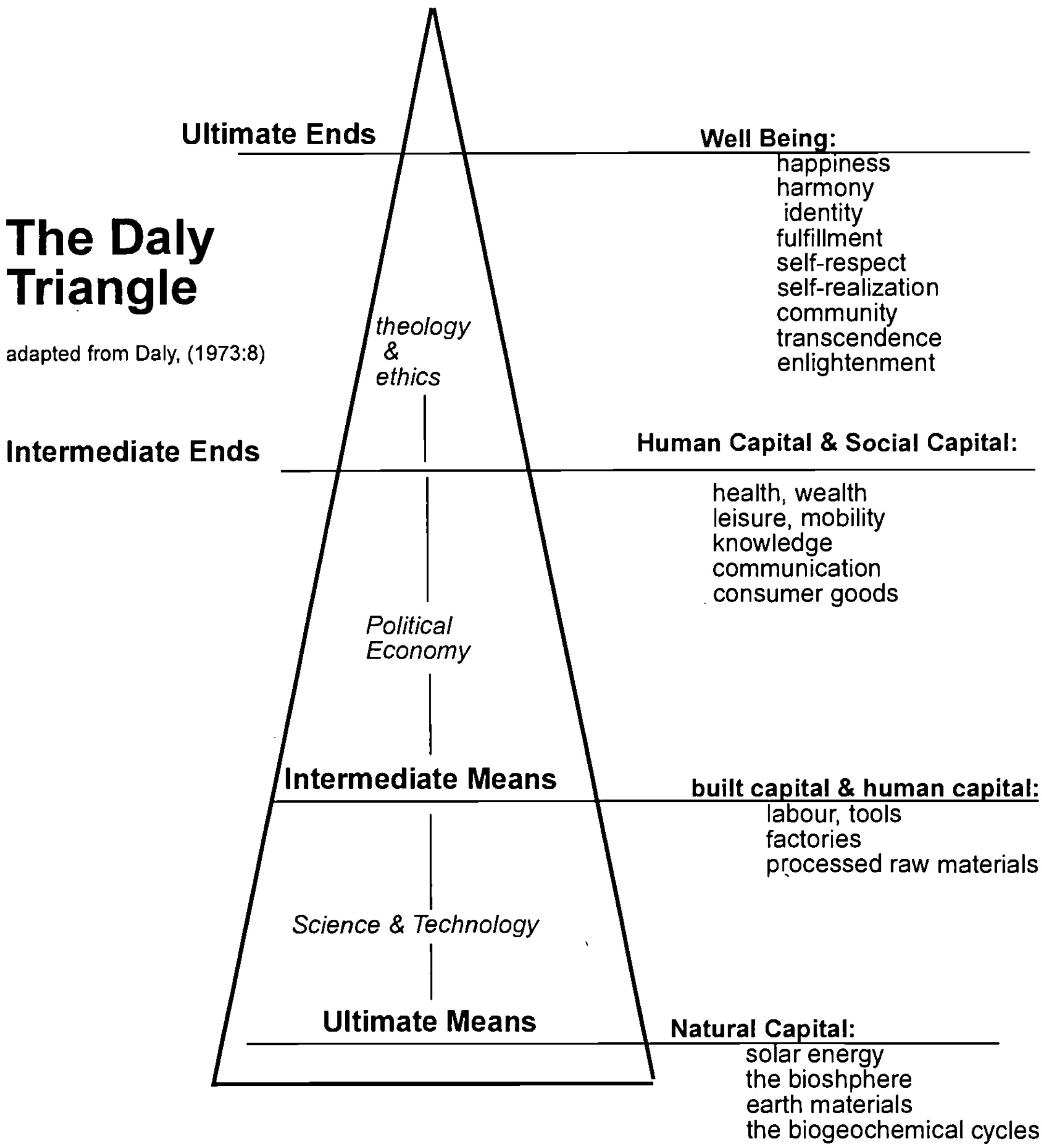



**Figure 2.**

Helping students understand and relate science, technology and technoculture to the considerations of ultimate ends (happiness, harmony, identity, fulfillment, self-respect, self realization, community, transcendence and enlightenment) and ultimate means (solar energy, biospheric productive capacity, biogeochemical cycles) as outlined in the *'Daly Triangle'* has never been a priority within instrumental forms of science and technology education. However, considerations of ultimate ends and means are inescapably bound up with the pragmatic issue of sustainability and the development of a more holistic perspective toward technology and cannot be avoided in any curriculum which is genuinely concerned with preparing students for life in the future.

**Caring in the context of Science and Technology Education**

Nel Noddings challenges educators to consider whether an 'ethic of care' infused into teaching and learning can lead us to a less violent, more caring way life. She distinguishes *'natural caring'* a form of caring which is spontaneous and based in a basic human response from *'ethical caring'* which must be consciously summoned from within. Ethical caring according to Noddings, arises from our memories of caring and being cared for and from our picture or ideal of ourselves as carers (Noddings, 1995:187). As opposed to ethical decision-making processes which are made on the basis of logico-mathematical reasoning, in an ethic of care, decisions are made in caring interactions with those involved in the interaction. At the heart of this notion is the element of relationality. Fostering an ethic of care entails helping students develop a deep appreciation that different cultures have different life-worlds and that how we engage the world deeply influences how we come to understand it. Our science and technologies to a large measure create the fundamental structures of our life-world, they are deeply embedded in almost all of our daily activities and structure the way we perceive of the world in subtle and not so subtle ways. An ethic of care embedded in science and technology education is focused on awareness of the reciprocal *'storied relationships'* which exist between us as individuals, communities and cultures that are mediated by the technological artifacts we create.

For Noddings (1994:366) our main educational aim should be: "to encourage the growth of competent, caring, loving and lovable people". Few would disagree with these broad educational aims, but we need to explore what an ethic of care might mean in the context of science and technological education. A number of reflective questions arise:

- Can we conduct science and devise technological products or systems which embody an ethic of care?
- How does science and technology influence the way we understand and care for one another and the natural world?
- How can science and technology promote and extend caring relationships between not only people but with the natural world as well?
- Can we identify and articulate the powerful stories of care where science and technology are used with honesty, compassion, moderation, and charity to improve the world in substantive ways?
- How are students perceptions of science and technology mediated by their immersion in consumer culture where both are increasingly understood as mere means to ever quickening and malleable ends, namely, fashionable, transitory disposable products and financial reward?

Care extends to the potential user or customer of the products students create in technological education. Not in the sense of legal liability, but rather the sense of care which grows out of a concern and empathy for people and the genuine and lasting value that products and services brings to their lives. The creation of products are which deceive others or provide a mere transitory benefit if any at all, are eschewed. Teachers need to introduce students to concepts such as *'extended producer responsibility'* whereby the creators of products take them at the end of their useful life for recycling and refurbishing.

We also need to ask a number of questions concerning care and social justice for unseen and unknown others involved in providing our technological goods. These include:

- How the sub-products or raw materials were obtained, what natural systems were degraded or polluted?
- How did the extraction and production of these materials impact their communities of origin?
- How were the people involved with their extraction and processing treated?
- How were the indigenous peoples involved with the region or land where these materials were produced treated?

- How will future generations be impacted when this product decays?

For Noddings (1995): "Caring is not just a warm, fuzzy feeling that makes people kind and likable. Caring implies a continuous search for competence" Competence in technological design today entails the creation of products which incorporate an ethic of environmental care throughout their lifecycle. Papanek (1995) suggests that important ethical/moral/spiritual issues are raised when designers reflect on questions like:

- Will the design significantly aid the sustainability of the environment?
- Can it make life easier for some group that has been marginalized by society?
- Can it ease pain?
- Will it help those who are poor, disenfranchised or suffering?
- Will it save energy or - better still- help to gain renewable energies?
- Can it save irreplaceable resources?

(Papanek, 1995:54)

Science and technological education are critically important to the overarching societal goal of making our lifestyles and the systems of production which support them, more sustainable. Moving towards sustainability entails preparing young people to take an active and responsible role in not only the development of science and technology, but also the public policies which shape them. If students are not engaged in participatory decision making experiences and real community contexts for problem detecting, design and testing, the nonparticipatory regime of technological decision making is left unchallenged.

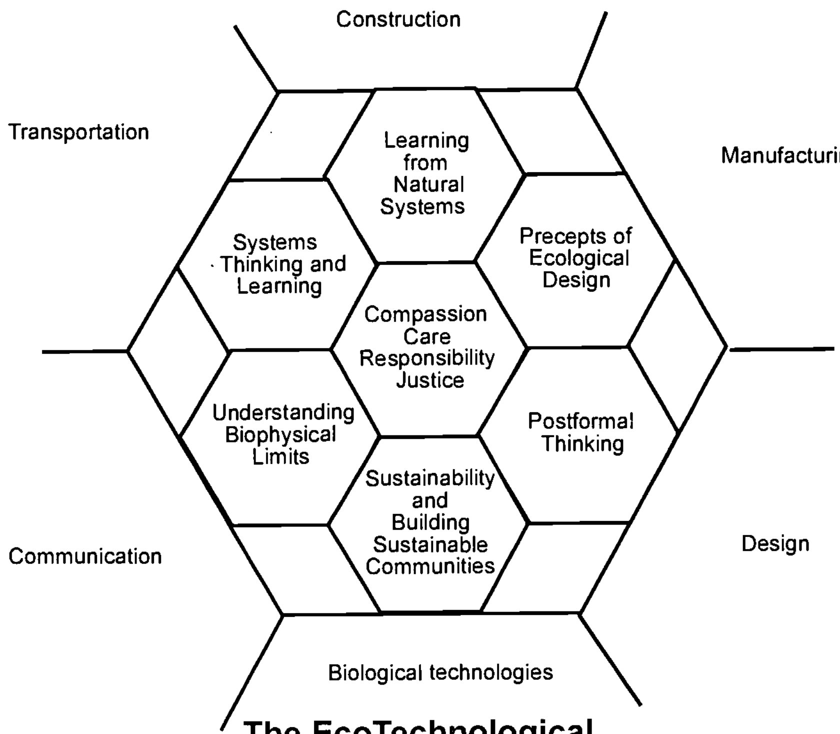
It is crucial that students immerse themselves in problem contexts and through the exploration of significant questions and problems facing individuals and communities form the basis for seeking answers through other means. Fostering *'sustainability consciousness'* entails helping students model and participate in a variety of multi-stakeholder processes (Hemmati, 2000) within science and technology education. Science and technology education must help prepare students to function in a 'turbulent environment,' one characterized by:

- uncertainty;
- inconsistent and ill-defined needs
- unclear understanding of the means, consequences or cumulative impacts of collective actions; and
- fluid participation in which multiple, partisan participants vary in the amount of resources they invest in resolving problems (Carley and Christie, 2000).

Given emerging environmental imperatives, it is crucial that educators engage students in environmentally conscious design activities such as Life-Cycle-Analysis (LCA), Design for the Environment (DfE), Design for disassembly and recyclability, Product –Stewardship and Industrial ecology ( Billatos and Basaly, 1997; UNEP-WG-SPD, 1997; Papanek,1995; McDonough, 1996; Canadian Standards Association, 1995a, 1995b). We will now turn to a holistic integrated curriculum model which encompasses care and sustainability at its core.

**Toward An Ecotechnological Model**

The main components of the ecotechnological curriculum model are shown in figure 3. It consists of a non-hierarchical open-ended hexagonal pattern of interrelated processes and components of sustainability. The honeycomb model is also an appropriate metaphor for design and engineering efficiency, the more economical the lattice, the lighter the space frame it forms, and the more efficiently it distributes weight in all directions (Hersey, 1999). Just one kg. of wax honeycomb can support 22 kg. of honey. The *ecological efficiency* of the hexagonal pattern for bees owes to the fact that the total perimeter length of the cell walls for hexagonal cells filling a given area is less than that of square or triangular cells enclosing the same area. In other words it takes less wax to make hexagonal walls (Ball, 1999). In a real honeycomb two layers of cells must be brought together, the problem becomes three dimensional and more complex. Bee engineering elegantly solved this by use of the *rhombic dodecahedra* to pack the cells tightly.




**The EcoTechnological Model**

**Figure 3.**

In a honeycomb all the angles are exactly 60 and 120 degrees, symmetry is all important. The activity inside the hive keeps the temperature at a constant 35ºC in order to keep the wax malleable. In addition to constructing the precise 120º angle, bees also measure the tilt of the cell along its axis. The cells are tilted at an angle of 13º to prevent the honey from running out. The thickness of the cell walls is machined to a tolerance of two-thousandths of a millimeter. Bees measure the resiliency or flexure of the cell walls to achieve the required elastic behaviour. Bees orient and align the honeycomb with respect to the Earth's magnetic field. This allows thousands of bees working simultaneously and in succession, sometimes working in complete darkness, to create a well ordered non-chaotic assembly (Ball, 1999). As Ball points out, there would be no way we could detect the 'presence' of this geometric principle by decoding the bee's DNA. A reductionist approach won't work; we have to learn by observing the bee as a *whole organism*. The symmetry, efficiency, elegance and precision of the comb make it a marvel of natural engineering.

The ecotechnological model is expandable, reflecting an ability to accommodate new technological and ecological knowledge as well as new patterns of social organization. It is non-hierarchical, as different components will be emphasized according to local contexts and priorities. Figures 5 and 6 illustrate how the central concepts can be expanded and built upon to reflect the construction of new understandings and knowledge. The model is expandable and open, it doesn't rely on a centralized or predominant locus of control but depends rather on a *synchrony of purpose*, further reflecting that there is no *one* pattern or path to achieving sustainability. Finding a point of dynamic balance between our use of technology and the social and ecological systems which support them is crucial, as is avoiding the systemic 'avalanche' or runaway conditions mentioned earlier. This model also reflects the notion that sustainability initiatives must grow in place, and that exotic new technologies, materials and skills are not necessarily required. What is required is a commitment to learn and adapt and to work together toward a larger purpose. This model itself may be considered a holon, in turn part of a larger whole. It is important to emphasize that as with all models or metaphors, they are: " less crutch than vaulting pole, less security than springboard for new alternatives" (Olds, 1992:69).

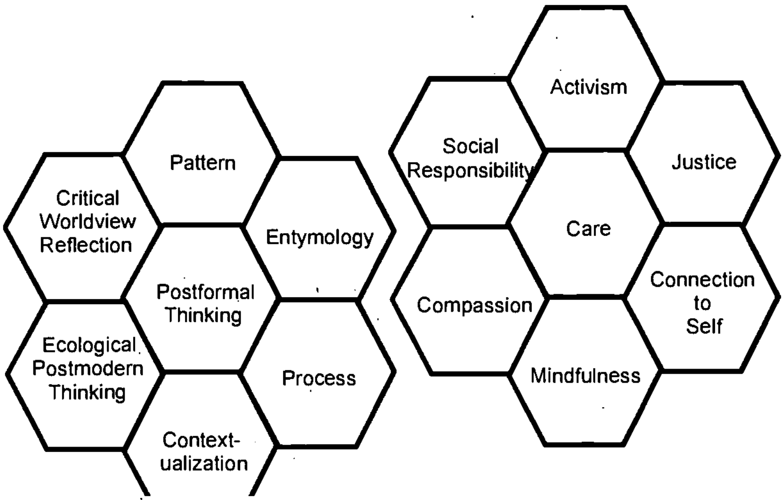



**Figure 3-6.**

**Caring and the Role of Postformal Thinking**

Post-formal thinking process involves struggling with questions of purpose and issues of human dignity, freedom, authority and social responsibility, and developing a 'critical system of meaning' which could be considered an alternative to technicist models. Its objectives are emancipatory in nature, and involve developing intelligence concerning the nature of the interrelationships between ideas, behaviours, outcomes and contexts (Kincheloe & Steinberg, 1999:171). All are essential components in developing an ethic of care. Post formal teachers are involved in an ongoing struggle to become fully aware of their own ideological inheritance through a process of what Kincheloe calls *'ideological disembedding'*. Only in becoming aware can we then become critical. Four important features of post-formal thinking are identified by Kincheloe and Steinberg are:

1. Etymology
2. Pattern
3. Process
4. Contextualization

**1. Etymology- the exploration of the forces that produce what the culture validates as knowledge;**
The terms 'epistemological entymology' and 'subjective etymology' are used to refer to the processes by which social forces are involved in shaping our understanding of what constitutes knowledge and involved in shaping our subjectivities, our identities. (Kincheloe & Steinberg, 1999). For teachers, an entymological perspective involves reconceptualizing what they 'already know' about their professional practices and the sociocultural connections between classroom practices and the broader cultural forces at work, which shape not only their own subjectivities, but also those of their students.

An exclusive focus on technical rationality often impedes our ability to ask unique questions and to detect problems which do not arise from the linear problem solving process. Technology education is primarily in the business of helping students develop the ability to formulate technological answers or solutions to human problems. However, an exclusive focus on finding 'answers' may be simultaneously : " a mechanism for avoiding questions" (Saul, 1994:25). Many of the questions and problems posed for students in technological education are predisposed to exclusively suit technological solutions. A vast array of the complex problems facing communities require changes in behaviour and values related to technological use and thus are not amenable to simple *'techno-fixes'*. As Kincheloe and Steinberg (1999) point out, pedagogies of problem solving and intelligence testing ignore the essential initial steps of questioning and problem detecting, both of which are prerequisites to creative post-formal thinking. Students need to be involved in problem solving situations which have dimensions of community learning and service, as well as the social marketing of sustainability initiatives they devise.

**2. Pattern- the understanding of the connecting patterns and relationships that undergird the lived world**
The ability to expose and explore deep patterns, hidden assumptions and tacit forces which shape our perceptions of the world is central to post-formal thinking. Kincheloe and Steinberg argue for a *'metaphoric cognition'* which is fundamental to scientific and creative thinking and involves the "fusion of previously disparate concepts in unanticipated ways". It involves understanding the physical and social worlds as 'dynamic webs of interconnected components' (Kincheloe and Steinberg, 1999:181). Metaphoric cognition recognizes that the mutual interrelationships of the components of a metaphor, not the components of the metaphor , are the most important aspects of it. (Kincheloe and Steinberg, 1999:181). Drawing on imagery and affective associations, metaphor creates 'semantic resonance', and in introducing 'a new view of the world' metaphor can play a part in changing culture by contributing to new insights and promoting social critique (Olds, 1992:24). Metaphors can help draw our attention to the similarity and connections between disciplines, events and modes of knowing, they allow us to see what Bateson calls *'the pattern which connects.'* Bateson (1999) points out that all thought relies on metaphor, on ways of noticing similarity and pattern in one situation that can be transferred to another. Most of these metaphors lie in our unconscious and so are unexamined.

New metaphors like *'dynamic equilibrium' 'interconnecting patterns', 'dances of interacting parts,' 'systems of synergy,' 'living webs,' 'symbiosis'* and 'dynamic interactions' all invoke an invitation to explore the interaction between existing conceptual relationships in the minds of learners and new experiences, new ways of being which are not prescriptive or linear in nature. Post formal thinking concentrates less on the fragmented parts of living systems and more on patterns of relationships and life as 'synchronicity'(Kincheloe & Steinberg, 1999:183).

Students need to learn that the complexities of whole sociotechnological systems must be taken into account as far as possible to avert unintended effects. This necessarily entails developing skills around systems thinking. In fact, Mitroff and Bennis argue that this one of the most important characteristics of systems thinking:

> *The ability to understand and to appreciate complexity and paradox is the quintessential essence of the new thinking.....It calls for the ability to see broad patterns that influence our world and to avoid getting caught up in irrelevant details (Mitroff and Bennis,1993:38).*

As De Rosnay (2000:5) points out, the major functions of life, the economy, the ecosystem and most complex systems are based on the same types of structures and laws. These structures are: fluid, adaptable communications networks; energy cycles; the circulation of information and materials; transactional interfaces; and regulatory loops. The behaviour of complex systems both natural, social and technological share the laws of autocatalysis (self selection), competitive exclusion, hierarchy of complexity, dynamics of evolution and natural selection (Capra, 1996).

A post-formal reconceptualization of the science and technology curriculum yields the essences contained in the relationships exhibited by sociotechnical systems, their energy requirements, their ability to meet genuine human need equitably, justly and sustainably. Students come to understand sociotechnical practices as a living *embodied process* of meaning making, a manner in which to better interconnect people, to meet genuine needs and to fashion more symbiotic, more creative and life affirming ways of living within the sustainable limits of the planet. We recontextualize life as a *'community of subjects, not a collection of objects'* (Berry, 1988).

**3. Process- the cultivation of new ways of reading the world that attempt to make sense of both ourselves and contemporary society;**
Post-formal thinking involves seeing the world as a text to be read, an interpretive process that seeks to deconstruct the meaning encoded in cultural practices, norms as well as physical reality. Post-formal thinking is an attempt to transcend 'the tyranny of common sense' and to expose the 'unconsciousness' of a culture (Kincheloe & Steinberg, 1999:185). Cultivating new ways to read the world is not a passive activity, it involves reading technological texts with the full awareness that all texts have authors or a tradition which may blind them to alternative perspectives or ways of seeing the world. In today's complex society, ill structured problems that lead to ambiguous multifaceted answers are not the exception but rather the norm (Handy, 1994). Cultivating new ways of reading the world also fosters a reluctance to accept univocal, monocultural interpretations of what

the particular means and ends for science and technology should be. A postformal understanding of process also seeks to reconnect the severed ties between logic and emotion with respect to the design and interpretation of technoculture.

These connections would involve students in exploring how particular technologies make them feel about themselves, about others and the natural world. This entails an acknowledgement that the nature of the relationships that students create with and through technologies is of vital importance in any kind of a reconstructive project that seeks to build a more sustainable human ecosystem. By engaging students in critical worldview reflection, teachers help them develop in exploring the nature of our sociotechnological norms, asking them to reflect on the roles of power, agency, authority and agenda in the social shaping of technology. A technicist view of teaching focuses on the mastering of various sets of techniques in a rule following, controlled methodological format. There is little reconceptualization of existing social relations or power relationships, all of this is.a given background over which technological systems are developed and applied.

**4. Contextualization- the appreciation that knowledge can never stand alone or be complete in and of itself**
Contextualization for the post-formal teacher involves examining 'the ecology of everything,' and awareness that the contextualization of what we know is more important than the content (Kincheloe & Steinberg, 1999:189). While technology education as a whole is one of the more contextualized learning experiences for students, it is also in many ways decontextualized from issues surrounding the interactions with ecological, sociological and political contexts. Technology is situated front and centre in the great modernist narrative of progress and growth. However, the 'real world' fallout from the subtext of this narrative - namely, the blind pursuit of economic growth, control over other humans and the planet as a whole, and an increasing alienation from others and the natural world - is left unnarrated or critiqued. An ecotechnological education emphasizes the bioregional uniqueness of 'place' and provides an all important starting point for the discussion of how important technology is in sheltering, feeding and providing our basic human needs.

Science and technology education can and should draw students into an understanding of the materiality of the world. This includes an understanding of the manner in which materials are extracted, designed, manufactured and applied to solve physical problems.

We live in economic, political and cultural webs of abstraction that are ultimately all supported by the natural world, yet connections to that physical reality are becoming ever more virtualized. The danger in our increasing and ever more exclusive life within these virtual webs of meaning is that: we will lend our lives more to consolidating, defending or bewailing the fate of these ephemeral entities than to nurturing and defending the actual places that physically sustain us (Abram, 1996:267).

For Orr (1992:151), future survival will depend as much on rediscovery as research, a rediscovery of: environmental and social justice, appropriate scale, a synchronization of 'morally solvent ends and means,' how to live well in a place and a sense of *sufficiency*. Berry offers some guidance concerning our approach to knowledge:

> *If we want to know and cannot help knowing, then let us learn as fully and accurately as we decently can. But let us at the same time abandon our superstitious beliefs about knowledge: that it is ever sufficient; that it can of itself solve problems; that it is intrinsically good; that it can be used objectively or disinterestedly (Berry quoted in Orr, 1992:152).*

## Summary

There are compelling reasons why science and technology educators need to consider incorporating an ethic of care into their curricula. Young people today are living in a world where increasing strain is being put on ecological systems by population growth, habitat loss, and increasing resource extraction. Coupled with an ever increasing disparity between rich and poor, the need for an ethic of care has never been more acute. We attend to what we care for, so if young people are to maintain a livable world for themselves and their children it is vitally important that they look outside of and beyond narrow short-term commercial imperatives for guiding the development of science and technology.

**References**

Abram, D. (1996) *The Spell of the Sensuous*. New York:Pantheon.

Ball, P. (1999) *The Self Made Tapestry*. New York:Oxford University Press.

Bateson, G. (1972) *Steps to an Ecology of Mind*. New York:Ballantine.

Billatos, S. B., & Basaly, N. A. (1997) *Green Technology and Design for the Environment*. Washington:Taylor & Francis.

Canadian Standards Association. (1994a) *User's Guide to Life Cycle Assessment: Conceptual LCA in Practice*. Toronto:Canadian Standards Association.

Capra, F. (1996) *The Web of Life*. Toronto:Anchor Books.

Daly, H. E. (1977) *Steady State Economics*. San Francisco:W. H. Freeman.

De Rosnay, J. (2000) *The Symbiotic Man*. New York:McGraw Hill.

Handy, C. (1994) *The Age of Paradox*. Boston:Harvard Business School Press.

Hawken, P. (1993) *The Ecology of Commerce, A Declaration of Sustainability*. New York:Harper Business.

Homer-Dixon, T. (2000) *The Ingenuity Gap*. Toronto: Alfred A. Knopf.

Kincheloe, J. L., & Steinberg, S. R. (1999b) "A Tentative Description of Post-Formal Thinking: The Critical Confrontation with Cognitive Theory. In *Breaking Free. the Tranformative Power of Critical Pedagogy*. Harvard Educational Review No. 27." (Eds).Leistyna, P., Woodrum, A., & Sherblom, S. A.Cambridge:Harvard Educational Review.167-195.

Noddings, N. (1995) *Philosophy of Education*. Boulder Colo.:Westview Press.

Orr, D. (1992) *Ecological Literacy: Education and the Transition to a Postmodern World*. Albany New York:State University of New York.

Papanek, V. (1995) *The Green Imperative*. London:Thames & Hudson.

Robinson, J. B., Van Bers, C., & McLeod, D. (1996) "Life in 2030 The Sustainable Society project. In *Achieving Sustainable Development*." (Eds).Dale, A., & Robinson, J. B.Vancouver:UBC Press.3-22.

Suzuki, D. (1998) *Earth Time*. Toronto:Stoddart.

UNEP. (1999) Global Environment Outlook 2000 (GEO-2000). Available Online at: http://www.unep.org Nairobi, Kenya:United Nations Environment Programme.

**Keywords:** sustainability, care, ingenuity-gap, innovation, post formal thinking

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# THERE'S AN ESSAY QUESTION ON THIS IN THE EXAM: EVALUATIVE LEARNING IN BIOETHICS.

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## Abstract

This paper discusses how evaluative learning strategies can be useful for high school students to develop self-regulation and responsibility for their own learning. An intervention unit of work on bioethics was taught in a final year Biology class in New Zealand. Students were required to use inquiry to investigate the biological, social and ethical aspects of cancer using a range of classroom activities and independent research. A constructivist approach was implemented to access prior content and procedural knowledge in various ways so that students could reflect on what they needed to know and what they needed to do. Small group work, scenarios, case studies, and videos were used as stimulus activities for getting students to clarify and analyse their values. Independent learning skills were developed through activities that promoted metacognition. These were prompted by the teacher, through self and peer assessment activities and various artefacts.

Data is presented from a sample of 16 students from the class. Three case studies are used to illustrate how the learning strategies were used differentially.

By the end of the intervention, most students knew of learning strategies that could help them learn more effectively. The findings show that those students who not only knew, but also used evaluative learning strategies to plan and monitor their work, produced essays of higher quality.

## Introduction

*Biology in the New Zealand Curriculum* (Ministry of Education, 1994, p28) includes the achievement objective for the final year of high school "investigate contemporary biological issues and make informed judgements on any social, ethical, or environmental implications". Bioethical issues are included in the curriculum to give students the opportunity to develop critical thinking skills and become more informed decision-makers about bioethical issues. Students are required to write an essay of about 500 words (worth 20% of the three-hour National University Bursary exam).

The investigative skills and attitudes required of students are clearly outlined in the curriculum document (Ministry of Education, 1994, pp. 37-47). At level 8, students are expected to ask a series of related questions of themselves, their group, and resource people, and refine these questions. Students are also expected to locate and process relevant information using a variety of sources and to evaluate the quality of information gathered and its degree of relevance.

In previous years as a teacher of Biology, I had been frustrated about the lack of students' awareness of the bioethical issues and the seeming lack of ability of many students to purposefully research information, apply their understandings and use text organisation structures to write more effective essays. Therefore, together with a teacher from an inner city school, we designed an intervention to try to address these two issues.

This paper discusses the students' knowledge and use of evaluative learning strategies, which is a small aspect of a much wider study. Because inquiry about bioethical issues encourages students to articulate, question and evaluate their personal views, this context was considered very suitable for developing reflective, planning, monitoring and evaluative aspects of learning.

## Evaluative Learning Strategies

The underlying drive of research on constructivist learning has been to develop teaching and learning procedures to maximise the effectiveness of learning for understanding. If students believe they have processes to help them to learn more effectively, they are more likely to invest effort and time to use these processes. Knowing what learning strategies to use and how and when to use them (control aspects), contributes to lifelong learning (Perkins, 1992).

The development of cognitive and metacognitive processes in formal education includes the need to extend students' awareness of their learning in general. More specifically, students need to be aware of possible learning strategies and evaluate their use of them. Evaluative processes could include: planning, strategising, identifying, monitoring, checking, questioning, reflecting, assessing and reviewing. These processes have also been implicated for the promotion of critical thinking in classrooms, by Resnick (1987).

Critical thinking in schooling has tended to be linked and applied to the consideration of content material and reasoning skills. However, its application through questioning and evaluation to the processes of learning, have been the guiding forces for developing more self-regulated learners, through incorporating metacognitive processes (Kuhn, 1999).

The classroom has not generally been a place where critical thinking has been developed and encouraged due to the content restraints of examination systems. Critical thinkers have to be able to challenge prevailing norms (Siegel, 1988) in relation to both the content and the processes of learning. It is often difficult to challenge the assumptions students bring to their work and to foster self-questioning. They frequently expect to be 'spoon-fed', to be told the facts and where and how. Some students may think a transmissive way of operating is an easy option, since it requires less effort on their part to engage in thinking.

Through critical thinking processes, students may become aware of their prior knowledge and evaluate it. Through evaluation, learners could gain a greater awareness of their own learning needs and set goals or intentions for addressing these. Ideally, they also become more aware that they have a choice in the way they tackle tasks, thus allowing them to take charge and have more control over their decisions regarding their own learning. Further, if these processes are used prior to, during and after completing tasks, it is more likely that students develop, self-directed, self-regulating learning.

More able learners seem to consciously use evaluative processes to keep themselves on task and to obtain feedback about their learning. This active monitoring, planning and deliberate, self-directed use of learning strategies to achieve a goal has been called intentional learning (Brown & Campione, 1994) and incorporates metacognitive processes.

In theory, metacognitive approaches to learning should encourage students to develop their abilities to evaluate, self-direct and self-regulate learning (Paris & Winograd, 1990). In terms of the use of metacognition for strategic development, the question is whether students employ conditional knowledge to use appropriate learning strategies. The extent of use of metacognitive processing will drive how individuals preferentially deploy strategies. Without prompting, students intuitively interpret tasks according to what they think the task demands, and for most students, apply their knowledge of strategies as best they can. However, if students are left to their own devices, their strategy choice may or may not be task appropriate. If teachers want to help students to move forward in their learning, to become more intentional, more evaluative and more self-regulating in their learning, then it is imperative that they actively encourage students to use specific strategies for particular learning situations. This can be done through the direct teaching of strategies or by incorporating them more subtly into tasks that students are required to do. The latter approach can be aided by developing 'tools' to prompt students as was the approach taken in this intervention.

## The Unit of Work

The usual class teacher continued to teach the class. A constructivist approach was used to help students reflect not only on their prior content knowledge but also on their procedural knowledge. Activities which 'tapped into' students' prior knowledge were a group brainstorm activity, group discussions and journal writing.

It was assumed that students would need instruction on how to use text conventions and how to monitor and control their inquiry and writing. Specific instruction was given for activities to help students in procedures such as planning, researching, drafting and editing their writing. The teacher acted as a facilitator by prompting students with questions and various artefacts.

Written guidelines were given to students to help them plan their research and write their essays. Most of the students planned their individual research, chose the two types of cancer they wanted to investigate and derived key words and key questions that would drive their work. They were also given notebooks to record their thinking. These were used with prompter bookmarks that had the following prompts to help them:

Something I Learned Today...
What does what I've found out today mean?
It seems important to note .....
I want to...
A question I have is....
I'm lost with....
I disagree with............... because.......
What I need to do now is........
I can't decide if......
I'm stuck on.......
I wonder...
What I need to do now is...
I'm wondering why......
One point of view is....
How...

The students were encouraged to write questions into their notebooks as a guide for their research. Student journals were collected at the end of most sessions to give feedback on progress and "feedforward" in the form of questions the students might like to consider. The teacher also went through a checklist of features of an essay. Peers using a negotiated marking schedule marked draft copies of essays. This allowed students to share ideas: what content could be included and how text could be structured. The teacher also marked the essays according to the same negotiated marking schedule.

## Research Methods

The research methodology employed for this part of the study was based on an interpretive case study approach (Merriam, 1988). Sixteen final year High School students from the same class were interviewed prior to and after the unit of work (iv). The interviews were semi-structured but open to allow them to describe how they learned. Students' journal entries (j) and essays (e) were also used to augment the interview analysis for determining the use of learning strategies. Utilising Guba and Lincoln's (1989) credibility criterion for judging the quality of the research, the extent to which the students' accounts during the pre and post unit interviews honestly portrayed their experiences was gauged through classroom observations (co) of approximately three quarters of the lessons. Detailed field notes of observations were made.

## Analysis

The data presented here concern only a small part of a broader study. Knowledge or use of a strategy was recorded if students reported it in their pre or post unit interviews or if they showed that they applied the strategy in their class work, journals or essays.

Since producing an essay was the intended product outcome of the unit of work, students were grouped into the following categories according to the quality of their essays; "Invisible Product", "Satisfactory Product" and

"Quality Product". The last two categories were further subdivided into "Multiple Satisfactory" and "Multiple Quality" to indicate students who had produced more than one essay. The students are ranked by their essay mark within each group.

Three case studies are also presented here to describe how these students used evaluative learning strategies.

### Evaluative Learning Strategies

The strategies identified below which develop evaluative processes include planning, monitoring by checking on progress, using information from peer-checking or setting priorities, asking evaluative questions and making decisions about the learning process. Although self-questioning can be a planning and a monitoring strategy, it is highlighted as a separate category specifically to illustrate the number of questions written in journals.

Table 1 shows that students who produced quality essays knew and used evaluative learning strategies. The extent to which students used planning, monitoring and self-questioning was also greater for those who produced quality essays. Planning by writing lists or paragraph headings, deciding on the logical order to write the content, reflecting on what they needed to find out or do, and general outlining strategies were more evident for students in the "Quality Product" category. As a group they also showed a greater amount of reflective thinking when self-reporting and asked more questions in their journals.

**Table 1:** Knowledge and use of evaluative learning strategies

| Group | Student | Planning | | Monitoring | | Self questioning | |
|---|---|---|---|---|---|---|---|
| | | Know | use | know | use | Know | In journal |
| Invisible Product | Daniel | 3 | | | | | 0 |
| | Tulane | | | 3 | | 3 | 0 |
| | Sally | 3 | 3 | 3 | 3 | 3 | 3 |
| | Mary | 3 | | 3 | | 3 | 4 |
| | Kay | 3 | | 3 | | 3 | 2 |
| Satisfactory Product | Mitchel | 3 | | 3 | | 3 | 2 |
| | Vincy | 3 | 3 | 3 | | 3 | 3 |
| | Awar | 3 | | 3 | 3 | 3 | 2 |
| | Samantha | 3 | 3 | 3 | 3 | 3 | 4 |
| Satisfactory Multiple | Ann | 3 | 3 | 3 | 3 | 3 | 3 |
| Quality Product | Niome | 3 | 3 | 3 | 3 | 3 | 10 |
| | Lois | 3 | 3 | 3 | 3 | 3 | 5 |
| | Charlie | 3 | 3 | 3 | 3 | 3 | 5 |
| Quality Multiple | Terri | 3 | 3 | 3 | | 3 | 4 |
| | Liz | 3 | 3 | 3 | 3 | 3 | 14 |
| | Marianne | 3 | 3 | 3 | 3 | 3 | 5 |

## Case Studies

The following section describes three case studies to illustrate how students used evaluative learning strategies.

### Mitchel

Mitchel tended to describe his learning processes in general terms. For example in the pre-unit interview he stated very broadly:

> Mitchel (iv1): I have a plan on what I am going to use on an assignment.

After the unit he explained how he discriminated between relevant and irrelevant information and organised the information into sections.

> Mitchel (iv2): I did that just jotting down everything that is relevant and working out what I needed and what I didn't and putting into sections.
> Researcher: So you organised it into sections. How did you decide what sections to have?
> Mitchel (iv2): Sort of what went with what, just depending. Like I did the breast cancer with mammograms and that comes into sort of treatment and causes.
> Researcher: So how did you plan your essay, or did you plan it?
> Mitchel (iv2): I just wrote it.

So although Mitchel knew to plan according to sections, he did not actually do this.

There was some evidence that Mitchel monitored his progress in his learning journal.

> Mitchel (j): Need more info on specific types of cancer, treatments, causes, effects. Practice essay writing. Still having problems with wording and making it flow.

Although he had identified practising writing as a useful strategy, it would not be helpful unless he also addressed getting more information and linking the ideas so that they flowed. He also stated during class after getting a draft back from the teacher that he needed to make stronger connections between his ideas.

> Researcher (co): Will you change what you've written?
> Mitchel (co): I'll need to link my ideas more.

He considered the checklist for the essay provided by the teacher was useful. Learning organisational structures was an area that Mitchel had identified as needing help with.

> Mitchel (iv2): Once he (*the teacher*) put it up on the board and we went over what had to be in there and [then] I worked out what I didn't have in there, which helped.
> Researcher (j): What else helped you write the essay?
> Mitchel (j): Learning the correct layout. What's needed in each paragraph.

One characteristic where he differed from others in the "Satisfactory Product" category was that he strategically sought feedback from the teacher. My observation notes indicate that he did this frequently when writing his pre-write paragraph and essay in class time. This indicates how he relied on others to help him to make changes. He preferred to work with others, rather than independently and set up a buddy/study arrangement with another student out of school time. Getting feedback from someone else was his way of external monitoring. He did not work in an independent way very effectively.

By the end of the unit of work, Mitchel improved his abilities to write essays, even though he did not score very highly. He lacked knowledge about text structure and organisation and therefore did not write an essay with a clear logical sequence. This lack of knowledge prevented him from achieving a good mark in the essay. Despite the efforts of the teacher to help him during class and to give him oral and written feedback on his writing, Mitchel did not integrate this information sufficiently to write a good essay. Mitchel admitted he had little prior knowledge, which is why he sought help. He also thought his essay writing capabilities had improved as a result of the unit of work.

**Charlie**

Charlie knew from previous learning experiences that when he planned he was more successful.

> Charlie (iv2): [if] You can have a plan and do exactly what you have been asked, you will definitely get high marks.

He also described how he planned his essay.

> Charlie (iv2): I can show you *(then he proceeded to write on my pad paper)*. Like in my essay, this is just the way it works out in my head, you have a flow chart, the opening and in that you introduce the question and then you have main point number one, and I think on my one it was about carcinogens. You talk about cancer and then there are two types of carcinogens and I put for example, the first type of carcinogen and then I talked about lung cancer that was my example.... and then the other question was talking about the social and ethical. I just stuffed them all [*social and ethical issues*] in one paragraph I think, and then a conclusion. So that is why I don't plan it [*on paper*], I just remember it.

His statement also suggests that he used planning to make connections between what he thought was required in tasks with what he did. In other words he evaluated what he needed to do. This is an example of when planning also becomes a monitoring strategy. Charlie also asked himself many questions which self-motivated him to find out the answers.

> Researcher (iv2): Just thinking too about the whole thing to do with cancer and ethics and social stuff, can you think of things that made you ask yourself some questions about it? Things that you haven't thought of before?
> Charlie: Yes it did. I had so many questions about cancer. I found them out as well. I found out about telemeres. I thought they were really interesting and I learnt one of my questions that I wanted to know was, if plant cells get cancer as well and I found out that they do, that it doesn't usually kill plants and I think insects can induce cancer in a plant. I though that was quite strange.

Charlie linked the information he found out about telemeres and their function in determining the life span of a cell, to the concept of immortality in his essay.

Of all the students, he had the highest number of separate entries in his learning journal (9) (as evidenced from dates or slightly different writing styles) and wrote 5 questions in his journal. He was keen to read the written feedback in response to his entries. Perhaps as a response to getting feedback on his journal entries, he became more interested in using it. Charlie also used his journal to integrate and extend his thinking about cancer to plants and the significance of telemeres in determining a person's life span.

For Charlie peer checking was the most valuable aspect that helped him to write a good essay, particularly since the essay he checked was, in his opinion, quite a good one.

Of all the students, Charlie probably had the most sophisticated knowledge of the ways he went about his learning and knew that using the strategies actually helped him. This was linked to his success in tasks where he had consciously been aware of using them previously. The focus of his planning and monitoring was to maximise the efficiency of his time. He always worked consistently well in class, and separated himself from others when he wanted to work independently. This was another example of how he applied his awareness, knowledge and use of learning strategies effectively.

**Liz**

Although Liz considered that the learning journal was not useful, of all the students she wrote the most questions in her journal (Table 1). She also answered some of her own questions in her journal and clarified some questions with the teacher.

She checked her essays to make sure the content was relevant to the essay question.

> Liz (iv2): I just read it and picked out bits that went for one of the headings of the questions. You know what your essay lacked and what to put in next time. I didn't have time to do more than one essay, but I had lots of other things to do at this time of the year. It might've been better at a different time of year.

Liz produced her second essay after this comment, perhaps after realising that there might be a benefit in writing more than one essay.

When asked what she would do differently she replied:

> Liz (iv2): I'd get everything done a lot quicker.
> Researcher: What do you think we could do to help with that?
> Liz: I've got to organise my time better. If it [the essay] was part of internal assessment it would be more motivating.

In this last comment, Liz was referring to the fact that she spent a lot of time in class talking, and not being "on task". She was also inferring that had the essay been part of the internal assessment component of the course, the external motivation for finishing the essay would have been more immediate. As it was, students finished school in mid November, sat the exam in late November and did not get their grades back until January.

Liz was aware that she needed help with structuring essays and that this was what made essay writing difficult for her. Her final marks for essay structure (essay1:10/10 and essay 2: 7/10) indicate that she developed these skills.

Her use of reflective and critical thinking processes to make decisions about what to include in her essay, helped her greatly. Of all the students, she asked the most questions in her journal, used them to help her research information and incorporated some of the ideas from these questions into her essay. She actively and intentionally sought information. The way she used monitoring strategies allowed her to identify what information she needed and what strategies she needed to improve her essay structure and its impact.

## Discussion

Although the strategies have been separated for identification in this project, this is somewhat simplistic because they interact with each other. The ways students go about using these strategies can not be tracked in a linear fashion since their use is very complex. However through the use of a range of methods (interviews, observations and student work) the strategies have been documented as given above.

Evaluative learning strategies contribute to making decisions about controlling and regulating learning processes. For example some students checked their essay structure which was prompted by an essay-writing checklist. Discriminatory strategies were also promoted by activities where students had to make decisions about what information to include, either in research notes or in essays. Journal writing was also a key activity in promoting self-questioning, not only about the content but also about procedures for learning.

Some students already knew some of the evaluative strategies. However, this was the first time that students had ever used a learning journal to ask themselves questions and monitor their learning in this way. Two students in the "Invisible Product" category did not use their journals at all. Other students only tended to write in them when they were reminded and given time at end of the lesson to do so. Despite this, many students used their journals to write plans, select information to support their ideas, apply personal organisation, consider alternatives and elaborate on ideas. Self-questioning seems to be fundamental for evaluation.

When evaluative processes are required, students firstly need to identify their learning strengths and weaknesses. Those students who could identify their learning strengths and weaknesses more specifically rather than broadly, were more likely to develop and use strategies for addressing their weaknesses (compare Mitchel and Charlie's knowledge and use of strategies). However, all students probably need guidance in identifying what they need to know. If students lack knowledge of their own learning or lack an understanding of how they come to know, they can hardly be expected to be reflective on utilising this knowledge to their own advantage by choosing or developing learning strategies (National Research Council, 1999).

It is not until students become aware that there are gaps in their knowledge, or that aspects of knowledge are uncertain that they see the need to use learning strategies to interpret and build on experiences. The uncertainty of a situation is important, for without a "right" answer or any sense of doubt about a situation, there would be no need for evaluation. The uncertainty and ambiguity inherent in clarifying, analysing and evaluating issues is precisely why evaluative learning processes are useful for learning in bioethical contexts.

Even though many students used evaluative strategies for planning, monitoring and checking their work there are still difficulties for students as listed below.

1. Students often ask questions that require little effort to answer, and that may only require factual answers. They may also ask questions related to personal interest, which is motivating and essential in considering bioethical issues, but which may obviate a focus on the scientific ideas.
2. They often have trouble finding or discriminating between relevant and irrelevant information. A lack of monitoring or not knowing the depth of what is required, accentuates this, especially if students are not accustomed to using an inquiry mode.
3. It is also possible that students may judge their understanding of the text as complete, consistent and compatible with their prior knowledge when in fact it is imprecise or inaccurate.
4. Similarly students may judge their own writing as being adequate, even though it lacks sufficient content, is not substantiated with reason nor sufficient examples.
5. A lack of initiative to monitor work or reliance on the teacher, rather than being self-starting, may be a hangover form previous learning and reflect the level of confidence students have in their own abilities.
6. Students may also have an intention to complete work or to achieve well in the examination rather than to understand the meaning. All of these factors can influence how well students evaluate and regulate their work.

An emphasis on student self-regulation means teaching and engaging students in specific strategies that offer them opportunities to make decisions and solve problems on their own, without being told what to do at all times. It means providing or prompting students to use strategies designed to help them process information more effectively. This is so that they increase their self-confidence through believing they have the "tools" to succeed (Kluwe, 1982). Through the use of learning strategies, especially evaluative ones, individuals are likely to develop more responsible roles and enhance their sense of agency (self-regulation and control over learning).

This intervention provides an example of how evaluative strategies were prompted by the teacher through oral questioning and through a range of written artefacts for checking, revising and promoting self-questioning. Students who not only knew, but also used evaluative learning strategies to plan and monitor their work, produced essays of higher quality.

**Corollary**

Examining this section of the curriculum by essay enables students to have choices about what they write and how they structure their essays. However, this mode assesses not only students' ability to identify, analyse and evaluate bioethical issues, but also their ability to transform this knowledge meaningfully into an essay structure.

Students often score low marks because of their inability to write logically and coherently. As a result of a recent review of assessment in New Zealand, this section of work will be examined as an internally assessed achievement standard, marked by teachers, in 2003. This means this section of the curriculum can be assessed by multiple modes, rather than being restricted to an essay.

## References

BROWN A. L. & Campione, J. C. (1994). Guided discovery in a community of learners. In K. McGilly (Ed.), (pp. 229-270). *Classroom Lessons: Integrating Cognitive Theory and Classroom Practice*. Cambridge, MA: MIT Press.

GUBA, E.G., & Lincoln, Y.S. (1989). *Fourth Generation Evaluation*. Newbury Park, CA.: SAGE.

KLUWE, R. H. (1982). Cognitive Knowledge and Executive Control: Metacogntion. In D. R. Griffin (Ed.). Animal Mind- Human Mind, Dahlem Konferenzen, 1982. (pp. 201-224), Berlin: Springer-Verlag.

KUHN, D. (1999). A developmental Model of Critical Thinking. *Educational Researcher* (),16-46.

MERRIAM, S. B. (1988). *Case Study Research in Education: A Qualitative Approach*. San Francisco: Jossey-Bass.

MINISTRY OF EDUCATION. (1994). *Biology in the New Zealand Curriculum*. Wellington: Learning Media.

NATIONAL RESEARCH COUNCIL (1999b). How People Learn: Brain, Mind, Experience and School.

PARIS, S. G. & Winograd, P. (1990). How metacognition can promote academic learning and instruction. In B. F. Jones & L. Idol (Eds.), *Dimensions of thinking and cognitive instruction* (pp. 15-51). Hillsdale, NJ: Lawrence Erlbaum Associates.

PERKINS, D. (1992). *Smart Schools*. New York: The Free Press.

RESNICK, L. B. (1987). *Education and Learning to Think*. Washington, DC: National Academy Press.

SIEGEL, H. (1988). Educating reason: Rationality, critical thinking and education. New York: Routledge.

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044

# BRIDGING CONTEXTS: PREPARATION TO TEACH AND EARLY FIELD EXPERIENCES

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## Abstract

Field experience has been an essential component of teacher preparation programs for many years. However, research findings illustrate a disconnection between teachers' preparation and field experiences. This paper investigates the impact of a scaffolded teaching experience – the simulation of an elementary classroom setting – on prospective teachers' understandings of teaching science as inquiry.

This study utilized a qualitative case study design (Merriam, 1998) to examine the development of prospective teachers' understanding of teaching science through inquiry as supported by and illustrated through their reflections on a controlled teaching experience within the context of an elementary science methods course (SCIED458). The purpose of SCIED458 is to help prospective teachers develop robust ideas for K-6 science teaching consistent with contemporary science education reform ideals. As part of the course, prospective teachers are required to co-plan and co-teach portions of a technology-enhanced, inquiry-based, mini-lesson to their peers. Then, the lesson is revised, based on the feedback received by peers and the instructor and is used with elementary children who visit the science methods class onsite at the university.

In particular, the research questions that guided this study are: a) What is the nature of prospective teachers' reflections on a controlled teaching experience? and b) In what ways does an inquiry experience in a simulated elementary classroom setting influence prospective teachers' understandings about teaching and learning science as inquiry? For the purpose of this study an individual was investigated within the larger case, which is the development of prospective elementary teachers' understanding of teaching science as inquiry. The main source of data was the participant's inquiry analysis paper, that required her to reflect on her experience of co-planning and co-teaching an elementary science lesson (i.e., properties of sound) to her peers and to the elementary school students. A content analysis of the participant's paper revealed that the experience had a positive impact on her views, self-confidence, and readiness to teach science through inquiry. In conclusion, the findings of this study illustrate that "practice teaching" in controlled settings can scaffold prospective elementary teachers' learning while providing them with a positive learning experience that smoothes the transition from the context of learning to teach science to the context of student-teaching.

## Introduction

Field experience is currently a fundamental component of the curriculum of teacher preparation programs (Darling-Hammond & Cobb, 1996). According to Broadbent (1998), for many student teachers, field experience is perceived as the most important and challenging component of their preparation. As cited in Broadbent (1998), during this time, prospective teachers are called upon to deal with a multitude of problems, including personal relationships within the school environment, catering to the specific needs of individual students, teaching effectively and implementing appropriate discipline strategies (McInerney & McInerney, 1994).

As cited in Maxie (2001), in the 1970s, research on field experience exposed a disconnection between teacher preparation and the practice of teaching. Studies reported negative outcomes of field experience, including changes in student teachers' attitudes (Mahan & Lacefield, 1978) and the development of bureaucratic orientations after student teaching (Hoy & Rees, 1977). By the end of the 1970s, major efforts to restructure field experiences in teacher education had been made. Such efforts, according to Maxie (2001) included the extension of time in the field (Denemark & Nutter, 1979); the modification of supervision (Griffin, 1983); and the establishment of partnerships and professional development schools, linking university teacher training programs and public schools (McIntyre, Byrd, & Foxx, 1996).

### Theoretical Underpinnings

Wideen, Mayer-Smith and Moon (1998) summarize the findings of seven studies that explored the first year of teaching. The findings of those studies are consistent and confirm the notion that the first year of teaching is a culture shock for beginning teachers, especially those who are poorly prepared for it. Two of those studies, one by Rust (1994) and the other by Hargreaves and Jacka (1995), suggest that the idealism created during the teacher preparation year may have created serious problems for these beginning teachers. What prospective teachers learn in their education classes often clashes with preconceived notions about teaching and what they see happening in schools. Similarly, Putnam and Borko (2000) state that teachers, both experienced and novice, often complain that learning experiences outside the classroom are too removed from the day to day work of teaching to have a meaningful impact.

Many prospective teachers associate early field experiences with a high level of anxiety and negative socialization. Standing in front of a classroom for the first time, many student teachers undergo a form of culture shock, which can rob them of important learning experiences (Brett & Turner, 1996). According to , and (1998), numerous recommendations have been made by many researchers in order to help ameliorate detrimental preservice stress levels (e.g.,, development of realistic expectations, workshops for cooperating teachers). An approach to supporting a smooth transition between preparating to teach and student teaching field experience is scaffolding prospective teachers' learning.

Wood, Bruner and Ross (1976), as cited in Stone (1993), introduced the term scaffolding in the context of an analysis of adult child interaction. They described scaffolding as the adult controlling those elements of the task that are initially beyond the learner's capacity, thus permitting him or her to concentrate upon and complete only those elements that are within his range of competence (p. 169).

According to Roehler and Cantlon (1997) scaffolding characterizes the social interaction among students and teachers that precedes internalization of the knowledge, skills and dispositions deemed valuable and useful for the learners (p. 9). Scaffolding builds upon Vygotsky's model for the mechanism through which social interaction facilitates cognitive development. This model resembles an apprenticeship, in which a novice works closely with an expert in joint problem solving in the zone of proximal development (Rogoff, 1990).

An example of a scaffolded teaching experience is the simulation of classroom settings which can help prospective teachers adjust in the elementary school context. As pointed out by Brett (1996), by setting up a controlled teaching experience, as well as a teaching experience in a natural setting, educators can allow prospective teachers to practice and hone teaching strategies before they become student teachers. An example of such an approach is the Science and Technology Experiences at Penn State (STEPS) where local elementary school students visit the Elementary Science Methods Course (SCIED458: Teaching Science in the Elementary School) for part of a day.

### Purpose and Guiding Questions

The main purpose of this study was to investigate the effects of a controlled teaching experience on prospective elementary teachers' readiness to teach science as inquiry.

Specifically, the research questions that guided this study were:

- What is the nature of prospective teachers' reflections on a controlled teaching experience?
- In what ways does an inquiry experience in a simulated elementary classroom setting influence prospective teachers' understandings about teaching and learning science as inquiry?

## Research Methods

**Study Design:**
This study utilized a qualitative case study design (Merriam, 1998) to examine the development of prospective teachers' understanding of teaching science through inquiry as supported by and illustrated through their reflections on a controlled teaching experience within the context of an elementary science methods course.

For the purpose of this study an individual was investigated within the larger case, which is the development of prospective elementary teachers' understanding of teaching science as inquiry. The specific case was chosen because it was believed by the researcher, who also served as the instructor of the course, that its representativeness would lead to main assertions about prospective teachers' perspectives about controlled teaching experiences. The participant was purposefully selected from a group of 32 prospective elementary teachers. As cited in Merriam (1998) the logic and power of purposeful sampling lies in selecting information-rich cases for in-depth study. Information-rich cases are those from which one can learn a great deal about issues of central importance to the purpose of the research (Patton, 1990, p. 169). In order to maintain the confidentiality of the participant, the pseudonym Ellen is used in all aspects of the study. All indications of the participant's identity are removed from the data. Ellen is a traditional prospective elementary teacher 22 years old, female and with no science-specific background.

**Context:**
SCIED458 is a required course for majors at Penn State university. The elementary science methods course is one of three in a block of courses, called the Disciplined Inquiry (DI) Block, taken the semester prior to student teaching. The other two courses deal with teaching mathematics and social studies in elementary schools. The participants of this study were enrolled in the DI Block courses and concurrently were enrolled in a three credit practicum (i.e., pre-student teaching field experience). Prospective teachers that are enrolled in the practicum are required to observe and teach a number of lessons in public schools where they spend two days of the week for 9 weeks and a whole week towards the end of the semester.

The purpose of SCIED458 is to help prospective teachers develop robust ideas for K-6 science teaching consistent with contemporary science education reform ideals. As part of the course, prospective teachers are required to co-plan and co-teach a section of a inquiry-based mini-lesson enhanced with technology. This mini-lesson is presented to their peers, then it is revised based on the feedback received by the peers and the instructor. Next, the lesson is used with elementary children who visit the science methods class onsite during STEPS (Science and Technology Experiences at Penn State). The STEPS experience provides prospective teachers with the opportunity to teach a technology-enhanced inquiry lesson in a safe and mentored environment. As Sillman, Zembal-Saul & Dana (2000) state, the purpose of the experience is to "help prospective elementary teachers learn science through technology and become proficient in its use so they can teach technology-enhanced science lessons to elementary students, first at the university and then within their field experience classrooms" (p. 43).

**Data Sources and Analysis:**
The main source of data was the participant's 'inquiry analysis paper', that required her to reflect on her experience of co-planning and co-teaching the lesson (i.e., properties of sound) to the class and to the elementary school students. More specifically, the assignment required prospective teachers to reflect on and analyze their two inquiry experiences in the spirit of thinking reflectively and metacognitively about their learning and growth as teachers. Prospective teachers were asked to compare and contrast the two inquiry experiences, to illustrate three things that they learned about themselves as teachers, about students' learning and how they, as teachers, can support it, and about teaching and learning science as inquiry. A content analysis of the participant's paper was done in order to illuminate the influence of the controlled teaching experience on her learning about teaching and learning science as inquiry.

**Findings and Interpretations**
Overall, the findings of this study provide support to the argument that controlled teaching experiences have a positive impact on prospective teachers' understandings of teaching science as inquiry.

**Reflection on both of the experiences:**
Ellen emphasized throughout her paper how beneficial the STEPS experience was. Specifically, she stated in the beginning of her paper:

> *The second inquiry experience was with the actual second grade classroom. I learned a lot about teaching science through this experience that I am thankful for!*

Furthermore, Ellen referred to the benefits of presenting the lesson to their peers before having to teach the children. She mentioned in her paper:

> *The first inquiry experience I participated in was a peer teaching situation. We taught the lesson to our peers who played the part of a second grade classroom and gave us feedback and suggestions when we were finished. I found this to be beneficial as they pointed out areas of our presentation that needed some work and adjustments. Also, by teaching the lesson once before the actual inquiry with the second grade students, I was able to catch some classroom management flops that would need to be changed.*

Ellen pointed out how valuable the experience was, emphasizing the fact that she received feedback from her peers and that she was able to deal with some management issues.

**What I learned about myself as a teacher:**
In response to the first prompt asking prospective teachers to comment on what they learned about themselves as teachers through this experience, Ellen referred to issues of classroom management, teacher's questioning skills and teacher's and students' observation skills. Specifically, regarding the role of classroom management in the success of the lesson, she stated:

> *In the context of the STEPS lesson, it was clear that classroom management played a huge role in the success of the lesson. I feel that I did many things well in terms of classroom management but there were also* aspects *I would change as I look back.*

Moreover, Ellen referred to observation skills as a required quality of both teachers and students engaged in inquiry-based investigations. In particular, she stated in her reflection statement:

> *As a result of teaching the sound lesson, I have come to value an aspect of inquiry more now than I had before. This aspect is observation. I know that observation is characteristic of a quality teacher but I do not think that I realized how important it is for students to be good observers until after my experience in the STEPS program. It became evident very quickly that inquiry in science requires students who are good observers. Students must engage in observation of materials, activities, circumstances, and events throughout all stages of scientific inquiry.*

Ellen pointed out that observation skills are very important for both teachers and students. Specifically, she mentioned that teaching science as inquiry requires students to be very good observers.

**What I learned about students' learning:**
Ellen emphasized how important it is to supports students' ownership for leaning, engaging them in activities and enhancing collaborative work. For her first claim, stating that students learn best when teachers provide them with ownership of their learning,she pointed out:

> *I believe a crucial element in helping students learn best is to provide them with ownership of their learning. When children are given responsibility of constructing their own learning, it is*

*amazing how much they really take pride in their work. When a student can say that they figured something out and can explain what that is, they are more likely to remember it because they "own" it in a sense. Inquiry is clearly a proponent of student ownership! Student ownership makes learning meaningful and authentic.*

In the above excerpt, Ellen emphasized the fact that students learn best when they develop a sense of ownership of their learning and when they are provided with the opportunities and support to construct their own learning. As inquirers, learners assume major responsibility for constructing their own knowledge and understanding (Carin & Bass, 2001). Moreover, Ellen noted that children learn best when they engage in activities:

*Students learn best when they are actively engaged in meaningful learning activities. My group used a guitar to present the idea that there are variables that cause different pitches of sound. The activity we implemented served as an excellent tool to get each student in the class engaged and interested because it was hands-on and it made noise! The fact that they were able to see and hear the concepts they were learning in action made the task meaningful and promoted understanding and comprehension. Instead of simply reading about the concepts related to pitch from a textbook, the students were experiencing them in the physical sense.*

Engaging children in physical activities was something that Ellen paid attention to throughout her paper. In this abstract she explained why engaging children in physical activities supports their learning. She referred to the activity that her group did (i.e., played the guitar and then asked the students to create their own guitars using shoeboxes and rubber bands in order to explore how tension affects sound) and described how the students learned from it because they experienced the physical sense of the concepts of sound rather than merely reading about it. The last thing that Ellen noted in this section of her paper is collaborative work. In particular, she noted:

*Students' learning is enhanced through collaborative group work. When students work together in groups they automatically have one thing in common.that is, the goal. However, I believe the aspect, of any group, that supports learning is the diversity that each member of the group brings to the table. When working in a group, students are exposed to the methods and processes used by other students. These may be strategies that students adopt as their own or ones they decide to discard depending on whether or not they work for them.*

Ellen described the value of collaboration claiming that when students work together they benefit from the interaction with others with different background knowledge and experiences.

**What I learned about teaching and learning science as inquiry:**

For the last section of the assignment, which asking prospective teachers to discuss what they learned about teaching and learning science as inquiry through the STEPS experience, Ellen pointed out that inquiry promotes higher level thinking, that it is an effective method of teaching, and that it heightens motivation. In specific, she mentioned her claim that inquiry promotes higher level thinking:

*I believe that the high-level thinking occurs within the inquiry framework because inquiry's aim is to get student's asking questions (engagement), exploring those questions on their own initiative, making what they find their own (explaining), and applying or extending concepts to different, yet appropriate, situations. I believe that higher level thinking brings students to a comprehension of the concept(s) behind information, data, problems, etc. Children engaged in inquiry learn the how's and why's behind their subject of study.*

In the above quote, Ellen stressed how inquiry supports high level thinking because the central element of inquiry is students' asking questions, engaging in activities that will help them answer their questions and apply their findings to a different context. Moreover, Ellen referred to teaching as inquiry as an effective method to teach science. She stated:

> *I believe that inquiry is effective because it helps children learn to think for themselves. It teaches them that they are capable of coming to their own conclusions based on evidence and past experience. Engagement is a very important aspect of effective inquiry as this is the stage where students begin to ask questions based on their interests about the topic. I also see the exploration stage of inquiry as an extremely critical stage. This is where students step out on their own and begin to take risks. They start to find answers to those burning questions they began with and realize that they have even more questions than they started with! These first stages contribute to the effectiveness of the inquiry model because interest and brings about the motivation to move forward with discovery.*

Ellen noted the value of inquiry in support of students' learning. In particular, she emphasized the stage of engagement and the stage of exploration because, as she mentioned, during these two stages the students begin to find answers to their questions and this results in motivating the students. Lastly, Ellen claimed that inquiry heightens motivation. She stated:

> *When students are engaged in activities they enjoy, their motivation to learn then, is heightened. They are naturally motivated to grow in their understanding of a topic or subject as opposed to memorizing information they care little about. Inquiry allows students the freedom to ask their own questions and provides a plethora of choices for children. With the ability to choose, students prove themselves imaginative, creative, and enthusiastic.*

In the above statement Ellen pointed out how inquiry allows students the freedom to form their own questions and hence get motivated to learn. Also, she referred to the positive impact that engagement in activities (as part of the inquiry based instruction) has on the students' motivation.

## Discussion

The discussion is structured around the two research questions that guided this study: a) What is the nature of prospective teachers' reflections on a controlled teaching experience; and b) In what ways does an inquiry experience in a simulated elementary classroom setting influence prospective teachers' understandings about teaching and learning science as inquiry?

**a) What is the nature of prospective teachers' reflections on a controlled teaching experience?**
*POSITIVE IMPACT ON PROSPECTIVE TEACHERS GROWTH:*
Throughout her paper Ellen emphasized how beneficial the experience was in regard to gaining an understanding of how theory applies to practice associated with teaching and learning science as inquiry. In addition she stressed the fact that she gained confidence in herself as a teacher because she was provided with the opportunity to teach the lesson to her peers before teaching it to the elementary school students, and received feedback in order to improve the activities she designed and her teaching actions.

Similar findings have been illustrated by Brett (1996) who investigated controlled and natural teaching settings. Specifically, he stated that preservice teachers indicated the usefulness of the peer teaching settings, agreeing that the opportunity to practice their teaching skills in front of peers and analyze their teaching for improvement helped prepare them to teach more effective in the natural setting.

**b) In what ways does an inquiry experience in a simulated elementary classroom setting influence prospective teachers' understandings about teaching and learning science as inquiry?**
*TEACHING SCIENCE AS INQUIRY:*
As stated earlier, Ellen noted that inquiry is an effective method of teaching because its central aspiration is having students forming their own question, which motivates the students to engage in activities and explore their own questions. The value of students' forming their own question has been emphasized through current

science education reforms stating that, "Inquiry into authentic questions generated from students' experiences is the central strategy for teaching science" (NRC, 1996, pp. 32-33).

This finding is important because it reveals that the participant's developing understandings about teaching science as inquiry are consistent with current reforms in science education calling for inquiry as the main approach to teaching science.

*PHYSICAL ENGAGEMENT IN ACTIVITIES:*
Ellen noted the value of the physical engagement of students in activities in many sections of her paper. According to Prawat (1992), this is firmed with a set of beliefs about teaching and learning, termed 'naïve constructivism'. As Prawat (1992) stated, beginning teachers have the notion that student interest and involvement (i.e., in 'hands-on activities') constitutes both a necessary and sufficient condition for worthwhile learning. However, this is just as problematic from a constructivist perspective: the tendency to equate activity with learning (Prawat, 1992). Gustafson and Rowell (1995) confirmed this in their exploration of prospective elementary teachers' conceptions of science teaching and learning. As the researchers reported, nearly 70% of the responses connected hands-on activities with how children learn science. This was characterized as a tendency of the prospective teachers to view learning as a situation in which children use process skills during hands-on activities to gain information about some science concept.

*COLLABORATIVE WORK:*
An issue that Ellen highlighted was the one of collaboration. In particular, she pointed out that a feature of an inquiry-based approach is supporting collaboration among students of different skills and abilities. This way, students can interact, socialize, learn from each other and construct their own knowledge.

The creation of a collaborative classroom is believed to result in better motivated, and presumably more successful students (Kitchen & McDougall, 1999). As Harasim, Hiltz, Teles and Turoff (1995) pointed out, selecting appropriate activities and assessment strategies that support the collaborative classroom is essential to the formation of a successful environment for collaboration.

*CLASSROOM MANAGEMENT:*
Classroom management concerns were revealed through Ellen's reflection on her experience with teaching science as inquiry. Specifically, she pointed out the significant role that classroom management plays in an inquiry-based approach to teaching science. Research findings provide support to the notion that prospective teachers are mostly concerned with how to deal with discipline problems during their field experiences (Avraamidou & Crawford, 2001).

## Conclusions

Improving the quality of teacher education programs and developing bridges between coursework and field experiences requires new approaches drawn from situative perspectives on cognition – that knowing and learning are situated in physical and social contexts (Putnam & Borko, 2000). Such an approach may include scaffolding prospective teachers' learning by exposing them to controlled teaching experiences that engage them in reflective and metacognitive activities about their own and their peers' learning while concurrently influencing their self-efficacy and growth as teachers.

The findings of this study illustrate that practice teaching in controlled settings can scaffold prospective elementary teachers' learning while providing them with a positive learning experience that smoothes the transition from the context of learning to teach science to the context of student-teaching . Investigating prospective teachers' perspectives about their experiences in their methods courses could provide more in-depth information about positive science learning experiences upon which they might build in learning to teach (Van Zee & Roberts, 2001).

## References

Avraamidou, L., & Crawford., B. (2001). Elementary prospective teachers' use of an online communicative tool: Implication for the use of technology in science teaching preparation. Paper presented at the Association for the Education of Teachers in Science national conference, Costa Mesa, CA.

Brett, E., & Turner, E. (1996). Preservice clinical experiences: Using controlled and natural settings for practice. Journal of Physical Education, Recreation and Dance, 67(4), 62-67.

Broadbent, C. (1998). Preservice students' perceptions and level of satisfaction with their field experiences. Asia-Pacific Journal of Teacher Education, 26(1), 27-37.

Carin, A. A., & Bass, J. E. (2001). Methods for Teaching Science as Inquiry (8th ed.). Upper Saddle Rive, NJ: Merrill/Prentice Hall.

Darling-Hammond, L., & Cobb, V. L. (1996). The changing context of teacher education. In F. Murray (Ed.), The teacher educator's handbook. Building a knowledge base for the preparation of teachers. San Fransisco, CA: Jossey-Bass Publishers.

Denemark, G., & Nutter, N. (1979). The case of extended programs of initial teacher preparation. Paper presented to the Forum of Educational Organizational Leaders.

Griffin, G. A. (1983). Clinical Preservice Teacher Education: Final Report of a Descriptive Study. Austin, TX.: Research and Development Center for Teacher Education, University of Texas.

Gustafson, J. B., & Rowell, P. M. (1995). Elementary preservice teachers: constructing conceptions about learning science, teaching science and the nature of science. International Journal of Science Education, 17(5), 589-605.

Harasim, L., Hiltz, S., Teles, L., & Turoff, M. (1995). Learning Networks. Cambridge, MA: MIT Press.

Hargreaves, A., & Jacka, N. (1995). Induction or seduction? Postmodern patterns of preparing to teach. The Peabody Journal of Education, 70(3), 41-63.

Hoy, W. E., & Ress, R. (1977). The bureaucratic socialization of student teachers. Journal of Teacher Education, 23-25.

Kitchen, D., & McDougall, D. (1999). Collaborative Learning on the Internet. Journal of Educational Technology Systems, 27(3), 245-258.

Mahan, J. M., & Lacefield, W. E. (1978). Educational attitude changes during year-long student teaching. Journal of Experimental Education, 46(41-55).

Maxie, A. (2001). Developing early field experiences in a blended teacher education program: From policy to practice. Teacher Education Quarterly, 28(1), 115-128.

McIntyre, J. D., Byrd, D. M., & Foxx, S. M. (1996). Field and laboratory experiences. In J. Sikula (Ed.), Handbook of research on teacher education (Second ed.). New York: Simon & Schuster Macmillan.

Merriam, S. B. (1998). Case Study Research in Education: A qualitative approach. San Fransisco, CA: Jossey-Bass.

National Research Council. (1996). National Science Education Standards. Washington, DC: National Academy Press.

Patton, M. Q. (1990). Qualitative Evaluation Methods. California: Sages.

Prawat, S. R. (1992). Teachers' Beliefs about Teaching and Learning: A Constructivist Perspective. American Journal of Education, 354-392.

Putnam, T. R., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning. Educational Researcher, 29(1), 4-15.

Roehler, L. R., & Cantlon, D. J. (1997). Scaffolding: A powerful took in social constructivist classrooms. In K. Hogan & M. Pressley (Eds.), Scaffolding Student Learning: Instructional Approached and Issues (pp. 6-42). Cambridge, MA: Brookline Books.

Rogoff, B. (1990). Apprenticeship in thinking: Cognitive development in social context: Oxford University Press.

Rust, F. O. (1994). The first year of teaching: It's not what they expected. Teaching and Teacher Education, 10(2), 205-217.

Sillman, K., Zembal-Saul, C., & Dana, T. (2000). STEPS into Learning. Science and Children, 38(3), 42-45.

Stone, C. A. (1993). What is missing in the metaphor of scaffolding? In E. A. Forman, N. Minick, and C. A. Stone (Eds.), Contexts for Learning: Sociocultural Dynamics in Children's Development (pp. 169-183). Oxford: Oxford University Press.

Van Zee, E. H., & Roberts, D. (2001). Using pedagogical inquiries as a basis for learning to teach: Prospective teachers' reflections upon positive science learning experiences. Science Teacher Education, 733-757.

Wadlington, E., Slaton, E., & Partridge, E. (1998). Alleviating stress in pre-service teachers during field experiences. Education, 119(2), 335-348.

Wideen, M., Mayer-Smith, J., & Moon, B. (1998). A critical analysis of the research on learning to teach: Making the case for an ecological perspective on inquiry. Review of Educational Research, 68(2), 130 -178.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. Journal of Child Psychology and Psychiatry, 17, 89 100.

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045

# TRAINEE TEACHERS, ENVRIONMENTAL THEMES AND NATURE OF SCIENCE

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**Abstract.**

Teaching two subjects in a Biology Teacher's Course — The Practice of Science Teaching and The Practice of Biology Teaching — since 1996, I have tried analysing, in general, the science and biology teaching activities related to both ecological and environmental themes carried out by trainee science and biology teachers when they are invited to consider the production of scientific knowledge. In this attempt, I am trying to identify the possibilities and constraints in the process of supporting these teachers trainees in planning lessons, preparing resources and carrying out ecological and environmental teaching activities in schools.

The data and results that I present in this paper are part of these wider attempts and were collected in the initial phase of this research. In 1996 and 1997, at the beginning of our teaching activities in The Practice of Science Teaching we asked students to answer three questions related to their ideas about science, the scientific method and the relationship between science, technology and the problems that we have in our society.

The different positions claimed by future teachers and their contradictory point of views about science can be explored as rich material for discussions about science teaching, environmental themes and the nature of science.

## Introduction

Promoting an "adequate comprehension of the nature of science" or a "comprehension of science as a way to knowledge" has been one of the historical aims of science teaching (Lederman, 1992; Solomon et al, 1992). The work and research that I have carried out over the last decade has called my attention to the importance of this matter in environmental education proposals.

For almost a century, teachers have been called on to give up the usual practice of stressing factual aspects or listing meaningless content, and instead to work in classroom on the process of scientific investigation and aspects related to applications of science. The literature on this subject is extensive, and Lederman's above-mentioned article gives an excellent review of research carried out in this area up to 1992. A series of other papers stress the need to incorporate this theme into science teaching activities and gives feasible ways of doing so. In addition, special attention should be paid to the inclusion of this viewpoint in various curricular proposals at the national and international level.

What are the main arguments that we can find in the literature supporting these proposals? We point out the following arguments:

- An adequate understanding of the nature of science is a necessary component of scientific literacy. Aspects of the nature of science and its application would be an essential element of any programme which aims to promote improved public understanding of science.
- An adequate understanding of the nature of science is important in facilitating the learning of science content.

Nevertheless, to implement these proposals, or to change the tradition of stressing factual aspects and emphasizing content, is not easy; and recommendations from specialists in science education and researchers have not been reflected in practice. Science is seen, generally speaking, as a body of knowledge and a result of the objective, neutral application of the scientific method (King, 1991).

Among the different reasons for this fact, I think that we can point out two aspects that play important roles in this process:

To teach about the nature and application of science is to teach about the philosophical and epistemological dimensions of science. For those who had their academic experiences in natural science it is not easy to deal with these matters. Besides this, when we talk about philosophical or epistemological questions we have a broad range of positions. We can say that nowadays, we have a considerable consensus about the content domains in science education. It is easier to teach about content than to try to answer questions like "What is science?" or "How can we explain scientific methods?" or even try to answer whether we actually have any method of producing scientific knowledge. We do not have a single unique answer to these questions. In contrast, we have different positions, use different arguments and offer several answers.

Some research data show that the simple fact of stimulating science teaching activities related to the nature of science does not assure a well founded classroom activity, from a philosophical point of view. Nor does it necessarily develop pupils' knowledge about science. There is always the danger of teachers interpreting "epistemological development" as a synonym for persuading pupils to believe in the epistemological premises that the teachers themselves believe (Alters, 1997). Sometimes when teachers teach about "scientific method", for example, we have in the classroom much more of a caricature about what science is.

On the one side, we have these difficulties; on the other side, we have not developed efficient mechanisms to prepare teachers for these issues. In general terms, and in different countries, we encounter a scenario of natural science teachers unprepared to embody in their classroom activity aspects on the process of scientific knowledge production.

The attempt to synthesize considerations raised by different authors on the concepts and postures of teachers regarding science has lead us to the following scenario:

- Science teachers have a very rigid view of scientific method, seeing it as precise, unfailing, dogmatic and as a linear sequence of steps. Generally, their view of science is elitist, individualist and socially neutral (Gil - Perez, 1996);
- To science teachers scientific knowledge exists in the world or in the teacher's mind and the pupils must receive it or rediscover it; thus, science is not perceived as a human invention but as a process of discovering knowledge already existent or present in nature (Abell and Smith, 1994);
- Their comprehension regarding the nature of science - its objectives, the processes developed by scientists in building it, its characteristics and social role - is very far from the interpretations of contemporary philosophers (Thomaz et alli, 1996).

Thus, the different studies made in this area point to the need for wide-reaching changes in the proposals for the initial qualification of teachers. The possibility of altering the teachers' work unavoidably leads to new proposals for training and qualifying them. Although some experiences have shown that the development of undergraduate courses for future fundamental school teachers does not always bring positive results in changing the minds of these teachers on the nature of science (Gustafson and Rowell, 1995), Lederman (1992) indicates that, in a general way, attempts to broaden teachers' conceptions have had quite positive result when actions oriented to this purpose are carried out.

Some considerations by researchers in this area provide a starting point for reflections on reformulating and preparing proposals for initially qualifying teachers (Carvalho, 1989, 2001).

### Objectives and Research Procedures

As a science teacher trainer, I am interested in exploring this traditional and historical correlation between science teaching, environmental themes and the nature of science in programme of science teacher education.

Teaching two subjects in a Biology Teacher's Course, that is, The Practice of Science Teaching and The Practice of Biology Teaching, I have tried analysing in general, since 1996, science and biology teaching activities related to ecology and environmental themes, carried out by trainee teachers (TTs) when they are invited to consider the production of scientific knowledge. In this attempt, I am trying to identify possibilities and constraints in the process of supporting these training teachers in planning lessons, preparing resources and carrying out of these activities in schools. I collected the data for this research when I was teaching these subjects in the Biology Teacher Course. In these subjects besides discussing theoretical aspects of science and biology teaching, I have the responsibility for supporting these trainee teachers in their science lessons. I tried to record these activities systematically, and different recording tools, techniques or procedures were used, including written answers to questions, notes made by teacher, video recordings, teaching plans elaborated by trainee teachers, pedagogical materials prepared by them, reports of group work, reports of science and biology teaching and interviews. This process of data collecting could be seen as being composed of three different phases, which we may call: initial phase, intermediary phase and final phase.

The data and results that I would like to present in this paper are part of these wider attempts and were collected in the initial phase of this research. In 1996 and 1997, at the beginning of our teaching activities in The Practice of Science Teaching, I asked the students to answer three questions related to their ideas about science, the scientific method and the relationship between science, technology and the problems that we have in our society. The two questions proposed were:

1. What are the fundamental problems that our society confronts at the end of this century? Do you see any relation between Science and Technology and these problems? Justify your answer.
2. How do you define Science and what do you understand by scientific method?

These questions were not proposed with the intention to carry out a deep study concerning the trainee teacher's epistemological conceptions or views about science. The objective in this paper is to identify some conceptions related to science, and the relationship between the developments of science, technology and environmental themes, in a group of trainee science teachers when they are starting their science teaching training and, furthermore, to discuss some implications for science teaching and science teacher education.

## Results and Discussions

When we asked trainee teachers (TTs) to point out fundamental problems that our society confronts at present, the majority of TTs (76%) stressed in their answers different aspects related to social problems. Apart from the social issues specified in table 1 (hunger, misery, unemployment, violence and criminality) other TTs mentioned in their answers problems related to human demography, housing, exclusion and social inequality, drugs, infancy problems and adolescent pregnancy. One future teacher referred to the lack of the socialisation of scientific knowledge.

Half of the TTs answering this question referred to educational problems, pointing out the lack of basic knowledge and literacy, and problems related to educational systems and politics.

Turning to environmental problems, 30% of TTs made explicit reference in their answers to issues related to the environmental problems. Some of these TTs referred to environmental problems in general, without specific examples or situations, but some of them gave specific examples such as green house effects, ozone depletion, deforestation, incorrect use of mineral resources, nuclear and hydroelectric energy, contamination of water sources, pollution, extinction of species and waste. Additionally a significant number of TTs mentioned problems related to economy and health. We can observe from table 1 that only a few TTs mentioned in their answers problems related to the political and ethical level of human life.

In this same question, we asked TTs to record their views about the relationship between scientific and technological advances and the problems that our society confronts nowadays. These answers were classified in four different groups:

- Group 1 – stressed positive aspects of science and technology.
- Group 2 – stressed negative aspects of science and technology.
- Group 3 – stressed both positive and negative aspects of science and technology.
- Group 4 – did not specify clearly positive or negative impacts of science and technology, although they had admitted the relationship between science and technology and contemporary problems.

Overall, all TTs who answered this question admitted clearly some kind of relation between scientific and technological advancements and the problems which confront contemporary society.

Almost half of TTs' answers (42%) were classified in group 4, and 22% of TTs made explicit one view that we could name as realistic, regarding scientific and technological advancements – these TTs stressed in their answers both positive and negative impacts (Group 3).

A lower number of TTs' answers was classified as either optimistic or pessimistic views of science. In this kind of answer TTs stressed positive or negative aspects of science and technology (Group 01 and 02). Table 2 summarises these data, identifying the groups in which each TT answer was classified and showing the number of answers classified in each group.

When stressing positive impacts of scientific and technological advances, TTs emphasised the possibility that science and technology are able to solve various problems, or at least to help to solve or to deal with these problems. One TT mentioned the resources developed by science and technology in order to control environmental problems. It is interesting to note that some of these TTs pointed out factors that limit these different possibilities of science and technology, and in this case they stressed the limits imposed by educational levels and economical problems.

On the other hand, some TTs who made explicit only negative aspects of science and technology (unemployment, environmental problems and poverty), added comments pointing out factors that contributed to determine or cause negative impacts. Among these, they referred to the educational level, the economical system in general, the different access to scientific and technological goods of different social groups and the values system of our society

Some of these TTs (10; 20%) trying to record their views about the relationship between science and technology and the problems confronted by society, stressed both positive and negative impacts of science and technology, and thus came closer to what we named as a realistic view about these human activities. We can see from these data that the possibility of solving problems, the advances in knowledge, and examples of improvements and financial profits were positive aspects stressed. Among negative aspects, the TTs in this group mentioned the possibility of causing problems, or the limits of science and technology in solving these problems, and the relationship between scientific and technological development and unemployment. Besides pointing out both positive and negative aspects, 06 out of 10 TTs in this group added some comments about the relationship between different social groups and access to technological goods.

Furthermore, it is interesting to observe that a significant number of TTs, although admitting relationships between science, technology and society's problems, did not specify clearly the positive or negative impacts of these activities. The majority of these TTs stressed the effects of economic factors on the development of or access to science and technology. The complex interaction between educational level, propagation of information and technological means of communication was also present in some of the TTs' comments. Additionally, we can see references to the relationship between scientific and technological advances and unemployment, political factors, the indiscriminate use of science and technology, and the necessity for considering scientific and technological advances and their short and long term and consequences.

The last question presented to TTs in this first phase of data collection asked them directly how they defined science and how they understood scientific method.

Analysing the TTs' answers, in which they defined science, it was possible to identify clearly two categories: firstly, answers in which the TTs recognised science as a process and secondly, answers in which science is seen as a product.

The group of TTs who characterised science as a process can be also subdivided in two other groups. In the first subgroup of answers we can identify that a significant number of TTs relate this process to the word "study".

Among these TTs, only 03 associated this study with some aspect of the scientific method. It was more common to make general comments about this study, and we could find in TTs' answers expressions such as "varied study", "study to produce knowledge" or "to explain different matters in human science and exact science". In some of these answers, TTs specified that they were referring to studies linked to natural things or phenomena, or linked to applied studies such as hygiene care, health prevention, environmental issues, or social issues. Some TTs made explicit that these studies should have included aspects of human life.

In the another subgroup we have answers that characterised science as a process. Different aspects are pointed out by TTs, some of them stressing what we could name as a coherent or realistic view about this human enterprise. Some TTs related science to research, to investigation or to a process that occurs through research or a process of discovering. Other TTs considered science as a way of knowledge or as a way to produce knowledge and some of them put emphasis on the process of searching for understanding. In these cases, searching or looking for understanding of social and cultural reality and/or natural law and phenomena was mentioned. It is interesting to observe that two TTs referred to science as a social or human activity and part of social culture. Other answers characterised science as attempts to explain things in the world and to create methods of specific analysis, or still as a process of discussion, and raised hypotheses related to environmental, social or political problems presenting or suggesting solutions for these problems.

Turning to the second group of answers on views of science, some TTs made explicit ideas that defined science as a product, making explicit the view in which science is "human knowledge already produced". The majority of these students made only general references to this knowledge, but two specified a "group of theories that are accepted nowadays" or "specific matters such as biology and math". Another subgroup restricted their views about science as "knowledge produced through specific ways". In these cases, words such as "experiences", "observations", "methods", "readings" and "reflecting" were stressed.

When they were asked to express their understanding about the scientific method, we could observe that the majority of TTs (26; 52%) stressed some elements or procedures related to the process of production of scientific knowledge. From table 3 we could identify 3 TTs ((1), (13); (30)) who, although they presented very general answers, held a sort of realistic view about scientific method. Despite the fact that all the other answers classified in this group recognise scientific method as a process linked to the production of scientific knowledge, we have also to recognise that these answers either stressed particular aspects of this process or assumed certain meanings which are questioned nowadays. Therefore, although we could identify some merit in these answers, they show some elements of bias in the TTs' views about science.

Nevertheless, it is necessary to point out that a significant number of TTs (20; 40%) stressed procedures or aspects not directly related to the process of production of scientific knowledge. We can see that TTs associated scientific method mainly with "ways to apply science", "techniques to prove science". Two of these TTs related this process to the process of science teaching. Thereby, we can say, without a doubt, that these answers reveal a naïve conception about scientific knowledge.

**Main aspects raised from the data:**
**implications for science teaching and science teacher education.**

As a whole, how can these data be interpreted? In the context of other studies, and of the literature related to teachers' knowledge about different aspects of the nature of science, what do these data mean?

Other authors have stressed findings on teachers' views of science in which science is seen, generally speaking, as a body of knowledge and a result of the objective, neutral application of the scientific method. Usually scientific method is seen as a linear sequence of steps; an exclusively analytical or merely accumulative outlook; an elitist, individualist and socially neutral activity (King, 1991; Gil-Perez, 1996). Besides this, some authors have insisted that teachers' comprehensions regarding the nature of science – its objectives, the process developed by scientists in building it, its characteristics and social role – are still very far from the interpretations currently defended by contemporary philosophers (Thomaz et al, 1996)

In this context we can say that the data collected in this research confirm that most TTs' views are very far from the philosophical interpretations that contemporary philosophers accept nowadays. Nevertheless, it is necessary to recognise some coherent elements and "realistic" observations about science and about the relationship between science, technology and the societies' problems in the TTs answers.

Taking into account the TTs' answers as a whole, it would be useful to bear in mind Koulaidis and Ogborn's recommendation (1989). These authors pointed out that we should always be prepared to find amongst natural science teachers much more complex conceptions on science than that normally indicated and usually called naïve inductivism. The data collected in this research reinforce the idea expressed by these authors that this model, even if it explains in part the teachers' position, is not sufficient to explore the diversity of conceptions found among science teachers. Other authors also support this idea.

Rather than finding rigid categories to classify answers to complex issues, it seems to me more appropriate to choose a scheme of analysing in which degrees of legitimacy and contradiction in teachers' answers could be considered. As an example, we can mention the scoring procedure used by Rubba and Harkness (1993) to analyse teachers' answers to a multiple choice instrument entitled "Teachers' Belief about Science – Technology – Society (TBA – STS)". Three scoring categories wer used to classify the answers:

- realistic – the choice expresses an appropriate view about the nature of science, technology and the interactions of these within society;
- has merit – while not realistic, the choice expresses a number of legitimate points about the nature of science, technology and the interactions of these within society;
- naïve – the choice expresses a view about the nature of science, technology and the interactions of these within society that is inappropriate or not legitimate.

Although I did not use these three scoring categories in a systematic way in order to analyse the data collected here, I can say that a small number of the TT's answers, in this initial phase, can be considered to be "realistic", and the majority of answers can be classified as having "merit" and "naïve."

It is necessary to encourage future teachers to think and to discuss the relationships between science, technology and environmental themes. Although 15 trainee teachers referred to environmental problems when they were invited to mention problems that our society confronts nowadays, the fact that only one made explicit the relationship between these problems and the development of science and technology might mean that this group was not concerned with these aspects.

In addition to these comments, the most important point to record regards the variety of aspects raised by TTs' answers. The different positions made explicit, and the contradictory point of views expressed in their answers, as a whole might be seen as rich teaching material. It could serve as the basis for discussions and reflection with them about their views about science and science teaching. Instead of classifying the trainee teachers' answers in rigid categories, they could be seen as rich teaching material, presenting a variety of aspects raised, different positions claimed and contradictory point of views. Without a doubt, the answers as a whole could be used as a basis for discussion with the future teachers of their views, and of the idea that when we are teaching science we are teaching, whether we know it or not, about science – its history, methodology, structure, values, cultural relations. As Mattews (1994) pointed out, the teaching of science "depend upon some rudimentary understanding by teachers and curriculum developers of the methodological and epistemological aspects of science". Therefore, a starting point for clafying a teacher's (or trainee's) own understanding is to ask them to make explicit their ideas about science. After this, we can try to ask them to answer Alter's questions about "whose nature of science "we would like to teach (Alter, 1997). We can see this step as a way to discuss with beginning teachers the risks of accepting an epistemological position as a basis of carrying out natural science teaching activities. There is always the danger that teachers and experts will understand "epistemological development" to mean bringing pupils around to believing in the epistemological premises that teachers themselves believe.

Indoctrination can be avoided by discussing with beginning teachers about this type of risk. One good way to start is to discuss their views about the nature of science. As the data collected in the first phase of this research showed us, the different positions claimed by future teachers, and their contradictory point of views about science, can be used as rich material for discussions about science teaching and the nature of science.

## Bibliographical References

ABELL, S. K. and D. C. SMITH. What is Science ?: preservice elementary teachers' conceptions of the Nature of Science. Int. J. Sci. Educ. 16 (4):475-487. 1994.

ALTERS, B. J. Whose Nature of Science? J. Res. Sci. Teach. 34(1):39-55. 1997.

CARVALHO, L. M. A Temática Ambiental e a Escola de 1º. Grau. São Paulo, Universidade de São Paulo, Faculdade de Educação. 1989. (Doctorate Thesis).

CARVALHO, L. M. A natureza da ciencia e o ensino das ciencias naturais: tendencias e perspectivas na formacao de professores. Proposicoes, 12 (34):139 - 150. 2001.

GIL-PÉREZ, D. New trends in science education. Int. J. Sci. Educ. , 18(8):889-901. 1996.

GUSTAFSON, B. J. and ROWELL, P. M. Elementary preservice teachers: constructing conceptions about learning science, teaching science and the nature of science. Int. J. Sci. Educ. 17(5): 589 - 605. 1995.

KING, B. B. Beginning Teachers' Knowledge of and attitudes toward history and philosophy of science. Sci. Educ., 75 (1): 135 - 142. 1991.

KOULAIDIS, V. and J. OGBORN. Philosophy of Science: an empirical study of teachers' views. Int. j. Sci. Educ. 11(2):173-184. 1989.

LEDERMAN, H. G. Students' and teachers' conceptions of the Nature of Science: A review of the research. Journal of Research in Science Teaching. 29(4):331-359. 1992

MATTEWS, M. R. História, Filosofia y Ensenãnza de las Ciencias: La aproximación actual. Ensenãnza de las Ciencias. 12(2):255-277. 1994.

SOLOMON, J.; DUVEEN; J.; SCOT, L. and McCARTHY, S. Teaching about the nature of science through history: action research in the classroom J. Res. Sci. Teach. 29(4):409-421. l992.

THOMAZ, M. F; CRUZ, M. M.; MARTINS, I. P. y CACHAPUZ, A. F. Concepciones de futuros professores del primer ciclo de primaria sobre la naturaleza de la ciencia: contribuciones de la formación inicial. Enseñanza de las Ciencias. 14 (3): 315 - 322. 1996.

**Table 1:** Problems pointed out by beginning teachers as the big problems that our society has at the end of the century.

| Problems pointed out by TTs | Specifications | 1996 | 1997 |
|---|---|---|---|
| Social: 38TTs | Hunger and food distribution | 12 | 11 |
| | Misery - Poverty | 08 | 10 |
| | Unemployment | 10 | 08 |
| | Violence, Criminality, Marginalization | 06 | 04 |
| | Others | 15 | 15 |
| Educational: 26TTs | Lack of basic knowledge information and literacy | 07 | 08 |
| | Educational Systems and Politics | 05 | 09 |
| | Others | 03 | 02 |
| Environmental: 15TTs | In general | 02 | 08 |
| | Specifics | 03 | 05 |
| Economical: 14TTs | Internal Economical Problems | 02 | 04 |
| | International Economical Problems | | 04 |
| | Others | 02 | 04 |
| Health: 12TTs | Health Systems and Health Politics | 04 | 02 |
| | Control and Prevention of Parasitic diseases and sexual transmissible diseases | 04 | - |
| | Spread of general and specific diseases. | 01 | 03 |
| Political: 07 TTs | Political Integrity | | 03 |
| | Political Management | 02 | 01 |
| | Wars | 01 | 01 |
| Value or ethical: 05 TTs | Science and ethics | 02 | 01 |
| | Integrity, dignity and sensibility | 02 | — |
| | Self confidence and good models | 01 | — |

**TABLE 2:** Beginning teachers' answers about the relationships between science, technology and the present problems confronted by society.

| GROUPS OF ANSWERS | SPECIFICATIONS | NUMBER OF TTS | |
|---|---|---|---|
| | | 1996 | 1997 |
| GROUP 1: Stressed positive impacts of science and technology: 8 TTs 16% | Positive impacts: | | |
| | – Solving problems. | 04 | 03 |
| | – Providing wellbeing and comfort. | / | 01 |
| | – Controlling environmental problems | 01 | / |
| | Limiting factors: | | |
| | – Educational level. | 01 | 01 |
| | – Economic problems. | 01 | 01 |
| GROUP 2: Stressed negative impacts of science and technology 8 TTs 16% | Negative impacts: | | |
| | – Causing unemployment. | 01 | 04 |
| | – Causing environmentalproblems and poverty. | 01 | 02 |
| | Contributing or determining factors | | |
| | – Economic problems. | / | 03 |
| | – Educational level. | 01 | / |
| | – Value systems of society. | / | 01 |
| GROUP 3: Stressed both positive andnegative impacts of science and technology: 10 TTs 20% | Positive impacts: | | |
| | – Solving problems. | 04 | 02 |
| | – Promoting advances in knowledge | / | 01 |
| | – Providing financial profits. | / | 01 |
| | – Promoting improvements through application of science. | / | 01 |
| | – Providing better conditions of life | 01 | / |
| | Negative impacts: | | |
| | – Causing problems. | 03 | 03 |
| | – Causing unemployment. | / | 02 |
| | – Being limited in solving problems | 02 | / |
| | Other aspects pointed out: | | |
| | – Economic and politicalproblems. | 01 | / |
| | – Environmental problems. | 01 | / |
| | – Access to technological goods. | 01 | 03 |
| GROUP 4: Admitted relationship between science and technology and problems without specifying positive or negative impacts. 20 TTs 40% | Pointed out relationship between science and technology and: | | |
| | – Educational level | 02 | 04 |
| | – Propagation of information by mass media. | 07 | 02 |
| | – Economic factors. | 02 | 01 |
| | – Unemployment | / | 03 |
| | – Politics | / | 04 |
| | – Others. | | |

**TABLE 3 :** Beginning teachers who stressed, in their answers, procedures related to the process of the production of scientific knowledge .

| ASPECTS POINTED OUT | 1996 | 1997 |
|---|---|---|
| 1.1-Ways in which people can do science or produce scientific knowledge. | 4 | 3 |
| – Mentioned the existence of several kinds of scientific methods | (1) | |
| – Stressed aspects related to "how to do it" | (18) | (23) |
| – Stressed the process of concluding from observations. | | (37) |
| – Pointed out the relationships between scientific method and historic context-Mentioned scientific method as one of the ways. | (8) | (30) |
| – Related scientific method to researching rigor. | (13) | |
| 1.2-Way of obtaining satisfactory results or verifying the results in scientific work. | (12,14,18) | (44,48,40) |
| 1.3-Way of formulating hypothesis or testing hypothesis. | | (22,28,29,40) |
| 1.4-Stressed the process of experimentation | | |
| – in general | | (24) |
| – experiments to test a hypothesis | | (25) |
| – observation, experimentation, elaboration of hypothesis, laws, and theories from facts. | | (27) |
| – universal, linear and systematic move from facts to data to conclusion. | | (35,36) |
| 1.5-Scientific method as a way to achieve understanding- it is subject to constant modification, with no immutable truth or reality. | | (32) |
| 1.6-The hypothetical - deductive method is used as synonym of the scientific method. Pointed out the possibility of quantifying the phenomena. | (19) | |
| 1.7-Methods of scientific discovering. Pointed out historical aspects of scientific knowledge and laboratories and field methods for studying animal behaviour and plant biology. | (16) | |
| 1.8-Study with a theoretical base and tested by experience | (15) | |
| 1.9-Referred to the process with very general comments-"discovering something, or knowledge construction. | | (38,42) |

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# CONSTRUCTING SCIENCE VIA MULTI-MODAL EXPERIENCES

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## Abstract

The blends of multi-modal presentations, e.g. audio, visual and verbal, that are enacted in the new technological communication channels influences the nature of the transmitted message and concurrently shape the mental tools of the learner for understanding the physical and social environment. Multi-modal presentations involve the utilization of multiple senses and engage the learner in embodied experiences of a different nature than those of the common verbal mode. Actually these blends contrive new languages that are extraneous to most students. This new reality raises the need for a new pedagogy, one of multiliteracies, that will provide students with an opportunity to develop a meta-language that will incorporate words, images and possible interactions among these, that will enable meaning making in various realms. The need for educating towards multiliteracies is also substantiated by Gardner's (1993) claim regarding the multiplicity of intelligences that humans were blessed with and employ in processes of learning. Thus the new pedagogy should provide students with experiential environments through which they can sense multiple meanings that are communicated by different modes. The multiple meanings that comprise the complex and holistic understanding of scientific concepts, can be categorized in terms of typological and topological aspects of a phenomena.

The presentation deals with experiential settings for learning the concepts 'measuring length' and 'respiration' by elementary school six graders. The process of learning involved a multi-modal setting each one providing a unique contribution towards the emergence of a multi faceted understanding of concepts.

## Introduction

The verbal mode of communication enjoyed cultural supremacy for thousands of years. The written or oral presentations were many times supplemented with visual or concrete illustrations. However, these illustrations tended to complement and strengthen the verbal messages. With the development of technology based modes of communication, e.g. films and video, it was recognized that the new blends of visual, audio and linguistic aspects create unique languages with specific features that influence the nature of the transmitted messages and concurrently shape the mental tools of the learner for understanding the physical and social environment. The unique structural features of the hybridized modes actually render the latter the status of different languages that act in broadening the learner's cognitive benefits by enrichment or by the construction of new mental tools for understanding the physical and social environment (Messaris, 1994). The new languages involve multiple senses and engage the learner in embodied experiences of a different nature than those of the verbal mode. The capacity of the different modes of representation for sensing the environment can be analyzed as to their analytic and descriptive powers. The analytic capacity focuses on aspects such as generalities, classes of objects, or causality for which the verbal language has the appropriate signs that enable their expression. Other modes such as visual, spatial or interpersonal – are lacking with respect to these aspects. However, they are better than the verbal mode for explicating descriptive features of phenomena, e.g. gradual changes in quantities, continuity, dynamic states, etc. Lemke (1998) suggested to express the structural differences between the verbal and visual languages in the terms of typological and topological meanings; The verbal mode being more suitable for expressing – typological aspects, whereas the visual modality is better suited for the description of particular events or situations, of context embedded aspects, that present topological meaning.

Experiencing through different modes is encouraging the development of multiple embodied representations that are inclusive of emotional, aesthetic and cultural aspects in addition to analytic features, thus aiding the learner in comprehending the typological and topological aspects of phenomena.

The need for multi-modal experiencing for a more comprehensive understanding also emerges from Gardner's theory of human multiple intelligences (Gardner, 1993). Gardner claims that there is a variance in the preferred modes that humans employ in coping with the environment. His description of seven different modes that intervene in human learning and meaning construction, actually underscores the need and importance for a multi-modal learning environment. Our research also supports the importance of multi-modal presentations for learning. We have found that in problem solving of different populations of students gifted tended to show a preference for the verbal mode but the regular population of students had a preference for the visual mode (cartoons) (Klavir & Gorodetsky, 2000). It seems that the recent developments in different directions (technological - cultural, cognitive and affective) all call for the introduction of opportunities for multi-modal experiencing within the school.

At present there is a distinctive preference in the educational system for the verbal mode. The sciences curriculum emphasizes conceptual and analytical ways of understanding and neglects the grasping of topological aspects in the process of meaning construction. Providing students with opportunities to construct meaning via multiple modes will result in gains that will be not just additive, but multiplicative, making the whole far greater than the simple sum of its parts (Lemke, in press). This recognition actually, casts a moral obligation on the educational system towards constructing multi-modal learning environments for learning. The translation of the moral obligation into classroom activities delegates to the teachers and students a serious challenge. This is a demanding challenge as it calls the teachers and students to recognize the importance of exposure to multiple modes in addition to the traditional verbal one. Actually, it means to open the classroom to the new technology based multimedia as well as to the older 'technologies' of expression such as art, drama, or music. Lemke (1998) describes science as an hybrid of the verbal, mathematical, visual-graphical and actional-operational genres. Using his words "To do science, to talk science, to read and write science it is necessary to juggle and combine in various canonical ways verbal discourse, mathematical expression, graphical-visual representation, and motor operations in the world." In the spirit of holistic learning (Gorodetsky et al., in press; Gardner & Boix-Mansilla, 1994) we would add "to dance science, sing science, love science, feel science, breath science, etc". By providing students with opportunities to experience different ways of grasping and understanding science, a more holistic representation of the topological as well as the typological aspects of science will be achieved.

These recognitions actually establish a new pedagogy, one that incorporates multiliteracies and provides students with an opportunity to develop a meta-language that incorporates words, images and meaning making interactions for meaning making in various realms (The New London Group, 2000). We wish to report our experience of enacting such a pedagogy by activating students in multi-modal learning environments. We wish to provide two examples of the inquiry of the phenomena of 'respiration' and that of 'measuring of length', by employing multi-modal activities in the classroom.

## The context

The project involved six graders of an elementary school that were studying general science. The concepts of 'measurement' and 'respiration', are two central concepts in the formal curriculum of this grade. The formal curriculum addresses the study of these subjects in the traditional way by introducing definitions and mainly highlighting the 'scientific' typological aspects. We felt that in the spirit of bringing science closer to the students or the students closer to science, an exposure to multi-modal learning environments that are more 'natural' to students' world should be advocated. We felt that we should provide students with embodied experiences of different natures to ensure the devolvement of topological features in addition to the typological ones.

The presentation describes two examples of such environments. The information was gathered by video tapes taken of the activities, by active participation of the researchers in these activities, and by students' assessment reports.

### Measuring Lenght

The lesson started with the teacher's (YK) question: "How can we compare the distance between two points?" "By a meter" was the as if orchestrated answer. It was clear that the students had prior knowledge about the idea of measurement and the quantitative units associated with this task. However the teacher insisted that there are additional possible ways or tools to measure. Digging into their past learning brought forward some biblical measures, e.g. "cubit" that was used in ancient times. Comparison between the meter and the old measure device, established that though both approaches are based on the repetition of a 'standardized' unit, some units are more standardized than others, leading to the notion of accuracy. The teacher insisted poking for additional measuring devices but with no success.

At this point he diverted students' attention to a different context and asked how do they think animals measure distances. This question opened a new direction of thinking and production of ideas for measuring that stemmed from the animate world such as sight estimate, voice, animal excretions, etc. Moving to a different context released the students from the set of mind they were positioned in. New options for measuring distance were suggested such as: measuring the change in the length of a shadow, by the wind flow, by distances between the stars, etc. Though some of these ideas seemed to us not to be practical within the school system, no judgment in this direction was provided. At this point the teacher revealed a collection of artifacts and asked the students whether some of these could be used for comparing two distances. Again many ideas were raised of which some had been actually implemented. Students went out to the court and compared distances by counting the number of heart beats with a stethoscope; By counting the number of drum beats while walking the distance at a steady pace; Comparing the amount of sand needed to spread equally along the distances; By walking and singing popular songs and paying attention how far in the song they got; etc. Students were embodied in these activities and actually experienced the idea of measurement through as many senses as possible. Beyond the excitement and involvement, students' conception of measurement was broadened. Measurement as an abstract idea and some of its typological features like 'arbitrariness of units, 'repetition of a standard unit', and 'preciseness' were issues dealt with. They recognized that "there are many different ways to measure". That measuring can be qualitative and individual "without a ruler and exact means". Actually this understanding was generalized to the claim that "you can measure with everything". They were able to distinguish between precise and imprecise measures and wondered: "how can we measure with different mediums and yet be precise?" It seemed that the typological features of the concept were broadened. The idea of a measuring unit went much beyond the 'meter' and was understood as something that is at choice and can be changed. It can be personalized or uniform and can include different 'units'. Similarly, the idea of repetition that was introduced in different contexts became clearer which contributed to the understanding of preciseness. It seemed that experiencing through different senses benefited the meaningfulness of topological features as well. Through embodied activities students experienced measurement also sensually. Feeling the notion of continuity, of relatedness to their lives and interests colored the process of measurement with an individualized and affective flavor. As an alternative conception to 'meter' they now had in their possession personalized different embodied representations. In general it seemed that experiencing through different senses benefited the meaningfulness of the idea of measuring. They enjoyed the activities and expressed their delight and wishes for many more "lessons" of this kind.

### Respiration

The multi-modal environment for introducing the phenomena of respiration was designed by a group of pre-service teachers and their mentor (YK). They have structured, a priori, stations that included activities for experiencing respiration. These stations were designed to involve the students in embodied activities that provided opportunities for exploring through different senses and different intelligences. Students were divided into small groups and experienced all activities one after the other. The stations were: **a**. Verbal competence based activities such as crossword puzzles that included concepts related to the major attributes of the phenomena of respiration. **b**. An arithmetic based activity that involved the children in counting the number of breathes in a given time and calculating a personal as well a collective average respiration rate. The measurements of the respiration rate was performed at leisure and after a short exercise (climbing up and down a chair). **c**. An aquarium with fish that enabled comparative studies between fish and humans that highlighted the differences in respiration under water and in the open air. This activity called attention to the different mechanisms for oxygen intake by humans and fish. **d**. Tracing the passage of air in the body by using a stethoscope and identifying the organs engaged in the respiration process. While using the stethoscope students draw (each on the back of a friend) the organs that are involved in this process. **e**. Sensing respiration as a relaxing activity. Students were invited into a dark room with mattresses and background music and were asked to concentrate on their own respiration while flowing with the music.

As mentioned all students experienced all stations. At the end of the 'lesson' students were asked to assess the lesson. Their assessment clearly indicated their preference for multi-modal activities. The relaxing activity was the highlight. Adjusting their respiration to the playing music was a unique experience especially in the context of science. In addition to the known information as to the essentiality of respiration for physical survival they also recognized that respiration intervenes and affects their mental state; "I loved the music room because there I understood how to relax and we felt how we respire and the oxygen is flowing through our body". Students felt that tuning to their own respiration was a unique experience, as they said: "we study this subject also in the regular class but we don't check our own respiration system" or "we felt the respiration and thus understood it better". Listening to each other's lungs and hearts brought them closer to their own body and its activities. Their understanding of respiration was both widened and yet personalized. It was not only knowing about a detached phenomena but it was getting acquainted with their personal respiration which provides an embodied understanding of the dynamic, individualized and context embedded nature of respiration. These are topological features that usually are not addressed in a regular classroom. The mental and physiological aspects of respiration were interwoven –"when we are under stress our respiration is quicker than under rest".

Typological features of respiration were also recognized more fully. The interrelationship between heart beats and exercising provided information that "when we exercise the pace of respiration is enhanced and so is the heart beat". The comparison between fish in the aquarium and humans extended the knowledge regarding oxygen-availability – "we can't breath in the water and the fish can, their oxygen is in the water and ours is in the air."

The emerging understanding of respiration from the multi-modal experiences was richer and included aspects that can be grasped only by the senses. The importance of experimenting through the senses and of listening to oneself as a wider educational aim is of importance and value in enriching one's understandings in general.

## Discussion

Both experiential settings are educational environments that take the students beyond the common verbally controlled classroom. The students expressed preference for the activities that involved holistic, multi-modal involvement. Some of these activities were clearly better for analytical – typological understanding of concepts, whereas others enabled a better sensing of the broader and contextual features of topological understandings of the concepts of measurement and respiration. Some of the environments enabled the treatment of abstract concepts in a concrete - personalized manner enabling them to flow with their idiosyncratic personal knowledge and understandings. It is clear that the multiple modes of experiencing were not redundant presentations of the same features, rather each one of them had unique contributions to the multi faceted understanding of the concepts that led to multiple presentations. Multiple representations are more effective in promoting analogical transfer (Gick 1983) while coping with new experiences or problems. They can compensate as well as enrich shortcomings of solely analytical mathematical representation (typological features). For instance mental images seem to play an important part in creative processes. Among the stories of visualizing a solution without being able to develop it by typological means, is that of Kekule (Davidson 1986). He visualized the structure of benzene as a snake whose tail is touching its head, without being able to construct a precise structure. Einstein too acknowledges the importance of multiple representations and specifically the employment of imagination in constructing new representations. He regarded imagination as the main source of his creativity as quoted "I am enough of an artist to draw freely upon my imagination. Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world" (Calaprice, 1996).

**References**

DAVIDSON, J.E. (1986). Insight and giftedness. In R.J. Sternberg, & J.E. Davidson (Eds.), *Conceptions of Giftednes* (pp. 201 - 222). Cambridge University Press.

CALAPRICE, A. (1996) editor. *The Expanded Quotable Einstein*, 1st edition, Princeton: Princeton University Press

GARDNER, H. (1993). *Multiple Intelligence: The Theory in Practice.* New York: Basic Books.

GICK, N.L., & Holyoak, K.S. (1983). Schema induction and analogical transfer. *Cognitive Psychology,* 15, 1- 38.

GORODETSKY, M., Keiny, S., Barak, J. & Weiss, T. (2001). Contextual Pedagogy: Teachers' journey beyond interdisciplinarity, *Teachers and Teaching*, in print.

KLAVIR, R. & Gorodetsky, M. (2001). The processing of analogous problems in the verbal and visual-humorous (cartoons) modalities by gifted/average children, *Gifted Child Quarterly*, 45(3), 205-215.

LEMKE, J. (1998). Multiplying meaning: visual and verbal semiotics in scientific text, *Reading science*, ed. J.R. Martin & R. Veel, Routledge, London.

LEMKE, J.L.(in press ). Metamedia Literacy: transforming meanings and media, in: D. Reinking, M., McKenna, M., Labbo, L. & Kieffer, R. (eds), *Literacy for the 21st Century: Technological Transformation in a Post-typoraphic World*, Erlbaum

MESSARIS, P. (1994). *Visual "literacy" Image, mind and reality.* Boulder: Westview Press.

THE NEW LONDON GROUP (2000). A pedagogy of multiliteracies, in: Cope, B. & Kalantzis, M. (eds.), *Multiliteracies:literacy learning and the design of social futures s*, London: Routledge, pp. 9-37.

**Keywords:** multi-modes, multiliteracies, science learning, respiration, measurement, embodied experience.

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# CASE STUDIES FOR TRAINING: AN ACTION RESEARCH PROJECT CONCERNING THE INTRODUCTION OF A STS APPROACH ON THE CURRICULUM

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**Abstract**

G. Sykes (1992) points out that case studies used for training purposes, base their usefulness on how adequate the studies are for reflecting on the complexity of the teaching profession. The implementation of an STS approach in the science curriculum deals with this highly pertinent change which involves a high degree of involvement and complexity for secondary education teachers. The goal of the project, Introduction of biotechnology in secondary schools, is to research and to understand the effects on and the changes for science teachers on introducing an STS approach in classrooms. Several case studies were developed, focusing on each of the biotechnology units where the STS approach was implemented in the upper secondary level in both technology and health. The case studies produced in the project are based on an action-research process developed by teachers. It is intended to be used for training teachers, for helping them to implement this innovation and to understand the quota and contextualized nature of the teaching and learning process in the STS approach from the teacher's point of view. The distinctive features of these case studies for training have been analyzed.

## 1. Introduction

While curriculum theory is focused on the systems in schools, in Westbury's words (2000) didaktik theory seeks models for thinking about teaching, and for understanding the quality and character of the rationale that teachers yield in terms of justifying their teaching. The international project "Didaktik meets Curriculum"(Hopmann & Riquarts 1995a+b), aiming to improve communication between these two traditions, clarifies a few differences and similarities between the two. The term didactic is often used to determine the teaching strategies applied by the teachers, as an element from curriculum theory. Didaktik, on the other hand, offers a developed framework for thinking about teachers as theorists and makers of classroom curricula.

Curriculum tradition developed in the UK by L. Stenhouse (1980), based on Tyler's' rationale, built up a concept of curriculum as an experimental teaching situation for teachers that implements through contents the goals they would like to achieve with students. Curriculum development was also defined as a classroom research process when L. Stenhouse directed the Humanities Curriculum Project. Since then, educational action-research has been developed extensively. L. Stenhouse and others working with him in the HCP, further developed his idea that curriculum and professional development should grow together, because teacher reflection over the data obtained in the teaching and learning process in classrooms should really be considered a research process.

The notion of the teacher as researcher (Stenhouse 1980) differs with the conceptual notion of the reflective practitioner among American researchers such as D. Schön in the seventies. E. Terhart (1995) remarked that the historical roots of didaktikal thinking and teaching as an occupation are closely connected at the meeting point of teacher education. As in L. Stenhouse's theory, teachers' professional knowledge should be developed in practice, (i.e. where teachers develop their experience) implementing an experimental curriculum through teaching strategies in a learning process and acquiring personal knowledge about teaching in the first instance. Menck (1995), making a comment on Komensky´s work, noted the idea of empirical education science as didaktik which started to be shaped years later when teachers´associations began encouraging and carrying out empirical research. He came to the conclusion that "Didaktik is the theory of classroom" as well as an approach to the reality of teaching.

Around 1986, authors such as Doyle and Shulman argued about the importance of cases to the knowledge base on teaching. L. Shulman, in particular, argued that case knowledge is: "...a potentially codifiable body of knowledge conveying the wisdom of the practice, is as essential to the knowledge base of teaching as is the knowledge of principles derived from educational research" (Shulman 1986, 11). Brown, Collins and Duguid (1989) suggest that the propositional knowledge learned in classroom settings is the need of case based teaching for the research of the cognitive flexibility theory, which R. Spiro et al. (1988) also supported.

Based on the above, a possible definition of the case studies for training would be as follows: a document built up through the systematic investigation of the educational process in a classroom, with the aim being to come to a better understanding of the main issues and elements of educational theory in action. Classroom case study is concerned with the educational dilemmas that teachers face teaching a specific subject matter (Saez & Carretero 1996a+b).

G. Sykes (1992) points out that the case studies for training base their usefulness on how adequate the studies are for reflecting on the complexity of the teaching profession.

The training cases show an extraordinary ability for expertly understanding the varied reality of the teaching/learning processes in a narrative way. J Bruner (1990) described the narrative as especially suited to treating the vicissitudes of human intentions, which is undoubtedly an essential feature of the universal act of teaching and learning to teach.

Over recent years, the use of case study method for teacher training has revealed its capacity for reducing the distance between theory and practice in teaching, fundamentally due to the fact that it makes it possible to show the ambiguities and dilemmas. "Scientific Education", as an example of these dilemmas is the difference between social and societal issues in the case of the practical immunology unit. A social issue is the AIDS problem, how it is contagious, and the sexual relations among young people. The societal issue is the different control of the information that people have with the kits that can be used personally and not by the doctors, easy to see in the pregnancy cases.

It is possible to see another dilemma in scientific education that STS outlines. The use of kits for lab practice are considered "bad" examples of the scientific method by teachers. But it is difficult for teachers to see that they are good examples of problem solving because you have data at your disposal quickly, and can interpret it and then it is possible to make decisions.

The dilemmas of present education could influence the importance of science and technology in society. It must be stated that the changes that are occurring in teaching and in science curricula are significantly affected by the change in the concept of science (Saez 2002), although there are other factors affecting this change. The introduction of the STS approach in science classrooms deals with this highly pertinent change which involves a high degree of complication and complexity for secondary education teachers. For this reason, teacher training must be guided by the teachers themselves over a long process that will make it possible for them to analyze all the complexities arising with this innovation in the classroom. The introduction of social issues within science lessons is difficult for teachers, who often consider it to be "a waste of time". The introduction of knowledge about technology awakens very different feelings among science teachers.

## 2. An Action Research Project

An important goal of the project, Introduction of biotechnology in secondary schools, was to research and to understand, based on the notion of didaktik and curriculum development, the effects and the changes made by science teachers after the introduction of an STS approach in classrooms and in lessons through activities, from a biotechnology point of view.

Accompanying the research, several case studies were developed which focused on each of the units in which the STS approach was used to implement biotechnology topics at the upper secondary level in both technology and health. Practical Immunology, an important issue in which to establish the relationship between science and technology, and see differences between social and societal issues, is a very good example of the STS approach.

In the unit "Transgenic Plants" science and technology are outlined in terms of new food and the transgenia as an evolutionary mechanism. It is also a very good example in terms of the STS approach concerning the neutral role of the teacher regarding the new food. In Human Genetics, the teaching and learning strategy that encourages students to make informed decisions, and the values that emerge in the debates produced in the process, are important issues of the STS approach.

The professional training concept used was studied by J. Elliott (1990) and comes from the reflexive practitioner of D. Schön (1983), and from L. Stenhouse´s (1980) idea of teachers as researchers. Four units were introduced to teachers in a seminar conducted at a university in 1999, where 39 teachers were chosen to participate after receiving information about the main research issues of the project. The seminar was organized to introduce the four EIBE units mentioned earlier, their implementation in classrooms, to introduce the principles and rules for work in the project and about EIBE's purposes, goals and work. Participants in the workshop knew the units before attending the seminar and had chosen the units before attending the presentation, so as to make the final decision about which one to work with. Finally, four units were implemented in 40 classrooms and four case studies were written, one for each unit.

A maximum of 5 to 6 teachers implemented each unit and prepared their lesson plans together with other teachers. The sequence of implementation was planned with teachers who would implement the units to allow the collection of the information needed for the project. Teachers prepared the new topics, and the STS approach and the activities. At the same time they were identifying the materials they required in order to implement the units in classrooms (e.g. more documents for biotech information (bibliography), Spanish information about the diseases presented in the human genetics unit, more about the transgenic food used in Spain, or more practical work). A research team from the university provided them with papers and seminars to deal with their identified needs. The implementation of different student activities was proposed and the main issues were discussed in teacher seminars before being implemented.

The participating teachers were interviewed and were asked to complete a questionnaire. A lot of things can be said about the teachers' first contact with the units, but most of the questionnaires indicated that some of the questions about the quality of the units could only be answered after working with them, assessing their utility in the classroom. Other important insights have been reported in the written case studies. All of them include information about the general educational context, features of the school and about the discipline where the unit is placed. There is also data about the decision to implement the unit and lesson plans prepared for introducing it to the students. Teachers were interviewed about their work with the written unit, about workshop explanations, about suggestions concerning the unit content.

A questionnaire for students was elaborated with teachers concerning the basic knowledge teachers think students should have prior to talking about biotechnology, learning the attitudes and interests of students about the topic. Group discussion with some (4-5) students, chosen in collaboration with the teacher, discussed their expectations and previous knowledge in Biotechnology and in the topic approach in the units, and the implicit values detected in the selection or interpretation of the information given.

Written case studies are narrative descriptions of the relevant data acquired. Emergent questions led to following up research with students who were interviewed individually. Focus was on the interest developed from the social impact of the topic presented, as well as attitudes developed, etc. A final structured interview with the teacher was based on student perception, notes from the observer and his/her own notes, documents used in the classrooms and the assessment made by the teacher.

A short descriptive report was written about the implementation of the unit in the classrooms. This report was known by the teacher participating in the research so that explanations and details that had been forgotten could be included, concluding with the important issues that emerged from fieldwork. This draft, produced as a blueprint for an action-research cycle was read by the teacher and students to see whether the information had been fairly represented, if the analysis was accurate and whether they would like to make it "public" and under what conditions.

### 3. Methodology

The case studies produced by the action-research process began as an issue for discussion due to its research nature. Case studies have progressively become one of the most popular methodologies among educational researchers and many uses have been described for them (Stake 1988, Yin 1993, Saez & Carretero 1998b). Many goals can be achieved using this method of research and several types have been described (Stake 2000, Feagin 1994, Saez 1994, Yin 1989). A few things can already be said about why this methodological choice was made and why it was better adapted to the research goals. First, the possibility that the context may adequately be included. Second, because even if the focus of the phenomena to be studied is well defined, the main issues must be discovered. Third, because at the time of research, the boundaries between context and focus are not clearly evident in such an innovative development. Fourth, because they are extremely suitable for describing the "process" (of development, for example). Fifth, because of the potentiality for disseminating ideas for in-service teacher education (Simons 1996).

The case studies for training are defined as:

- Empirical research,
- Reflective and not reactive,
- Hermeneutic and not phenomenological,
- Focus on what and why the goals are reached according to the selected contents,
- Focus on all relationship dimensions of the triangle representing classrooms,
- Focus on the learning assessment process.

The data base has to be built up from non-participant observations in classrooms by an external researcher. Teachers' and students' interviews focus on:

- subject matter organization, structure, sequence, cumulative knowledge,
- communicated image of the subject (from the observer's point of view),
- implicit values detected in the selection or interpretation of the information,
- student's understanding of biology topics in the tasks proposed,
- communication established among teacher and students, and among themselves about biotechnological issues
- changes introduced,
- a final structured interview with the teacher, based on student perception, notes from the observer and his/her own notes, documents used in the classrooms and the assessment made by the teacher.

Preparing a narrative description of the relevant data acquired, the researcher identified the emergent questions leading to the research classroom. Three classrooms will be consecutively researched, developing main issues about the changes developed in teachers' conceptions in relation to the nature of the topic. The main topics, (e.g. genetics or immunology), helped in discerning differences in biology conception.

But whatever format the case studies adopt, they are rich in description including observation of classrooms where relevant, perspectives of key actors, examples of curriculum issues in practice, interpretations of experience and portrayals of key issues documented within and highlighting the specific context of the case. The evidence collected and displayed was sufficient to justify conclusions being drawn within the time scale allotted to the study. Analysis of the data was developed following the scheme developed by Saez and Carretero (1998b). Above all, the written case studies tell the story of the evolution, development and experience of the teachers' learning process in the school context. They are written in a clear and engaging style so that they can be used for in-service teacher training.

This type of case study could first be in a descriptive-narrative fashion, relating the events which, having occurred during the teaching and learning process, are deemed to be relevant. It is possible to envisage, however, that a critical point would be reached at which narration would give way to analysis. This would happen when the explanations of the events that had occurred would require well-supported inferences. The case studies are designed to allow deep insight into educational situations, the main concern is to collect the data that will throw light on those issues that, in the eyes of agents and the participants involved, are the most important in terms of theory. Writing case studies with a naturalist methodology means that the educational fact is described in its context, and that it has to be feasible and easily recognizable by those acquainted with the school's reality. The reader must also be able to

clearly distinguish those phenomena that are specifically linked to the school's culture from those that go far beyond such limits and are related generally to the subject of teaching and education.

Didaktik gives each teacher the expert task of discerning the formative value for his/her students of the contents chosen of the subject matter. It is the teachers who should explore, by way of hermeneutic reflection, the relationship of the biotechnology contents chosen and their educative potential. In fact, the core of teacher professionalism is to discern in which way these interactions are productively engaged. The focus is on examining the existing and implicit theories and concepts for teaching and learning, particularly those in the classroom. And on examining the practical strategy of teaching and learning in order to be able to confront their socio-historical reality actively and reflexively.

## 4. Nature of the case studies for training

The focus of the written case studies in the four units implemented is complex because the teachers made decisions, about the understanding and practice of the STS approach, which were often ambiguous. They follow carefully designed research together with their fieldwork, with a view to give a complete and objective representation as *far* as the educational situation in the classroom allows (debates, practical work, etc.). In a narrative way, these cases present a series of real accounts of the teaching for the analysis of the specific situation of the biotechnology topics that are implemented. It has been observed that the cases (teaching how to make decisions) combine analysis, based on content analysis, with informed-action-plans that reinforce the teacher when they comes to dealing with dilemmas in specific situations.

Fundamentally, the case studies focus in the units are the narration of a story, the teaching and learning strategies of biotechnology topics *from* a STS approach, a chain of events that happen in real time in a specific place. Despite the differences among the narratives they share certain characteristics:

- They have a beginning, a storyline and an ending, and they include significant tension for teaching, which is highly emphasized.
- They are exceptional and specific, and they refer to events that have happened or that are taking place.
- They set the events at specific places and times.
- They are stories of human activity and, as such, show motives, needs, conceptions of the world and things, frustrations, mistakes, etc.
- They reflect the cultural and social contexts where the events being told have happened.

In principle, these case studies for training purposes do not respect traditional disciplinary limits, nor do the problems they pose have any one single solution in the teaching of the biotechnology units. This makes them especially prone to revealing the thoughts of the teacher who is introducing the STS curriculum approach. As such, they are appropriate for encouraging the delving into aspects of unpredictability, uncertainty and judgement-making (Shulman 1992, 135), which makes this method especially suitable for analyzing the practical aspects of the new way of working in the classroom.

For over a decade at least, the permanent teacher training content has been the main subject of both its research and policies and practice. Teachers must think about "something", so the critical thought may be based only on a profound and detailed knowledge of the disciplinary content. It requires the possibility of presenting it in many types of activities (e.g. practical work activities, role-plays, debates, discussions in favor of or against the use of transgenic food, etc.) for students based on the understanding of the disciplinary content. G. Grant (1988) suggests that critical thought is linked to context. This strategy is based on the teacher's idea of discipline, on how this conceptualization is presented to students and how it maintains their attention during all tasks. In fact, the main tension existing in the classrooms observed was produced between the organization of the classroom and the students and the teaching process, because in some way, it is tension between the organization and the achievements made in the teaching and learning process.

In most professional training methods, there is tension between what happens in practice and the ideals suggested by the different reforms (Saez & Carretero 2002). This tension is heightened when beginners attend and act as observers at work centers, in order to complete their training in a real situation. This usually evidences a prosaic reality that is conservative and not very imaginative. The cases are capable of showing "good practice" impregnated with innovative features.

Using the case studies focus in the units with other teachers, it is possible to realize that the knowledge in question is not abstract because it is included in a specific situation being studied, the classrooms where the biotechnology units are implemented, but because the discussions among teachers led to it. It is possible to see that the more efficient decision-making cases are those which stimulate discussion at different levels of abstraction, even though on first reading they can basically be critical. An example of a level of abstraction is the difference between social and societal issues, or practical work as an example of the scientific method or technology use (the kit for determining a virus).

These case studies, used to teach how to think critically, first show the complexities of the teaching process, placing the teacher's "knowledge" at the center of the understanding of a teacher's actions. For example, the effectiveness in organizing a debate among students, or in debriefing after a role play exercise, is the first level of "knowledge" for training teachers. Together with the teachers, they also develop a second thought process level which requires information processing and not only the reproduction of knowledge, needing more than a refining of the skills of discreet teaching. The students, for example, learn to make informed decisions and to process the information acquired in the classroom.

In fact, the use of these case studies helps to teach beginners to think as members of the professional community of teachers. Learning the characteristics of professionalism goes beyond the skills inherent in the activities of the teacher and those skills included in the curriculum. They may be said to make up the style, which is not governed by rules, and which is more metacognitive than cognitive. L. Shulman (1992, 6) considers these strategies, which include personal orientations and professional habits, to be general.

Research on teachers` thoughts has shown that in the conceptualization of their task, teachers are not only transmitters of knowledge, but are also persons who makes hundreds of decisions everyday during their interactions with students (Calderhead 1987, Clark & Peterson 1986). This conceptualization is in fact based on the idea that teaching is more than the application of technical skills (Dewey 1933, Green 1985). As we can observe, the case studies pose questions that make it possible for the teacher to recognize classroom situations and the teaching learning process of the STS approach. It is the teaching and learning strategy with which students learn to make informed decisions or discuss social issues. In this way, teachers are capable of recognizing the situation in which they can or must use the principles they have learned through their own practical experience (Doyle 1990, 13).

This way of working with teacher training is part of a conceptualization of the teaching professional. It uses complex knowledge dependent on the context in which the content is neither completely defined nor fully specified so those teachers may make use of both the analysis and the decision-making. This enables them to make considered evaluations that lead them to the appropriate action. In other words, it permits using and simultaneously developing the capacity for analyzing specific situations in the carrying out of biotechnology activities. It permits the formulation of action plans and evaluation of those actions with regard to the variables of the specific context. These cases allow for the reflection on the reality of teaching, as an important part of the action research process.

The intention within the project was to use the case study method to encourage an understanding, from the teacher's point of view, the quota and contextualized nature of the teaching and learning process. The everyday experience with significant and extensive alternatives and concepts in the cases must provide the theoretical basis for teachers' decisions. In this case, it is for introducing the component *of Society* in science teacher training. In fact, some authors support the idea that teaching with this method is more appropriate for those areas of knowledge that lack strong structuring. For instance, this method can be used for those subject areas that are characterized by a high level of ambiguity in which relevant knowledge is still not organized for application to a situation. This makes it particularly adequate for the learning of the STS approach. Spiro (1988, 379) stated: "In ill-structured dominions, the general principles do not sufficiently understand the structured dynamics of the case. The growing flexibility, which responds to the great diversity of new case studies, comes dependently from the reasoning of previous cases.

In this way, the case studies cannot be assigned to the status of mere illustrators of abstract principles, which are key examples, but not necessarily good ones."

Therefore, the validity of what is presented refers fundamentally to the structure of the written narratives that impose a linear logic. In some ways they mistakenly represent the background noise of a class. However, some have an open end, and leave the resolution of the case open to discussion. These discussion themes are important when they enable more profound discussion. At present, we are analyzing how the selection of cases for teaching can be carried out with prior knowledge of how the structure of the case affects teacher learning.

Bearing in mind that the texts do not include "complete" detailed experiences, but only partially defined ones, it is difficult to specify exactly what the science teachers who read them might learn from specific case studies. This is so because of the fact that reading is the interaction between what has been written by the author and the reader in a particular context. In our study, the different teacher-readers have interpreted the same texts in different ways. For example, teachers have made different interpretations in the training course about the case study about "the role adopted by a teacher when teaching about transgenic plants who wouldn't like to explicate his own point of view about transgenic food until the discussion among the students finished". This feature is very important and characteristic of the case study method. For this reason, those using case studies must be aware that this ambiguity in learning together with the multiple nature of meanings is what allows discussion in the training sessions. Therefore, the essential task is one of bringing together the characteristics of this learning, through the use of case studies, with a view to developing teaching knowledge from them. The questions that need to be asked in the training process are at times the questions that guide the research.

We have succeeded in characterizing two features that are fundamental for producing an intense discussion of the cases:

a) Related to the nature of the social system of the class.
b) The concept of collective learning.

In the discussions, it was possible to observe the existence of a shared responsibility in learning terms. Moreover, the case study strategies stimulated reflection and decision-making as a collaborative learning experience, in which common interpretations were made, and this was used as a basis for the training of teachers as facilitators. Spiro comments, "The complexity of the case studies requires representations from multiple conceptual perspectives if the cases are treated restrictedly. Both from their characterization and from the relevance of their perspectives, the capacity for processing cases a posteriori is very limited" (1988, 380). We have observed the need for leaving the discussion unrestricted to a single case study. If discussion is restricted it leads to an oversimplification of the concepts of teaching and analysis.

A discussion topic is open up to the point at which, for the readers of the case studies, the structure of the research analysis is comprehensible, or if it makes them sufficiently understandable. Whatever the case, this leads to the different types of case studies that are written for research and the holistic structure, etc. adopted by the study. However, there is the question of whether shorter case studies are more convenient. And of the necessary amount of detail that allows a sufficient number of questions to be posed?

The case studies have also shown their capacity for faithfully reflecting the integration of thought, feeling and action that are uniquely blended in the action of the teacher. The conceptualization of the case study from this point of view currently indicates a significant number of powerful but habitual intellectual proposals, and presents itself as a promising source for improving teacher training.

## 5. Conclusions

1. The contents of the training case studies have been very significant because they involve teachers in active learning and critical reasoning with regard to their own knowledge on introducing the social perspective. The case studies that have been written have been sufficiently complex and capable of generating an atmosphere of discussion and debate. The debate has been presented at two levels: At the first level, the case study itself is a research objective, provoking its reading towards the recollection and preparation of multiple alternatives in the teaching of biotechnology subjects. And at the second level, the case study as a more reflexive dialogue on the dialogue itself when attempting its analysis. This is a metacognitive process where the first level is fundamentally cognitive. In other words, studying the case on the one hand, and analyzing the revision process on the other. This is exemplified in a sufficiently clear and unequivocal way of understanding the case studies as scientific knowledge and the second level of analysis.
2. Two significant advantages have arisen from the updating/training of teachers: a) the motivation for learning and debate, b) it gives teachers a way of acting where they direct their own learning in an assisted way, together with an innovative method which helps prevent the excessive tendency to try to teach with generalizations. Teachers who involve themselves in writing cases reap benefit.
3. In training terms, the cases have used mainly the following aspects for teaching:
   - Theoretical principles and concepts in the teaching of biotechnology.
   - Continuation of practical teaching learning strategies.
   - Professional ethics.
   - Strategies and personal disposition towards the teaching of controversial topics.
   - Images of what is possible.
4. The method has been successful in producing abstract knowledge of the content and knowledge of the theoretically argued teaching strategy. Although, perhaps the most significant point, is that it has been possible to later apply elements of this acquired knowledge in practice.
5. The main contribution of this strategy is the integrated presentation of contents, processes, thoughts and sensations. Teaching and learning are simultaneously approached as joint theoretical constructions. They are similar to true life in that for teachers, the problems are presented as intellectual challenges and as different actions and thought alternatives, so that both their knowledge and experience may be used to unravel what is to be done in practice.

## References

BROWN, J.S., Collins, A. & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher* 18 (1), 32-41.

BRUNER, J.(1990). Acts of Meaning. Cambridge, MA: Harvard University Press.

CALDERHEAD, J. (1987). Exploring Teachers' Thinking. London: Cassel Educational.

CLARK, C. & PETERSON, P. (1986). Teachers' Cognition. In: M. Wittrock (Ed) Handbook of Research in Teaching (3rd ed.) New York: Macmillan : 225-296.

DEWEY, J. (1933). How we think. Boston: Heath.

DOYLE, W. (1990). Case Methods in the Education of Teachers. *Teacher Education Quarterly* 17(1), 7-15.

ELLIOTT, J. (1990). Adult Learning and Development: Implications for In-Service Teacher Education. Paris: OECD.

FEAGIN, J. et al. (1994). A case for the case study. Chapel Hill, North Carolina University.

GRANT, G. (1988). Teaching Critical Thinking. New York: Praeger.

GREEN, M. (1985). Public Education and the Public Space. *The Kettering Review,* Fall 1985, 5-60.

HOPMANN, S. & Riquarts, K. (1995a). Starting a dialogue: issues in a beginning conversation between Didaktik and the curriculum traditions. *Journal Curriculum of Studies* 27(1), 3-12.

HOPMANN, S. & Riquarts, K. (1995b). Didaktik and/or curriculum. Kiel: IPN publications.

KEMMIS, S. (1980). The imagination of the case and the invention of the study. CARE Occasional Publications, no. 7. Norwich: East-Anglia University.

McTAGGART, R.; Saez, M.J. et al. (1997). Participatory Action Research: International Contexts and Consequences. Albany: State University of New York Press.

MENCK, P. (1995). Some Remarks on Research in Education and Didactics in Germany. In: Hopmann, S. & Riquarts, K. (1995b). Didaktik and/or Curriculum. Kiel: IPN Publications, 383-396.

SAEZ, M.J. (1994). El estudio de caso en evaluacion o la realidad a traves de un caleidoscopio. Revis. Interuniversitaria de Formacion, n° 20.

SAEZ, M.J. & Carretero, A. (1996). From the action research to the classroom case study. The history of ANTEC. *Educational Action Research: an International Journal,*4(1),29-48.

SAEZ, M.J. & Carretero, A. (1998a). Innovations in the Science Curriculum: A View of a Systemic Reform. *Journal of Curriculum Studies* 30 (6), 719-738.

SAEZ, M.J. & Carretero, A. (1998b). Evaluating Innovation: The case study approach. *Educational Evaluation Studies* 24 (1), 25-43.

SAEZ, M.J. & Carretero, A. (2002). The Challenge of Innovation: The New Subject Natural Sciences, *Journal of Curriculum Studies* 34 (3)(in press).

SCHÖN, D. (1983). The reflective practitioner. London: Heinemann.

SHULMAN, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher* 15 (2), 4-14.

SHULMAN, J.H. (1992). Case Methods in Teacher Education . Teacher College Press, Columbia University.

SIMONS, H. (1996). El Enfoque de Estudios de Caso en el Proyecto SMTE de la OCDE. *Revista de Educacion* 310, 173-187.

SPIRO, R.J. et al. (1988). Cognitive Flexibility Theory: Advance Knowledge Acquisition in Ill-Structured Domains. In: The Annual Conference of the Cognitive Science Society. Hillsdale, NJ: Erlbaum, 375-383.

STAKE, R. (1988). Case Studies. In: Shulman, L.S. Complementary Methods for Research in education. AERA publications.

STAKE, R. (2000). Case Studies. In: Denzin, N.K. & Lincoln, Y.S. (eds.). Handbook of qualitative research. 2nd ed. Newbury Park: Sage, 435-454.

STENHOUSE, L. (1980). Curriculum Research and Development. London: Heinemann Education.

SYKES, G. (1992). Foreword. In: Shulman, J.H.: Case Methods in Teacher Education. New York: Teacher College Press, Columbia University IX-XII.

TERHART, E. (1995). Didaktik/Curriculum in Teacher Education: Some German Complications. In: @bi = HOPMANN, S. & Riquarts, K. (1995b). Didaktik and/or curriculum. Kiel: IPN publications, 289-300.

WESTBURY, I. (2000). Teaching as a reflective practice: What might Didaktik teach curriculum? In: Westbury, I, Hopmann, S. & Riquarts, K: Teaching as a Reflective Practice. Mahwa, New Jersey: Lawrence Erlbaum, 15-39.

YIN, R.K. (1989). Case study research: design and methods. Newbury Park: Sage.

YIN, R.K. (1993). Applications of case study research. Newbury Park: Sage.

**Keywords:** Teacher training, case studies, action research, Didaktik, curriculum theory

**048**

# IS IT POSSIBLE TO TALK ABOUT FERNANDO PESSOA, NIETZSCHE, CARLOS DRUMMOND DE ANDRADE AND OTHER ENLIGHTENED WRITERS WITH CHILDREN OF EVERY AGE AND BE COMPREHENSIBLE? AN INTERACTIVE EXPERIENCE IN MUSEU DA VIDA – COC / FIOCRUZ DURING THE EVENT "PAIXÃO DE LER" ( PASSION OF READING) IN THREE DIFFERENT TIMES OF THE PLAY "I READ BECAUSE I WANT TO."

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**Abstract**

Requested to join the activities of "Paixão de Ler"(which means something like "Passion of Reading") in Museu da Vida – COC/FIOCRUZ, the author researched about some writers who published their thoughts about the relationship between reading, writing. It looked like a vertical cut into a very special moment in life: the moment someone chooses to open a book and pay attention to the meaning of what is inside. This moment, in my belief, is a turning point for people who will develop interest in any kind of research. So, it is possible to say that if children are stimulated and feel free to open books by themselves, then we are probably going to watch the development of a generation with a greater sense of concentration, observation, criticism and imagination. These qualities can improve the capacity of processing information and can create a point of view on their own, researchers or not. They act in public and private life as citizens and healthy people in the largest sense of the concept of health.

The activity had to integrate both the objectives of the event "Paixão de Ler" and the objectives of FIOCRUZ (Oswaldo Cruz Foundation Institute), an institution with a focus on Public Health through researching, developing products, attending people, and informing and educating. FIOCRUZ has an entity called Casa de Oswaldo Cruz – COC (Oswaldo Cruz House) focused on History, and on the promotion of culture. The COC includes the "Museu da Vida" (Museum of Life), an interactive science museum that contains among its spaces the Ciência em Cena (which means "Science on Stage" or "Science on Scene").This is the place in Museu da Vida (Museum of Life) where research is conducted on the relationships between Art and Science via an approach that includes the impact of sensorial perception and Culture in development of knowledge

This work describes the steps that formed the structure of the resultant activity: a play called "Leio porque Quero" ("I read because I want to"), respecting various specific things and certain limits. We believe that thinking about a way to integrate the conceptual steps and the operational steps may be useful to educators, scientists and artists. Also, we guess that prejudices about some authors can be questioned by the reaction of the audience that not only attends the play but also plays a role in it by contesting a letter in the middle of the spectacle.

## INTRODUCTION

### CONCEPTS THAT GUIDE EVERY ACTION IN *MUSEU DA VIDA*

Firstly, it is interesting to know a little about the way this museum in particular is organized, in order to understand some of the specific things we have already mentioned.

*Museu da Vida* is a space of non-formal Education and the focus in Health, Science and Technology Information is shared with the visitors by expositions, activities and attitudes that permit them the freedom to discover and to ask questions. It serves as the basis for future researchers or citizens interested in decisions that make our planet a good place to live or not, and it is closely related to the ways that Health, Sciences in general, Technology, intend to go through. At the same time, we understand that the visitor is a subject that may connect hands, feelings and brain, as parts of the same hole, each one being necessary as the other. This subject owns and is "owned" by a community, and the notion of space and time and the relationship among local and global cultures is the basis for developing a point of view and critical thoughts about matters like bioethics, chemical weapons, the possibilities of development of technology, transgenics, it's sponsorships and supports, and whatever that can act on them and the community. We guess that this attitude may develop respect in human beings and change or improve the conditions of life of the majority of the people around the Earth. So, it is this belief which underlies the main actions proposed by the Museum. As Hannah Arendt notices in her book, "The Human Condition" at page 201:

".the political recent history is full of examples that the expression *human material* is not just a inoffensive metaphor. The same can be said about innumerous scientific modern experiences in the fields of social engineering, biochemistry, brain surgery, etc., all of them looking to manipulate and modify the human material as if it were any other material. This mecanicist attitude is typical of the Modern Time. When looking at objectives like these, the Antiquity disposed to conceive man as a savage animal that should be tamed and civilized. In any case, the only possible result is the death of men, not necessarily as an alive organism, but as man."

If Arendt wrote the book in 1958, the danger that the expression "human material" is absolutely contemporary. It becomes necessary to comprehend the human being as a hole, as "the distinction, that he shares with everything that lives, become singularity, and the human plurality is the paradoxical plurality of singular beings." (Arendt, 189). Following this perspective, the Museu da Vida opted to be multidisciplinary, adding to the patterns that the institution Museum contains the patterns of Health, Science and Technology Education in a transforming point of view. Is important to notice, that since we are at a health research institute, that we work according to the definition of the Ottawa's Letter –1986, when the First International Conference of Health Promotion concept defined health as "the process of capacitating of the community to act in the development of it's quality of life and health, including a major participation in controlling this process. To reach a state of complete well-being in the different spheres of the individual (e.g. the body, the mental and the social), the subjects and groups must know how to identify aspirations, satisfy needs and modify his environment in a favorable way. (.).The responsibility of health promotion is not only of this sector, but also, points to a global well-being."

By this thought it was necessary not only to inform about health, but act more deeply. So, we look at matters that impact the human being through the times. We are going to look to the past, in order to imagine and plan the future. We will look at what we are doing with life on this planet, in order to understand the possibilities of balance we have. We will examine the way that energy and information are processed in different levels, in order to understand that everything is connected. We will examine the process of making Art, in order to recognize what we may do with that energy and information and also, the need of transcendence that we still have. Every activity is developed through research, and presented, and modified after hearing the answers of the public. They are continuously analyzed, by the people that conceive them as well as by the science education center of the museum.

## THE OPERATION OF *MUSEU DA VIDA*

The museum has been open since 1999. It is especially careful with the school visits that occur during the week. And since a year ago, at which time it began to open on weekends, the museum noticed that it is necessary to be careful about the families (a new public) which visit on those days. It is common that the student that comes with the school also visits with the family on the weekend. Many times, the students who live in low rent communities may have a better education than their parents. This is a specificity of this museum, located in the area of Avenida Brasil in Rio de Janeiro. The entrance to the museum is tax-free, attracting a segment of the population that usually doesn't have very many available cultural options, but not only them. As a result, we can see that it becomes a democratic space of social acquaintanceship. The Museu da Vida has a Science Education Center that proposes a constructivist point of view to each of the spaces. The spaces are: Parque da Ciência, which works on concepts about energy and information; Biodescoberta, which demonstrates many aspects of the phenomena of life; the Passado and Presente, which reflects on the History, the past and the present by a charming footing by the Mourisc Castle, a historic patrimony; and last but not least, the Ciência em Cena, which tries to reveal connections between the meanings above and the process of making science and art, in a critical and expressive way. During the week, the visits are organized in a manner so that the visitors can know two different spaces, staying at about one hour and twenty minutes in each one. They are going to spend a morning or an afternoon. It is necessary to make an appointment about a month before the visit. Teachers are invited to become familiar with the museum so that they can make choices according to their interests. On the weekends it is not necessary to make an appointment, but not everything is open. In the Ciência em Cena the activities change each day in a week and on Saturdays when there is a play or a show or a video, it is necessary to arrive about a half an hour before in order to get a ticket. So, on the weekend it is possible to visit more than two spaces, knowing that it is a different visit than that made during the week. Not only schools, but also groups in general can make an appointment and visit during the week. The museum is open from Tuesdays to Fridays from 9 a.m. to 5 p.m., and on Saturdays and Sundays from 10 a.m. to 4 p.m.

## *CIÊNCIA EM CENA*

### APPLYING CONCEPTS – TENSIONS, INTERSECTIONS AND RELATIONS AMONG ART, SCIENCE, TECHNOLOGY, EDUCATION AND COMMUNICATION IN A VERY SPECIAL MUSEUM

It is possible to detect a reaction in a "scientific" public when they know that *Museu da Vida* promotes a space dedicated to art and science. The exploration of science and art is mainly done through one of the most ephemeral of the arts: the theater. In general, people justify the existence of these activities with a utilitarian principle: the arts may talk about a matter without the obligation of the school, but being informative, and very charming. It isn't wrong, but at *Ciência em Cena* we look for something deeper. We intend to investigate the need for Art and Science, observing those aspects they have in common (in their processes they both use perception, observation, abstraction, research and imagination) as well as the aspects in which they are different from each other (such as the possibility of being measured and the primary finalities of application). We observe also the way one can communicate with the other, or by the technological advances that allow art to use new tools, or by the way that art may uncover some new reality, or the way that it may express the dreams of the society, each time showing the fight of human being between survival and transcendence. Not accidentally, someone already said that Art is the dream of the world. To make these ideals practical, we call on other knowledge fields, such as Education and Communication, and at the same time we must take a look at History and Philosophy. We do this in order to encourage complete human beings, which we mentioned above. So, it is possible to notice that besides the many concepts in Ciência em Cena, we also act and reflect on these on at least three different occasions: when we conceive the activities, when we attend our public, and at this moment it is done altogether, and after the activities, integrating what objectives were or not reached, the surprises of the process and the changes we intend to make.

### PERCEPTIONS ON: *CIÊNCIA EM CENA* WORKING

The multidisciplinary staff at *Ciência em Cena* (Science on Scene) is composed of actors, art educators, physicists, a neuroscientist, journalists, technicians and producers. There are university trainees as well as trainees in a course developed inside of the museum specialized in the formation of personnel for center and museums of Science. These people are usually divided among more than one of the projects, and it is the same staff that works during the week as on the weekend. There are three areas in which to perform activities: the theatre, called *Tenda*, with a hundred and twenty chairs, and structure of light and sound; the external area, a big garden exposed to the weather and the center of activities, also called *Epidaurinho*, a small stage containing about sixty places, a lab of Optics, a lab of Acustics, and two editing rooms.

There are three main projects developed by *Ciência em Cena* (Science on Scene): the Perception Laboratory, the Video Club of the Future and Theatre.

The Perception Laboratory integrates activities around the theme of playing improvisations, thinking about the way that brain processes information and noticing the optical illusions to which we are exposed. It is offered in four sessions, one day a week, to groups of up to forty visitors. Other activities came from the original activity: "Noticing Sound and Light", "The Art and Science of Perception" and "Hands on Brain!".

The Video Club of the Future works on the critical reading of image and information by stimulating the visitors, generally students, to create and realize a short video during the visit. In order for this to occur, the teacher comes first and forms a workshop with the staff, then, she (he) comes back to the school, prepares the script and the pre-production with the students, and returns with them to record, edit and evaluate the process. The idea is to stimulate the creation of Video Clubs in schools as part of the process of developing critical observation and expression while the students get in touch with technological processes of audiovisual and media .

The Theatre is the oldest project of the three, idealized by Virginia Schall, PhD. At first, it presented "The Messenger of the Stars", a play by Ronaldo Nogueira da Gama about Galileu Galilei's life. After the play, there was a debate about the subjects that interested the public: the holes of the moon, the moons of Jupiter, curiosities about Galileu and his family, questions about the Inquisition, and the process of making a play about it all. From 1997 to 2000, it had been performed to twenty six thousand visitors of different ages, mainly children from the public school. In 2001 a new play began, "The Mystery of the Barber" inspired in "The Night Barber" by Antonio Carlos Soares and directed by Jacyan Castilho. This play performs the discovery of "Chagas Disease", made in Lassance, Minas Gerais, by Carlos Chagas, one of the most important scientists of this institution. After the play there is also a debate in which the public asks about the cure of the disease, the role of the prevention, the importance of environmental care and also, the making of the play about it all. This spectacle is on stage nowadays and, depending on the audience, it will be in performance for a long time, or so we hope. Through December 2001, about seven thousand visitors cheered with us for theatre and science. The practice of these debates leads us to those things the public generally rejects (as a distant posture with difficult words or in the time of explanation) and to those things that attract them. We try to maintain the posture of no prejudice about questions or about whom is making the questions. We try to give short and interesting answers and we also introduce new questions in answers, questions that encourage everybody to think in a new way. The affective dimension of the activity can't be denied, and it is common to observe the continuity of the theme in schools.

### PAIXÃO DE LER

Paixão de Ler (Passion of Reading) is an annual event promoted by the Culture Secretary of the Municipal District of Rio de Janeiro. The objective is to develop the pleasure of reading and improve the access to books, especially in children.

Some institutions are invited to join the event. Museu da Vida has been since its opening in 1999, under the coordination of Laíse de Carvalho, our librarian. And it was at her request that we developed a special activity for the event.

### STRATEGIES AND DATA

Now we consider that the specifics are exposed. Also it is possible to notice the conceptual and operational state of movement that defines the museum. The limits were also clear: no budget, little time for rehearsal (since the theatre is busy almost every hour), the needing of making something very movable, little personnel in order to avoid troubles for the schedule. We could count on some resources: the video, that could help us to create an atmosphere since it was not possible to make scenery, the capacity of research, some fonts and time for it – this was the biggest phase, taking about three months.

### THE RESEARCH TO COMPOSE "I READ BECAUSE I WANT TO"
### CRITERIA FOR SELECTING THE TEXTS

In the beginning of the research, the method consisted of list of the main objectives, those already mentioned as concepts of the *Museu da Vida* and *Ciência em Cena,* added to the objectives of *Paixão de Ler*. So, it had to be pleasant, informative, critical, and creative and to be accessible and interesting to different kinds of people, while centered about the habit of reading. To meet these needs, and as exemption is an illusion, were added the personal anxieties and taste of the author. As we are in a science museum, it seemed appropriate to talk about the history of inventions and discoveries, and the impact or influence of these new technologies in history, in order to popularize the access to books and ideas. Among the prejudices around Science is the idea that it is something ready, perfect and untouchable, and that the old cultures thought as we do. The old scientist "ethos" contributes a lot to this idea. When we study the history of science and technology as something under construction, we transform it into a human activity, and not something made by gods, the gods of the knowledge. If science is a human activity, then, ordinary people can try to develop this activity or to think and have opinions about the profits and risks of research; then, it is possible that sometimes, scientists make mistakes, the same when they are up to discover or create something amazing. We had to talk about it in a language that children could understand. They didn't have to know every word, but they had to understand the idea and the action behind it. Monteiro Lobato, the Brazilian author that wrote for children in the thirties and stimulated a lot the pleasure of reading through generations, gave us the passages that covers all these necessities:

> "..Same in this way, man's life can't be compared with yesterday's life of man. The benefits of the inventions are extended to almost all of the habitants of the planet. The more humble modern worker has commodities that would be dreams of old kings. All the houses get light at night (.).If the emperor Carlos Magno wishes to listen to a concert executed in another continent, could he do it? (.).It's true, grandma, the poor Carlos Magno never saw an ice-cream nor cinema..." (Lobato, 290).

And in another point:

> "..we have the sewing machine, the ink and the paper, that we use to fix our thoughts and Emilia writes her memories, the kitchen knife...
> – We have the books!
> – Yes, the books, where the men of imagination and culture fixed their ideas, Pedrinho's camera that time from time obliges me to pose with a smiling face.."
> – What we didn't get yet is a way of life that makes the inventions benefit all creatures equally. And the biggest human invention will be this: a social system where everybody has everything (Lobato, p. 291)

In another scene, D. Benta, talks about the paper itself:

> "Pericles was deeply interested in an example of "*Reinações de Narizinho*" found there. - It is a model of a modern book – explained D. Benta – made of paper, a substance that the Greeks don't know yet. We do not use the papyrus nor the parchment anymore. This paper is made of cellulose, I mean, the substance that composes trees. The printing is made in printing presses. The invention of the book permitted that ideas get an incredible divulgation." (Lobato, p. 198)

As we try to make our visitor develop an understanding of the space he or she occupies, and as we are in Rio de Janeiro, Brazil and as our community speaks Portuguese, it was important to look for appropriate authors. As we are a human group, if we had this dimension, we could also have a look at other cultures of the same Earth. So, Aníbal Machado, Clarice Lispector, Carlos Drummond de Andrade and Cecilia Meirelles were possible. Much material of them couldn't be maintained, because of the time we know people use to consider theater an interesting experience. In this case, as we tried to develop interest, it would be dangerous to force time. As a Portuguese writer's of other countries, Fernando Pessoa and the Angolan Pepetela were chosen. José Saramago was chosen, too, but it was necessary to give up this intention, when the material was mixed, in despite of the intentions of the author. Domingos Oliveira, a Brazilian writer, entered observing the relationship between languages, the old tradition of telling stories, in this case of reading or writing a book. Malba Tahan, also, just points the action, in video, after a lot of trials of the author that wanted a moment about Maths. Nietzsche came as a counterpoint, calling in his own way the Dionysos when provoked in the famous passage called Read and Writing in the Zarathustra's book:

> "I only could believe in a God that knew dancing." (Nietzsche)

The apology of reading is made at the moment, that Pepetela the writer from Angola, underlines the need to read:

> "People must study, because that is the only way of thinking about everything with their own head and not with someone else's head. The man must know more, always more and more, to conquer his freedom, to know how to judge. If you don´t understand my words, how can you know if I am talking well or not? You have to ask another. It depends on the other one, all the time, you are not free." (Pepetela, )

## THE CREATION OF A NEW ORGANISM

The second phase was the most difficult one: how to connect in an interesting way, all these different authors, without hurting any of those writings and creating a sense? At this time it was not clear that it was going to be a play. It had to be an activity, something that could create thinking and joking at same time. So, it was necessary to develop a story. A story that can make children feel connected. We didn't want to make the mistake of telling: "Look, you must read, reading is good, so do it." We knew that if we did it no child would ever like to open a book. So, by opposition, it could be good if reading should be a problem. Also, we knew that it wasn't clear the connection between this matter and health prevention. Thinking of problems in children and adolescents, we can remember sex, parents, changes in the body, school, drugs..Yes, that was it, a girl who was addicted to books and a worried mother, because her daughter didn't swim, or have friends, or help her with the dishes. The other roles, the father, the grandfather and the father in law came to complete the frame. It was not possible to maintain all the chosen texts, it was a pity, but the big majority could stay. The text of Anibal Machado, one of the most difficult to find a place, finally could achieve a special scene. It was so important because it is the only one that showed a common man trying to write a telegram, and the difficulties about it. So, it was necessary to create a new text, in order to tie all the texts together and create an organism. The references of the texts are related in the end of this work.

## HOW TO REACH THE OTHER DIMENSIONS

The problems were not all solved yet: ok, the audience could listen to the authors, could see us reading, but what about see, and read, the letters? The video solved this problem. Images of phrases, and of hands writing would be projected.

But now the audience watched and read, ok, but what about writing? The answer came as a solution for the structure of the play: The characters would "write" to his friends, looking for help. And the friends would be the audience. It was necessary to create the letters in a way that could be easy to people understand and answer, also it had to seem to be written by the characters, telling their problems. The first letter, and the easiest to create was the mother letter, because the conflict was clearly written as hand-free, with an adult letter:

> " What *saudade* ("nostalgia")! Finally I may disclose my heart to you. But at first, I would like to know, how you all are? Here, everybody is ok, but Paula Efigênia gives me a headache. She doesn't stop reading! She doesn't help me at home, doesn't like swimming class and almost has no friends. I like that she reads, really, I am proud of it! But it is too much reading! Do you think I am wrong? Kiss, M.

The second was the Paula Efigênia's letter, written as hand-free:

> "Hi, is everything ok?
> Here it is ok, no news. Is it true that you will go to a lecture room? I would like to go there sometime. What do you like to read? Do you think that my mommy is right to not want me to read so much? Just because I forget and read anywhere? Kiss, Pefige.

The third letter was the father's letter, like a printed e-mail:

> "Do you know my last daughter, a Pefige? She wanted me to be a newsstand man. I don't have anything against newsstand men. But is it a shame to be an architect? Where do you think she got this idea? Her mother thinks that I must talk to her. But how, what should I do? See you, F.

The fourth letter is from the father in law, also like a printed e-mail:

> " Hi, friends, how do you do? Next week I will be there in that audience. I would like you help me to choose some gift for my sister and her daughter, Pefige, my daughter-in-law. I don't know if you remember her, she is almost ten years old, already.. . Well, I will have a short time. Is it possible? What is your suggestion for me?

So it is part of the structure to wait for the answers (a wait of about 5 minutes) that are written or designed in the moment by the audience. As we live in a country where many people can't read or write, people are invited to design if they prefer, or to ask for help from a neighbor if "they aren't with glasses", a usual and polite excuse when people can't read and we don't want to expose them. Some of the letters will be chosen and read by two children (a girl and a boy) on the stage. Two other letters have been previously prepared, in the case that no one wants to write (which may happen), which talk about the what a bad thing it is to be addicted to anything, and how it is important to look for balance in life. While people answer the letters, a 5-minute video is projected. In this video we show images of different alphabets, images designed in the caves in the pre-history, newspapers, books, different ways of writing or designing, the computer, and all the time we have music. And at the end, we have the sound of the arrival of e-mail, over the image of a post box, and a computer, in order also to connect the influence of technology in our expression. At same time we advise the public that the time to answer is over.

## FINALIZING THE CONCEPTION OF THE PLAY

The two prepared letters the play is brought to an end. A letter from a boy, Maicon (the Brazilian version to Michael) and other from a girl, gives the line:

> "Mrs mommy, this is a letter to you, but for the father-in-law too, to the father and the grandfather too. You adults complicate things so much. One day you will see that Pefige grew up and is teaching a lot of things to you, who even turn on a computer, TV and radio well, can. I hope you solve your problems and that they are only these. If you want to visit me, the address is above. I don't offer coffee because I am poor, but we always have water. Luis Maicon, the smart. Ps: I read because I want to.

"Pefige, you are such a fool for not swimming. Water is a delicious and fresh thing that I like. I read too. I prefer comics, but I already read "The boy of green finger"[1] and "The Crime Genious"[2] which I love. It gave me a lot of ideas. Did you notice that people inside the books do a lot of things? Life gets better if we do too.s. Leila M. Neves from Grajaú.

After this, the play comes to an end. It is necessary to finalize the themes. And here is the last challenge, to prepare the return of the audience to daily life, taking the sensation of the discovering of something that, at all, was inside of them. The capacity to analyze things, to create, to communicate and above all, the desire to making a better world. This is the time that Pefige answers the last letter:

> "I know this, but I have fear. Inside the book I have no fear. What I think is that one day, maybe I will have something to say. And then it will be good. I know I lost a lot of good things, I lost friends, I lost key, I lost the time to turn off the fire and the food get burnt..I guess if one day I lost the fear.".

After this, the father-in-law talks about how fear can push people also, how important it is to deal with feelings in order to grow-up. This is told in a Carlos Drummond de Andrade' poem, called "Magic Word" (given in Portuguese):

> "Certa palavra dorme na sombra
> De um livro raro.
> Como desencantá-la?
> É a senha da vida
> A senha do mundo.
> Vou procurá-la.

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1 Maurice Druon
2 João Carlos Marinho

Vou procurá-la a vida inteira
*No mundo todo.*
*Se tarda o encontro, se não a encontro, não desanimo,*
*Procuro sempre.*

Procuro sempre, e minha procura
ficará sendo
minha palavra." (Drummond de Andrade, 118)

At the very end, we return to the beginning text of Domingos Oliveira, followed by a video projection of the paintings of pre-history in order to connect time, space and the continuous need of human being to communicate and tell stories.

It was imagined to be a fifty to sixty minute play. After the spectacle, the letters are computed from tables in order to analyze the comprehension of the audience, and the meaning of their answers, in order to notice if they have the habit of reading, whether it caused any reflections, and other social structures that appear behind the answers.

**PERFORMING**

Now, is the show time: the play is performed by two actors (Alex Cabral e Duaia Assumpção) and two technicians (Armando Feitosa e Ronaldo Barboza). It is good to have a producer in order to prepare the letters and solve any problems while the staff rehearses. The *premiére* was on November, 2000 and it was also performed at an event called "Bienal do Livro", in May, 2001 and again in November, 2001. It was presented on Saturdays, to audiences of families with children, two schools, and a church group, adding 266 visitors. People of every age attended the play, divided by ages between 4-7 years old (30), 8-10 years old (45), 11-14 years old (38), 14-18 years old (53), 18-60 years old (70) and above 60 years old (23). Children love when they are mentioned by Fernando Pessoa:

> *"Children are so literary. Once, I saw a child who wanted to cry. The child didn't say "I want to cry" that is the way that an adult, or an idiot, would speak. The child said " I have a wish of tears".*

Since these early times, the play has changed in attempts to improve communication. After September, 11th, 2001, a passage by Pepetela about learning in limited situations got a different light. We were considering taking it out of the play, because we noticed a certain lack of understanding, but as a result of this terrible event, exactly the opposite happened: the scene grew and became a peace manifest. A folder was made with the reference of the texts, so people could find them and know more, if they wanted.

**THE LETTERS**

The letters were answered, by designing or writing, one of the four letters. The letters to Pefige also are the more kind, even when the answer comes from someone that doesn't agree with the girl. This is the one we give here as an example in table 1:

| Respostas de 11/11/2000 Paixão de Ler - Pefige | nome |
|---|---|
| 3. Por aqui tudo bem. Eu fui assistir ao Paixão de Ler ou é o evento mais bacana do ano na cidade. Eu gosto de ler de tudo, principalmente contos. Não concordo com sua mãe. Acho um absurdo! Tem mais é que ler mesmo. Continue lendo. Beijos, Leila | Leila de Oliveira |
| 4. bem. É. Histórias de guerras. Não . Não. | Izenilde Souza Monteiro |
| 5. revista. Não. Sim. | Felipe Félix da Silva |

| | |
|---|---|
| 6. Bem! É sim. Livros de tristeza, porque não estamos conformados com o mundo, para que mais tristeza?<br>Não porque faz bem ler, bom não em excesso. É claro que não. Beijos | Ana Carolina Meireles L M. de Senna |
| 7. Pefige, adorei receber sua carta. Está tudo bem! Acho que você deve continuar a ler e muito. Isso e muito bom para a alma. Gosto muito de poesias e histórias infantis. Beijo. (desenho de coração) | Prof. Rosane (Malvar) |
| 8. É claro quenão, a leitura não deixa ninguém sozinho, é a melhor companhia. | Daniel Ribeiro Carrero |
| 9. Graças a Deus está tudo muito bem aqui. Eu adoro ir a sala de leitura, pena que o tempo que me sobra não é possível que eu vá constantemente. Seria muito bom se se você pudesse ir lá. Eu gosto de ler romance e suspense. Não há razão de sua mãe proibir tanto que você leia. Só é preciso que haja um controle nos momentos em que você separa para as leituras. Um beijo. | Renata Costa |
| 10. desenho de cena com duas figuras de costas (cabelos grandes), mesa com livro, figura humana com livro, livros e um quadro, ou telão, ou janela com montanhas (?) | 2 desenhos<br>Suzany F. Bastos |
| 11. banca de jornaleiro | sem nome |

In the four kinds of letters are distributed, just one person in all the three plays refused to receive a letter, eleven returned without answer and eighteen didn't return. The others accepted and returned with different answers.

| dia | público total | média de 4 a 7 anos | média de 8 a 10 anos | média de 11 a 14 anos | média de 14 a 18 anos | média de de 18 a 60 anos | média acima de 60 anos |
|---|---|---|---|---|---|---|---|
| 11/11/2000 | 53 | 5 | 10 | 5 | 10 | 20 | 3 |
| 26/5/2001 | 160 | 20 | 30 | 30 | 40 | 30 | 10 |
| 10/11/2001 | 46 | 5 | 5 | 3 | 3 | 20 | 10 |
| | | | | | | | |
| cartas | distribuídas | devolvidas | padrinho | pai | mãe | Pefige | |
| 11/11/2000 | 53 | 44 | 11 | 7 | 14 | 12 | |
| 26/5/2001 | 160 | 101 | 6 | 8 | 32 | 38 | |
| 10/11/2001 | 46 | 41 | 10 | 13 | 4 | 14 | |
| | | | | | | | |
| cartas | resposta a outro pers. | enviou mensagem | desenhos extra | indefinidos | devolveu sem responder | não devolvidas | não quiseram carta |
| 11/11/2000 | 1 - mãe. | 0 | 9 | 1 | 0 | 9 | 0 |
| 26/5/2001 | 2 - pefige | 1 - mãe | 8 | 2 | 4 | 55 | 0 |
| 10/11/2001 | 1- pefige | 2- atores | 6 | 3 | 7 | 4 | 1 |

Analyzing the table, it is possible to wonder why the children follow the proposition with the help of their relatives. The preference to Pefige's letter or to the mother's letter is a possibility, because the letters are distributed in the same number, by chance, behind the chairs, but it is not controlled if someone changes one letter for another.

Other examples of the answers to the girl's letter are:

1. No, because it is good reading, well, not so much. Of course not. Kisses. Luiz.
2. Thanks God everything is so good here. I love to go to the lecture room, what a pity that in the time I have it is not possible I go constantly. It would be so good if you could go there. I enjoy novels and thrillers. There is no reason for your mother to forbid you to read. It is just necessary for you to control the moments that you choose for reading. A kiss. Renata.

- The mother's letter, where she asks to a friend if she is wrong. She worries about the health and solitude of her daughter and doesn't know what to do.

Example of the answers to the mother's letter:

1. Everybody here is fine. You are not wrong, you are right. You do what you want, even if people don't like you as you are, isn't a problem, the important thing is that you like it and are happy. Kisses, Daniele, 12 years
2. You are wrong. You have to stimulate her more, but show her that reading is important but is not the only thing, there is time for everything. Katia.

- The father-in-law letter, where he asks if the friend has a suggestion for a gift to give the girl.

Example of the answers to the father-in-law's letter:

1. A watch. Suely.
2. A book of stories. Marcelo. 7 anos.
3. A design of a flower written "To the mother" and a design of a book written "Pefige" (the girl). Kelvin. 6 anos.

- The father's letter, where he tells that his daughter told him she preferred if he were a day laborer in a newsstand than an architect, his profession. He says he has nothing against day labourers, and asks if is it wrong or ugly to be an architect.

Example of the answers to the father's letter:

1. Being an architect is not a shame. To be an architect you read. Try to enter in the world of your daughter, the world of reading because it is beautiful. I tried and I also am interested in this world. Try. Sorry for the mistakes, I wrote fast. Vânia. 24 anos. I loved it.
2. Certainly she took it by the books she read so much. You must talk to her you don't want to be a day laborer. Talk to her firmly. Good Luck!!! Tatiane. 11 anos.

It is also possible to note examples of other kinds of answers:

1. I loved to be here and I loved you both. I don't like reading but I always read the Bible. And I feel that the mother must support her daughter. Maria Celeste.
2. The aerodynamics of life is more fastened than our thoughts. The man turns on the character of life by reading a good book. Luiz Roberto.

The first time the play was performed, the people were not asked to give their age, so estimates were made. On the second and in third times, we considered that it could be done, and almost all of the people included their age besides their name. It is not mentioned that the letters will be read or that two children will do it, with our help if necessary. This surprise sounds good to the public, as the letters are chosen by a raffle and the children (volunteers) are the one that choose the letters. It is also not told to them that we give them four different gifts, either books or glasses of soap-bubbles after reading their letters. The gifts go to the children who read and to the writers of the letters. We let the children choose and there is no problem about choosing the soap bubbles, but this happened only one time.

Usually, this kind of moment may cause trouble at the time of the conclusion of the play, but in the three performances we didn't have difficulties returning to the story, since we also use the reading of our prepared letters and only softly do the lights begin to fall and re-create the atmosphere of stage.

## THE TECHNOLOGY BEHIND THE STAGE

A point we describe at the end is about the role of our technicians, without whom everything would be very different. It is at this moment that we reveal the making of a play. It is possible to look to our lights, to think about the video projection and if it was like this in the old times. There is also the moment to share the discovery of the importance of language, thought, knowledge, health, communication and transcendence for human beings. At this moment, Science and Art come together.

## CONCLUSION

We believe that this is a work under construction, and a force of its own nature. It is common for theater to be a living process. But many questions can be asked about this experience. Sometimes, fame precedes the work of a philosopher, a scientist, a writer or any creator. It may be a way to attract interested people or a way to maintain the distance of a shy audience, not so sure that they able to understand that language. When we work on creations and on research, it is necessary to look with respect, but without fear to the people who have made the history of our knowledge. They were people like us, who found a special method to develop their thoughts and acts. To reveal this by using the irreverence of the theater, this ancient way to look for the myths and legends, may be a way to make a dialogue between Art and Science, finding the Education and the Philosophy, creating intimacy with great authors and revealing new ones.

It is also a political choice to ask people to answer letters, to write, in the same space that these writers are occupying. It is just a seed, a possibility, not an obligation nor a ready work. It is to provoke, through amusement. The interaction here includes the moment of doing but also the moment of observing, of making part by breathing with, the silence and a moment after, the answer.

We believe also that exposing the method used to structure such work is a metalanguage of our own practices. We hope that it is something encouraging for people who are interested in this kind of work and different possibilities.

Here is a translation of Domingos Oliveira that summarizes these thoughts:

> *"They weren't many. During the day they hardly talked, because it was difficult to survive and there was too many things to do. But at night, they join around the fire to feel warm. Suddenly, one of them stands up and begins to say something!..The others pay attention. All these dramatic arts, the cinema, the theater, are just repetitions, more sophisticated of this old happening. When a man, near to a fire and under the stars, was telling to his fellows creatures, hallucinated and dizzy, his testimony about the mystery of life."*[3]

At all, here we are, so far from our old fellow creatures, so near from their doubts and wishes.

**Works used on the play**

MACHADO, A, (1989) O Telegrama de Ataxerxes. *A Morte da Porta-Estandarte* 13ª ed. José Olympio ed.,RJ.

LISPECTOR, C., (1984) Dicionário. *Água Viva*. José Olympio ed., RJ.

TAHAN, M., (1987) Prefácio. *As Maravilhas da Matemática* – 6ª ed Bloch, RJ.

NIETZSCHE, F., (1979) Ler e Escrever. *Assim Falava Zaratustra*. Hemus Liv Ed., SP.

[3] Eles não eram muitos. Durante o dia mal se falavam, posto que sobreviver é difícil e havia muito o que fazer. De noite, porém, reuniam-se ao redor da fogueira para se aquecer. Eis que, de repente, um deles se levanta e começa a dizer algo!... Com os poucos grunhidos de que dispõe, mas com uma necessidade imensa de se comunicar. Os outros prestam atenção. Todas essas artes dramáticas, o cinema, o teatro, são apenas repetições, mais sofisticadas, deste velho acontecimento. Quando um homem, na beira de uma fogueira e sob as estrelas, contava a seus semelhantes, alucinado e tonto, seu testemunho sobre o mistério da vida."

OLIVEIRA, D., (1987) Do Tamanho da Vida. *Reflexões sobre Teatro.* ed Inacen/Minc.

DRUMMOND DE ANDRADE, C., (1978) Palavra Mágica. *Obra Completa.* ed Bloch, RJ.

PESSOA, F., (1999) *Livro do Desassossego.* Cia das Letras, SP,

PEPETELA, (1985) *Mayombe.* ed. União dos Escritores Angolanos, 3ª ed, Cuba.

MONTEIRO LOBATO,( 1968) Volumes 8, 13, e 15. *Obras completas.* ed Brasiliense, SP.

**References**

BACHELARD, G. *O Novo Espírito Científico.* Edições Tempo Brasileiro Ltda. Rio de Janeiro, RJ.

BETTELHEIM, B. *A Psicanálise dos Contos de Fadas.* ed Paz e Terra. São Paulo, SP. 1992.

HAUSER, *A **História Social da Literatura e da Arte.*** Editora Mestre Jou, São Paulo, SP. 1980.

LATOUR, B ***Ciência em Ação: Como seguir cientistas e engenheiros sociedade afora***. Editora Unesp, SP, 1997.

LOWENSTEIN, O ***Os Sentidos.*** Biblioteca Universal Popular AS. Rio de Janeiro, 1968

OSTROWER, F. ***Criatividade e Processos de Criação.*** Editora Vozes. Petrópolis, RJ, 1993

PRETTO, N. ***Uma escola sem/com futuro - Educação e Multimídia.*** Papirus editora. RJ, 1997.

SPOLIN, V. ***Improvisação para Teatro***. Coleção Estudos. Editora Perspectiva. São Paulo, SP, 1993.

ARENDT, H. *A Condição Humana.* Forense Universitária. Rio de Janeiro, 2000.

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# THE NEW SCIENCE LITERACY: USING LANGUAGE SKILLS TO HELP STUDENTS LEARN SCIENCE

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**Abstract**

Good science—-and effective teaching and learning in science—-is dependent upon strong language skills. Indeed, science and language are inextricably linked in the pursuit, determination, and communication of meaning in the context of the physical world. Increasingly, public policy questions require citizens—-through their votes or voluntary actions—-to decide the answers to important questions requiring scientific knowledge. To make those decisions, citizens must understand the scientific facts and processes in play, and they must be able to use language to communicate accurately about the scientific information on which those decisions must be based.

Just as language clarifies and communicates the meaning of science, science can strengthen the meanings that students find in language studies. Research has shown that the acquisition of literacy skills is significantly enhanced when those skills are used for specific purposes within a meaningful and stimulating context. In The Foundations of Literacy, Holdaway argues that "an effective learning environment for the acquisition of literacy should be alive with activity which is felt to be deeply purposeful in all the ways of human meaning" (Holdaway, 1989). Language instruction in concert with materials-centered science activities can provide just that purposeful environment needed to reinforce students' emerging literacy skills.

Performance expectations, strategies for explicit teaching, and students' metacognitive techniques form the structure of support that teachers can use to help students learn science concepts while improving their language skills.

Performance expectations in each area of literacy directly support students' science learning. The expectations help students understand how to more effectively express the scientific concepts, facts, and skills they are mastering. As a result, the expectations also allow teachers to gauge students' progress not only in language, but also in science: if a student is unable to express an idea clearly, how will the teacher know if the student actually understands it.

Teaching strategies that successfully combine science and literacy are based on three principles. First, inquiry-based science in the classroom naturally presents countless opportunities to improve students' science learning by strengthening their abilities to use language. Second, effective teaching strategies for uniting science and language are metacognitive. The metacognitive skills and techniques that students develop through these activities help them "learn how to learn" and to remain life-long learners. Third, by investing a manageable amount of effort and imagination, a teacher can expand almost any science inquiry to embrace language skills more deliberately and completely.

## The New Science Literacy: Using Language Skills to Help Students Learn Science

*The important thing is to not stop questioning.*
Albert Einstein

In an age fueled by information and driven by technology, understanding the concepts and processes of science is as indispensable as knowing how to read, write, speak, and listen. As citizens and as workers, adults in the 21st century will need to effectively apply a range of scientific skills and knowledge to understand their world and communicate about it.

They will need to be scientifically literate — to possess a set of skills that marries knowledge of science concepts, facts, and processes with the ability to use language to articulate and communicate about ideas. The National Science Education Standards declares in its introduction that the standards "are designed to guide our nation toward a scientifically literate society" in part because "Americans are confronted increasingly with questions in their lives that require scientific information and scientific ways of thinking for informed decision making" (National Academy Press, 1996).

This new, central role of science in our everyday lives places new demands on educators. All students must learn not only how science works, but also how to apply the principles and processes of science in their daily lives as workers, citizens, and consumers. Educators are being called upon to ensure that students internalize scientific habits of mind, such as using evidence to separate opinion from fact. If students are to become adults capable of making informed choices and taking effective action as citizens, consumers, and workers, then educators must make sure that students absorb those habits into their regular patterns of thought so that those habits stay with them long after their time in school has ended.

At the same time, the new importance of science opens a new opportunity for educators. It enables us to merge the teaching of science and of language literacy to strengthen students' skills in, and mastery of, both. As Johanna Scott writes in the introduction to her book Science and Language Links, "Language plays [roles] in science learning...science can be used to develop children's language, and increased knowledge of language goes hand in hand with the development of scientific ideas" (Scott, 1992). Researchers have found that students learn science better when they write about their thinking and that the act of writing "may force integration of new ideas and relationships with prior knowledge. This forced integration may also provide feedback to the writer and encourage personal involvement" with what is being studied (Fellows, 1994).

In the classroom, science and language become interdependent — in part because each is based on processes and skills that are mirrored in the other. These reciprocal skills give teachers and students a unique leverage: by fusing science and language in the classroom, teachers can help students learn both more effectively. Moreover, teachers can do so without taking on undue additional burdens to their work time or professional education.

It is not suggested that middle and high-school science teachers become English teachers. It is suggested that science educators in the upper grades can find a myriad of opportunities to support and strengthen the skills and processes of literacy as they teach those of science; and that elementary-grade teachers can find just as many opportunities to teach the skills of science while they teach the skills of literacy. Today's inquiry-oriented, activity-based science courses and lessons present countless opportunities for science teachers to use science and literacy to strengthen each other. In the course of their work in guided inquiry-based science, students can regularly:

- read and follow instructions on data sheets
- read and understand informational texts and literary works related to a science theme or topic;
- develop analytical skills to make judgments about the sources and reliability of information;
- listen acutely to clearly understand and interpret information given orally;
- participate in cooperative learning groups where speaking and listening skills are the primary means of sharing information, expressing and communicating responses and analysis, and coordinating activities with other group members;
- speak to explain their understandings or points of view about a subject;
- write journal entries, data sheets, narrative procedures, reports, persuasive documents, and occasionally even creative stories related to their science investigations.

By emphasizing each of these activities in their program, teachers can enlist a range of language skills to strengthen students' mastery of science. Indeed, the ability to absorb and exchange ideas clearly and precisely by writing, speaking, reading, and listening is an embedded expectation of science: good science, and good science teaching are not possible without strong language skills.

### Reasons to Link Science and Lteracy

When teachers take advantage of ready opportunities to unite science and language to strengthen each other, several benefits result. Among them:

- In elementary grades, science gives meaning and purpose to literacy activities by providing a rich field of content that students are naturally curious about — their bodies, the sky, animals, and so on. When literacy skills are linked to science content, students have personal, practical motivation to master language as a tool that can help them answer their questions about the world around them.
- The stronger a student's literacy skills, the stronger the student's grasp of science will be. Among people who are not professional scientists, scientific concepts, principles, and information are most easily expressed and understood in non-mathematical terms. Therefore, language becomes the primary avenue that students must travel to arrive at scientific understanding. As Fellows points out, "Writing [enables] students to express their current ideas about scientific topics in a form that they could look at and think about." Her 1994 study found that "[w]ritten words provided cues for expressing ideas verbally to others. Listening to others' responses and verbal expressions helped them reflect on their previous ideas and evaluate what was useful for making sense. Writing, speaking, and listening provided practice as students constructed new ideas and supplied a rich playground for expressive exploration as students tried out their new conceptions" (Fellows, 1994). In that way, a student's achievement in science will be directly proportional to the student's ability to use language.
- Many teachers in middle and high school assume that students entering science courses in the upper grades have an adequate vocabulary and the necessary skills to decode print and draw meaning from language. But too often, this is not the case. Older students may be able to perform the mechanics of reading, but comprehension in content areas frequently eludes them. By employing a few simple literacy techniques, and by teaching students some self-help skills, science teachers can help students improve their reading comprehension and, therefore, their achievement in science and other subjects.
- Literacy gives teachers new tools to assess students' science learning. At least one study has found that "...analyzing students' narrative writings...provided a methodology sensitive to distinguishing changes in students' thinking (Kleinsasser, Paradis, and Stewart, 1992). Another has "demonstrated that student writing provided a vehicle for teachers to follow students' changes in thinking...Students' written ideas provided a window into their thinking processes" (Fellows, 1994).
- Linking science and literacy can help to rescue science education from a precarious future. At this writing, science education itself is at risk, especially in elementary grades. In recent years, policymakers and the public have been gripped by the idea that student scores on standardized tests in reading and mathematics must improve year by year. Consequently, in elementary grades other subjects are not infrequently shunted aside as disproportionate amounts of class time are devoted to drills and exercises in math, reading, and related test-taking techniques.

In the upper grades, science does not necessarily escape the damage wrought by the pervasive emphasis on standardized tests in language and math. Thanks to those tests, districts have powerful incentives to channel money and other assets disproportionately to those disciplines, robbing science education of the resources it needs to ensure that students learn science effectively.

Science educators can stem that trend by linking literacy and science. By making their subject a key element in strengthening literacy skills, science educators can demonstrate that emphasizing science — not ignoring or de-emphasizing it — is a crucial step in improving students' language skills. In that way, science can become a potent element in raising students' achievement scores on standardized language exams, currently a dominant aim among tens of thousands of school districts.

Using and adapting literacy ideas to their science classrooms, teachers will be able to support the goals of literacy as they use inquiry-based science activities to engage and challenge students. In The New Science Literacy: Using Language Skills to Help Students Learn Science (Thier, M. Heinemann , March 2002), teachers will find an arsenal of insights, techniques and strategies to help them further meet these goals.

Successfully implementing science literacy in any classroom depends on the synergy created by combining three interconnected approaches: specific performance expectations for students, strategies for explicit teaching, and student metacognition techniques.

When performance standards are explicit, students know what improvement "looks like". Teachers use strategies for explicit teaching to show students how to improve. Students then can use metacognitive techniques to continue to progress on their own without teachers' repeated intervention. In short, the three-part approach enables students to become independent and, therefore, life-long learners.

**Performance Expectations**

To know whether they are improving in their science-related use of language, students need clear, easy-to-follow guidelines that point them toward improvement. At the same time, teachers need easy-to-use tools to determine whether students are improving their language skills in ways that enhance science learning.

As an initial toolkit, we offer what we have termed "performance expectations". The brief lists of expectations serve as short reminders that can focus the attention of students and teachers on key skills of literacy that necessarily are called upon in the course of good science teaching and learning.

The expectations' purpose is to give students and teachers a single, shared list of criteria for good performance in literacy skills while doing and learning science—-a goal implied throughout the National Science Education Standards. The standards declare that "students must become familiar with...rules of evidence, ways of formulating questions, and ways of proposing explanations." The standards also define scientific literacy as not only "knowledge and understanding of science subject matter", but also "understanding [of] the nature of science, the scientific enterprise, and the role of science in society and personal life" (National Research Council, 1996). Teachers and students cannot achieve these goals set by the standards without acknowledging and using the intimate connection between science content and the skilled use of language.

The performance expectations are designed for both students and teachers to use. Teachers can use the expectations to monitor students' progress over time. Students can use them, with the teacher's help, as roadmaps to independent learning and greater skill. By using explicit performance expectations targeted to grade level, students and teachers share specific, common standards for literacy growth while doing science. When both students and teachers measure students' work against the same explicit performance expectations, both can closely track students' growth in achieving literacy goals within the science program.

The groups of performance expectations have evolved through work with teachers at all grade levels, helping them incorporate the tools and techniques of literacy into their science programs. As a foundation, the literacy standards established by the "New Standards" project, a joint initiative by the Learning Research and Development Center at the University of Pittsburgh and the National Center for Education and the Economy, has been used. Those literacy ideas were then connected to the goals embodied in the National Science Education Standards.

The result is a framework of performance expectations that have proven, through teachers' use and experience in working classrooms, to be effective. However, educators easily might find ways to refine, adjust, or customize them to specific projects in ways that heighten the expectations' power to guide and track students' progress. In that sense, all of the performance expectations can be viewed as generic—-templates or suggestions that individual educators can shape and adjust to fit their own classroom needs and programs.

The detailed lists of performance expectations for reading, writing, speaking, listening, and media analysis give teachers practical examples and show how relevant expectations might be used in guided inquiry activities.

Included also are performance expectations and explicit teaching and metacognition strategies in two other related areas: group interaction and persuasive strategies. Those two areas have been added because both are crucial skills in political and social policy discussions as well as in the workplace. For example, science and engineering are deeply technical but also highly collaborative: a researcher, and particularly an engineer, rarely works alone on a technical project. The larger the project is, the more communication among diverse individuals there must be. (When Boeing designed its 777 passenger jet, it formed 238 separate design teams. The typical team included specialized Boeing engineers, aircraft maintenance workers, and representatives of Boeing's suppliers, shippers, and passenger groups, each imposing their own demands and constraints on the design.) If such a project is to be completed efficiently, communication among such disparate groups must be as thorough, concise, and error-free as possible. That result depends on the ability of those involved to use the learned skills of speaking, listening, and the other forms of negotiation through language that frame interaction.

Outside of technical fields, group dynamics and information transactions also play an increasingly central role in determining an individual's success in life and work. If a problem is to be solved, the person defining the problem and recommending a particular solution—-parent, politician, or corporate executive—-must use evidence to make a persuasive case. Therefore, knowing how to work smoothly with others to marshal evidence, evaluate information, and make decisions is a skill that has been raised to the same plane of importance as reading, writing, listening, and speaking. The inquiry-based science classroom provides students with countless opportunities to work in groups, and the related performance expectations can help students and their teachers gain the most from those opportunities. Below is an example of a performance expectation:

**Student Performance Expectations for Group Interaction**

- Takes turns, adopting and relinquishing tasks and roles appropriately
- Actively solicits others' comments and opinions.
- Offers own opinions forcefully but without dominating.
- Responds appropriately to comments and questions.
- Volunteers contributions and responds when asked by the teacher or peers.
- Expands on responses when asked to do so and gives group members similar opportunities.
- Is able to use evidence and give reasons in support of opinions expressed.
- Employs group decision-making techniques.
- Works with other group members to divide labor in order to achieve overall group goals efficiently.

## How Students Benefit

Performance expectations are to be shared with students. When presented effectively by the teacher, the expectations show students not only the goals that they are expected to achieve, but also what they need to do in their work to achieve those goals. When used effectively, performance expectations can empower students in three ways.

First, students can use each group of performance expectations as sets of explicit personal strategies to guide and improve their work.

Too often, when a teacher tells a student that the student needs to "do better", the student is left wondering what "better" looks like. Learners who struggle without success often feel paralyzed; they don't know what good learners do in order to succeed. When teachers share performance expectations with students, teachers let students in on the strategies that good learners employ intuitively. With these performance expectations in hand, students then can know more clearly what is expected of them. They have a clear path to follow in improving their own work instead of waiting for a teacher to render judgment. When they know and understand explicit performance expectations, students are empowered to take charge of their own learning and improvement—-which also lifts some instructional burden from the teacher.

Second, when used as guidelines for achievement, the expectations help shift a student's motivation and sense of control from an external source—-the teacher or a grade—-to an internal one; their desire to succeed.

Third, the expectations demystify reading and writing. They help students understand the specific steps they can take to become better readers. The expectations also help students understand that, in practical terms, writing can be thought of as "just talking that's been written down"—-and, therefore, is something that they are capable of doing.

When first confronting a set of performance expectations, students may not be able to use them without help. Even middle and high school students may not clearly understand what it means to "exclude extraneous details" from a lab report or to "compare and contrast" the arguments in two essays expressing different views on the safety of genetically modified foods, for example. The teacher needs to invest adequate time to demonstrate to students how to use the expectations to guide them as they read or write, or prepare or critique a class presentation.

Once they understand how to use the expectations as self-improvement tools, students gain the knowledge and independence they need to begin to help themselves use language more effectively as they do science.

As noted earlier, there is a keen awareness of the pressures on class time. However, extensive practical experience dictates that time invested effectively here will reap rich dividends as the school year progresses.

**How Teachers Benefit**

The performance expectations are designed to empower not only students, but also teachers at all grade levels. For example, many elementary teachers are less certain of their own command of science content than they are of their ability to teach language skills and, therefore, lack confidence in their ability to teach science effectively (Abell and Roth, 1992; Tobin et al., 1990). For those teachers, the performance expectations can help highlight the links and the common territory between the two disciplines, such as identifying logical fallacies or using evidence to justify a statement. Teachers can use the literacy techniques they are comfortable with to broaden their teaching programs to less familiar areas. The performance expectations presented here can help those teachers identify key language skills to cultivate in their students and then link those skills to the content-rich context of children's boundless curiosity about the natural world.

For middle and high school teachers, the performance expectations fulfill a different function. These teachers are science specialists. They cannot be expected to understand in depth the techniques of teaching reading or helping students become better readers of content information. In addition, these teachers typically are not used to the idea that they can help students grow in literacy skills over time.

The good news is that science teachers need not become English teachers. Instead, these performance expectations can help science teachers support literacy as a key element of their science programs. By identifying and exploiting the endless opportunities that science offers to use language clearly and precisely, science teachers can foster the growth of those skills in their students—-and, as a result, teach science more effectively.

**Not An Assessment or Grading Scheme**

These checkpoints have been dubbed "performance expectations" in a deliberate attempt to differentiate them from any kind of formal assessment or grading protocols. Establishing assessment systems is the purview of teachers and administrators. Just as important, teachers need not alter or abandon their existing assessment systems or practices to effectively adopt and use these performance expectations. They can, of course, integrate components of the expectations into their assessment or grading system.

Educators can use these performance expectations as loosely or as formally as they choose. Some teachers might use them only as rough yardsticks for spot-checking the work of underachievers; others might choose to organize each set of performance expectations as a rubric to track each student's progress in one or more areas throughout the school year. The expectations are flexible enough to let an individual teacher do either or to create their own to fulfill a specific need in a particular classroom activity.

### A Fundamental Performance Expectation

One performance expectation underlies all others, regardless of their origins. Any time that a student uses language, **the student should be expected demonstrate a proper command of the language appropriate to the student's developmental level**. Consequently, performance expectations for general use of the language are an inseparable part of all other expectations for students' language activities. That overarching expectation requires that the student demonstrates an understanding of proper usage, the conventions of language, and the rules of grammar (appropriate to grade level) in all forms of writing and speaking, including such elements as:

- proper verb tenses and forms
- proper vocabulary
- sentence construction
- paragraph construction
- punctuation
- spelling

Some teachers or entire schools establish style guides that students and teachers can use as a common reference to determine what is proper in punctuation, grammar, and usage. If no such guide is readily available, science teachers may wish to ask their schools' or districts' language department for guidance or for help in compiling guides appropriate to grade levels.

### Student Metacognition Strategies

Metacognitive strategies are explicitly designed to help **students become aware of their own thought processes** and to modify them to make those processes more effective. When students recognize their patterns of thinking, they also can become aware of the signals that tell them that they are having difficulty comprehending or expressing. However, many students cannot become better at using and processing language unless teachers help them cultivate the metacognitive skills of reflection and analysis. When students understand explicitly what good readers do to improve their comprehension, students understand how to help themselves when they encounter difficulties. By guiding students to that understanding, teachers can lead students to adopt specific strategies that they can use to learn and improve on their own. These strategies enable students to build their capacity to learn independently, without the teacher's continuing demonstrations or intervention.

A report by the National Research Council's Committee on Learning Research and Educational Practice underscores the point. "Because metacognition often takes the form of an internal conversation, it can easily be assumed that individuals will develop the internal dialogue on their own"—-the assumption underlying implicit teaching (Donovan et al, 1999). However, "[b]ecause metacognition often takes the form of an internal dialogue, many students may be unaware of its importance unless the processes are explicitly emphasized by teachers...Research has demonstrated that children can be taught these strategies, including the ability to predict outcomes, explain to oneself in order to improve understanding, note failures to comprehend, [and] plan ahead."

The report also emphasizes the importance of teaching metacognitive skills explicitly. "Each of these techniques shares a strategy of teaching and modeling the process...class discussions are used to support skill development, with the goal of independence and self-regulation."

Explicit metacognitive teaching strategies work, the report states. "Evidence from research indicates that when these...principles are incorporated into teaching, student achievement improves. Teaching metacognitive strategies in context has been shown to improve understanding in physics, written composition, and...mathematical problem solving." The study emphasizes the idea that teaching language skills and science in the context of each other can further leverage the power of explicit metacognitive strategies.

"Integration of metacognitive instruction with discipline-based learning can...help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them," the report concludes.

Below is one example of a metacognition strategy for reading comprehension:

**Reading Comprehension Prompts for Students**

Predicting:
- With a title like this, what is this reading probably about?
- What will happen next? (Turn to your partner and tell what might happen.)

Reflective questioning before reading:
- Why am I reading this?
- Why does the author think I should read this?
- What do I expect to learn from reading this?
- How does this relate to my life?
- What do I already know about this topic?

Reflective questioning after reading:
- What do I still not understand?
- What do I still want to know?
- What specific questions do I still have about this topic?

Evaluating:
- What is the most important idea that the author presents? Why?
- If I were the author, what would I say is the main point I was trying to make?

Paraphrasing or retelling:
- What was the reading about?
- Can I explain to my partner or group, in my own words, the meaning of what I just read?
- The group or class also can engage in "group retelling", with one student beginning and others picking up where the previous speaker leaves off.

Summarizing:
- Can I identify all the key concepts from the reading and write a summary using these concepts?

Identifying words and meanings:
- Does that word or passage make sense? Why or why not?
- Can I find something about the passage that can help me make sense of it?
- Do I know something about an unfamiliar word or its context that can help me understand what it means?

Reflecting on reading strategy:
- If I were to read this again, what would I do differently knowing what I know now?
- What helped me most in figuring out what was confusing or unclear?
- What other things could I have done?

**Strategies for Explicit Teaching**

Merging literacy and science does not mean that teachers now must teach two distinctly different subjects within the same limitations of time and other resources in which they used to teach one.

When choosing teaching strategies that combine the two disciplines, teachers can find approaches that show students how they can help themselves learn and improve. To that end, the strategies suggested are **explicit** rather than implicit.

The language teaching strategies employed in science classrooms are too often implicit: teachers assume that if a student reads a book, fills out a data sheet, or writes a report, the student's language skills will somehow automatically improve. But teachers know from long experience, as well as from test scores, that this is not the case.

Effective language teaching within the context of science is explicit teaching: the teacher chooses a specific learning strategy, explains and demonstrates it explicitly to students, then guides and coaches them as they adopt the strategy as a tool to help them learn more effectively. Explicit teaching helps students cultivate skills that enable them to become independent, life-long learners.

The explicit teaching strategies suggest ways in which teachers can "teach for independence": many of the strategies shift the locus of effort and control from the teacher to the student. When used effectively, such strategies can free the teacher from a good deal of repetitive instruction. With that freedom, the teacher can use a greater range of professional skills to lead students to higher levels of achievement and satisfaction—-in mastering science concepts as well as in using language to articulate them.

Reciprocal Teaching is one example of explicit teaching. This modeling strategy (Vaca et al., 1995) is designed to improve students' reading comprehension by helping them explicate, elaborate, and monitor their understanding as they read," notes the National Resource Council (Donovan et al, 1999). In Reciprocal Teaching, teachers model a particular technique that students can use to learn on their own to improve their comprehension. The method is reciprocal because the teacher and students exchange roles during their discussions about how to understand written material.

In other words, fusing the two disciplines within the context of inquiry-based science actually can make the teacher's job easier and richer, not harder. It can do so for four reasons.

**First**, the ability to use and understand language effectively is essential to good science. Skill with language and skill in science cannot be separated. The better students are able to draw meaning from—-and infuse meaning into—-language, the better science students they will be.

**Second**, the language skills emphasized and strengthened during inquiry-based science activities are embedded in the activities themselves. Students need to use the skills in order to do science. These are not language techniques that teachers need to drill students on or hand out worksheets for. Teachers demonstrate the skills; students adopt them and use them as templates of effective habits for doing better science.

**Third**, the more effectively students are able to use language, the easier and more satisfying the teacher's work can become: students who have a greater facility with language are more easily able to understand, discuss, and apply scientific concepts and processes. When students are able to use language skillfully enough to clearly communicate their ideas, teachers can better understand their learning patterns and styles and, ultimately, whether each student is actually learning. Teachers can more precisely understand what students are thinking and no longer have to wonder whether fuzzy ideas are a product of poor facility with language or of fuzzy thinking.

**Fourth**, therefore, the effort and time that teachers give to strengthening students' language skills through science is an investment, not an expense. The work the teacher expends can pay practical dividends far greater than the effort. A relatively small amount of time spent imparting literacy skills to science students will save the teacher even more time later—-time that the teacher then can use to lead students to higher levels of understanding than otherwise might be possible.

## Conclusion: The Synergy of a Three-Fold Approach

**Performance expectations** in each area of literacy directly support students' science learning. The expectations help students understand how to more effectively express the scientific concepts, facts, and skills they are mastering. As a result, the expectations also allow teachers to gauge students' progress not only in language, but also in science: if a student is unable to express an idea clearly, how will the teacher know if the student actually understands it? In other words, is the student's problem a deficiency in understanding the content or in expressing that understanding? Teasing the two problems apart can be even more frustrating for the teacher than the student; "I know it but I can't explain it" is not an adequate foundation for accurate assessment. Incorporating literacy and its performance expectations into science education often can resolve the dilemma. If students gain new skills in expression, they will be able to recognize for themselves weaknesses in their conceptual understanding.

Just as important, the expectations enable teachers to track students' improvements in science and language skills without needing to learn elaborate new assessment schemes or devote significantly more time to assessing students' work.

**Teaching strategies** that successfully combine science and literacy are based on three principles.

**First**, inquiry-based science in the classroom naturally presents countless opportunities to improve students' science learning by strengthening their abilities to use language. Teachers need not replace their current inquiry-based curriculum or their teaching methods or styles to blend the two disciplines. Rather, teachers need only to be aware of opportunities to emphasize students' attention to, and care with, language in the course of science inquiry.

**Second**, effective teaching strategies for uniting science and language are metacognitive. The strategies demand from students a sophisticated use of language as a primary tool with which to explore their science experiences and the meanings of those experiences in their own lives. The metacognitive skills and techniques that students develop through these activities help them "learn how to learn" and to remain life-long learners.

**Third**, by investing a manageable amount of effort and imagination, a teacher can expand almost any science inquiry to embrace language skills more deliberately and completely. That bit of extra effort is not a cost, but an investment that is repaid in students' greater mastery of science as well as language.

The combination of performance expectations and strategies for explicit teaching enables students to make effective use of **metacognitive techniques** to guide their own work and improve on their own, freeing them from an orientation to grades or teachers' judgments. With proper modeling and coaching by the teacher, the techniques can become part of students' habits of mind and empower them to become lifelong learners. They begin to understand the power of self-assessment as a tool for taking charge of their own learning.

The primary task of any educator who teaches science is to help students master science concepts and processes. The secondary task is to help students improve their language skills within the context of science. Performance expectations, strategies for explicit teaching, and students' metacognitive techniques form the structure of support that teachers and students can use to reach both goals simultaneously.

## References:

Abell, S.K., and M. Roth. 1992. "Constraints to teaching elementary science: A case study of a science enthusiast science teacher." Science Education 76 (6): 581-595.

Bredderman, Ted, "Effects of Activity-based Elementary Science on Student Outcomes: A Quantitative Synthesis" in Review of Educational Research, vol. 53, no. 4, pp. 499-518.

Donovan, Suzanne, John D. Bransford, and James W. Pellegrino, eds. 1999. How People Learn: Bridging Research and Practice. Washington: Committee on Learning Research and Educational Practice, National Research Council.

Fellow, Nancy J., "A Window Into Thinking: Using Student Writing to Understand Conceptual Change in Science Learning"in Journal of Research in Science Teaching, vol. 31, no. 9, September 1994, pp. 985-1001.

Holdaway, Don, The Foundations of Literacy. New York: Ashton Scholastic, 1979. (p.14).

Holliday, William G., "The Reading-Science Learning-Writing Connection: Breakthroughs, Barriers, and Promises" in Journal of Research in Science Teaching, vol. 31, no. 9, September 1994, pp. 877-893.

Kleinsasser, A., Paradis, E., and Stewart, R., "Perceptions of Novices' Conceptions of Educational Role Models: An Analysis of Narrative Meaning". Paper presented at the annual meeting of the American Educational Research Association, San Francisco, Cal., April 1992.

Learning Research and Development Center at the University of Pittsburgh, and the National Center on Education and the Economy. 2000. New Standards: Performance Standards and Assessments for the Schools. Pittsburgh: Learning Research and Development Center.

National Research Council, National Science Education Standards. Washington: National Academy Press, 1996. (p.13).

Rowe, Mary Budd, "Science, Silence, and Sanctions" in Science and Children, September 1996, pp. 35-37.

Scott, Johanna, Science and Language Links: Classroom Implications. Portsmouth, N.H.: Heinemann Publishers, 1992.

Thier, Marlene, The New Science Literacy: Using Language Skills to Help Students Learn Science. Portsmouth, N.H.: Heinemann Publishers, 2002.

Vaca, J.L., R.T. Vaca, and M.K. Gove. 1995. Reading and Learning to Read. New York: Harper College Publishers.

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# THE METEOROLOGY: CENTER OF THE STUDENTS' INTEREST AND PROJECTION TO THE COMMUNITY

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## RESUMEN

En el marco de los Talleres de Ciencias y Tecnología de la Escuela Parroquial E.G.B. Nº 1345 "Nuestra Señora del Carmen" de Pujato, provincia de Santa Fe, Argentina, se han desarrollado durante los ciclos lectivos del año 2000 y el año 2001, actividades vinculadas con los fenómenos meteorológicos. Dichas actividades se integran en una línea de trabajo realizada en el marco del convenio suscripto entre la Facultad de Ciencias Exactas, Ingeniería y Agrimensura de la Universidad Nacional de Rosario y la Escuela antes citada. Este convenio generó en la Escuela Parroquial, donde se llevaron a cabo estas actividades, un Centro de Coordinación y seguimiento de los aprendizajes en el área de las Ciencias Naturales y Tecnología, que funcionó durante el año 2001 como un espacio de articulación y asesoramiento de todos los docentes participantes.

La presente experiencia ha sido realizada en el espacio curricular de la Tecnología, con un grupo de 20 alumnos con edades entre los 10 y los 12 años, desde la cual se venían abordando contenidos vinculados con los instrumentos de medición. A partir del interés de los alumnos puesto de manifiesto en el momento de estudiar el funcionamiento y utilidad del pluviómetro, se fue gestando el estudio de los diferentes instrumentos meteorológicos. Desde el estudio de los distintos instrumentos meteorológicos se comenzó a trabajar con la relación existente entre el estado del tiempo, el pronóstico y las estaciones meteorológicas, como espacio desde el cual se tendió al aprendizaje integrado con otras áreas. Así nació un proyecto, como propuesta de los alumnos, buscando satisfacer una necesidad: conocer cuestiones vinculadas con el clima local. Las docentes notamos cómo, cuando los alumnos son "sacados" del contexto áulico para estudiar un contenido que no es tratado habitualmente, están muy motivados; en particular, la motivación estuvo dada por cuestiones tan simples como observar el cielo y las diferentes formas de las nubes, escuchar el pronóstico todas las noches, salir a la calle a entrevistar gente, preocuparse por conseguir los materiales necesarios para las distintas actividades.

Desde los Talleres de Ciencia y Tecnología y durante esta experiencia áulica se integraron contenidos de las diferentes áreas en torno a los fenómenos meteorológicos. Estas áreas fueron: Ciencias Naturales, Matemática, Tecnología, Formación Ética y Ciudadana, Ciencias Sociales, Lengua y Educación Artística: Plástica.

## INTRODUCTION

In the mark of the Workshops of Sciences and Technology of the Parochial School E.G.B. Nº 1345 "Nuestra Señora del Carmen" of Pujato, Santa Fe (Argentine), activities linked with the meteorological phenomena have been developed during of the year 2000 and the year 2001. These activities are integrated in a work line carried out in the mark of the agreement subscript between the Facultad de Ciencias Exactas, Ingeniería y Agrimensura of the Universidad Nacional of Rosario and the School mentioned. This agreement generated in the Parochial School, where these activities were carried out, a Center of Coordination of the learning in the area of the Natural Sciences and Technology that it worked during the year 2001 as an articulation space and all the teachers participants' advice, so much of official schools as private of the region, being carried out workshops to approach the duality between the theory and the practice.

The present experience has been approached in the curricular space of the Technology, with a group of 20 students whose ages oscillate between the 10 and the 12 years, from which contents linked with the instruments of measurement came approaching. The study of the different meteorological instruments started from the interest of the students in the moment to study the operation and utility of the pluviometer.

We all know that the meteorology is an area of the knowledge that, due to the divulger work of the mass media, it has approached so much to our day-to-day that deserves attention and scientific study. As numerous natural phenomena that affect to the human life are developed in the atmosphere, this is constituted in a motivation for the student that has been taken advantage of as center of interest in the process of teaching learning. "Keeping in mind that the learning is not a lineal process but it is pluridimensional and dynamic, signed, frequently, for unequal advances that it requires of constant and multiple reorganizations" (Diseño Curricular Jurisdiccional, Primer Ciclo Educación General Básica, 1997), we, the teachers, propounded to teach, not only from the cognitive aspect but also keeping in mind the affections, the sensibility, the values, the attitudes, the interests and the states of spirit of each one, being these factors so fundamental as the other ones.

We are convinced that the school should not only give those contents that the adults think as appropriate, but to work starting from the student's next reality that it not only understands the cultural environment but also the natural physical components of that environment. Starting from the study of the different meteorological instruments we began to work with the existent relationship between the weather and the weather stations, like space from which we propounded to the learning integrated with other areas. A project was born this way, as the students' proposal, looking for to satisfy a necessity: to know questions linked with the local climate.

## OBJECTIVES OF THE PROJECT

To approach the teaching-learning process from a constructivist conception that supposes the interaction of the subject with the object to know, with the surrounding reality and with the other ones.

To generate a space where the student feels responsible and active participant in the process of construction of knowledge.

To raise situations where the teacher acts as mediator between the construction of the knowledge, the content and the reality.

To organize the spaces and the curricular times flexible and dynamically.

## DEVELOPMENT

### The meteorological phenomena as learning axis

In Santa Fe the contents linked with the meteorological phenomena are approached starting from the 6th year of the E.G.B., in the area of the Natural Sciences, in the axis "The earth and the external space", through the following conceptual contents: the atmosphere, structures and composition; origin of the wind and modifications in the terrestrial surface caused by climatic agents: the paper of the wind. The temperature is only studied in the axis "Matter, energy and change", in the 5th year E.G.B.

On the other hand the construction, use and operation of instruments to collect information on these phenomena are worked from the context of the Technology starting from second cycle of the E.G.B. Although in the first and second cycle of the E.G.B. the climatic elements are not studied, as atmospheric pressure, formation of clouds, precipitation, humidity, in Natural Sciences; it is a permanent activity to make registrations of observation of this type of phenomena from the initial level and the first cycle of de E.B.G. The most overwhelming example of this is the habit of placing the registration of the weather to the beginning of the day, next to the date; in written form or through the drawing of different icons in the smallest students.

**The workshop of Sciences and Technology like work space**

The present didactics proposed was carried out in the environment of the classroom-workshop, concrete physical space where the children were carried out the activities and social space where the interrelations between them took place, since it is a capable place for the work in group where they learn how to share and to learn of the own partners. A workshop in which was pleasant to be and to make things, a space that allowed the active participation of all, where each one built their knowledge in interaction with the other ones. In this didactic proposal also used as educational environment the places that surrounds the children (the house, the town, the school), this way the school left its walls and the world was used as "the classroom-world."

We stimulate the development of the observation providing opportunities so that the students carry out it, allowing that they speak informally about the same ones and what interpretation they make, listening to them and being listened, preparing observations of small groups to be exposed in colloquy. At the same time were propitiated environments where the students carried out simple and experimental observations.

**Activities - year 2000 –**

*A) THE CURRICULAR DESIGN AS EMERGENCY AXIS*

In the area Technology the students were working contents linked with the instruments of measurement in the daily environment working (the house, the school, the region). In this context the reading of objects was carried out, that is to say, the global analysis (how it calls itself, for what reason you can use, what utility it has, how it is used), the antecedents' analysis (in what time it was manufactured for the first time, what necessity it came to cover, what changes it has suffered from their discovery), the anatomical analysis (what forms it has, which their parts are, why has it that form and size, which is it aspect, drawing of the instrument), the functional analysis (how it works, on what principle its operation is based), the technical analysis (what material and tools are used in its production), and other outstanding aspects (what economic factors influence in its production, election of materials, existence of other elements that complete the same function) of the following elements of a laboratory: lighter Bunsen, flask, glass of precipitate, pipette, magnifying glass, microscope, pincers, universal support, dropper, test tubes, capsule of Petri, clock glass, graduated test tube, transporter, immersion thermometer, atmosphere thermometer, caliber, metric tape, pluviometer, compass.

In the context of the class of Technology a marked interest of the children by the pluviometer was detected. After that the teachers intended the observation of different types of pluviometers, they were investigating those that people of the town use and how they are manufactured of different classes, they were detecting the importance that this instrument has for the agriculture and the daily thing that it is for the inhabitants of the area.

*B) CONTEXT FOR A LOCATED LEARNING*

The same one was guided toward the study of other meteorological instruments, among them: weather vanes, anemometers, barometers, barographs, hygrometer, thermometers of maximum and minimum, heliographs, sleeve of wind, box of wind. The carried out activities can be synthesized in the stages that are detailed next:

- Delimitation of a problem related with the meteorology starting from the open dialogue and decisions of the group, which derives to posteriori in an investigation work.
- Formulation of the problem on which the group will work: "How can we offer the weather and the weather forecast in Pujato? "

The problem is focused and some answers are attempted to the same one through the formulation of conjectures.

  - "The inhabitants of our town consult the weather forecast for the planning of their daily activities"
  - "The rainwater is the most consulted meteorological variable, so much the rainfall as its prediction"

- Formulation of the objectives: they didn't outline a priori by the teacher; but rather they were being defined in function of the conjectures that the students had outlined. This allowed them to return to the problem, to delimit it and to propose the following objectives:
  - To identify and to describe the meteorological phenomena.
  - To build meteorological instruments using materials and appropriate tools and to know their operation.
  - To design and to develop experiments referred to meteorological phenomena.
  - To study the influence of the weather and of the weather forecast in the planning of the daily activities.
  - To collect, to organize, to process, to interpret and to communicate information

- Search of information in the school manuals, popularization texts, massive means of communication (the newspaper, magazines, Internet).
- Organization and processing of the information.
- The students analyzed information from the mass media about the weather
- The maximum and minimum temperature was registered in the area during seven serial days.
- The data were tabulated and the averages of each were calculated, analyzing about that adapted or not of those averages, in connection with the climatic station.
- The thermal width of the temperatures maxim and minimum were analyzed.
- The atmospheric pressure was registered and analyzed during those same seven days.
- The relationship between atmospheric pressure and rain's possibility was analyzed.
- The prediction idea and possibility was worked analyzing the terms "probability of", "possibly", "improving toward... ".
- The children worked on winds: direction and speed, fundamentally.
- Inquiries about "strong, light, moderate winds" arose and what these terms mean were explained colloquially. What influence the wind has with regard to the climate was studied too.
  This proposal was carried out with the newspaper "La Capital", of Rosario, since as first reflection it was determined that other newspapers, as "Clarín" or "La Nación", didn't contribute data about Santa Fe and a lot less than the regional habitat that concerned us.
  The first inquiry was carried out starting from the different icons that the page of the weather offers, what data they could be analyzed in the first place were bounded, to deepen the investigation gradually. The students got excited working starting from the linguistic and not linguistic signs, looking for their meaning and meditating starting from them what information they offered.
- Visit of study
  Starting from the inquiry on those "sources" in those that are based the mass media to give to know the weather and weather forecast, the children discovered as the next weather station to Pujato is in the International Airport Rosario.
  The visit to the Weather Bureau that is in the International Airport Rosario was carried out, where Mr. Rubén Darío Bersano offered us, to teachers and students, his advice, and this facilitated the contact of the students with the apparatuses that are good to determine the weather.
- The measurement's process and the introduction to the implicit mistakes in the same one.
  The students worked with the thermometer. The measurement's scale, the smallest divisions in the same one and their use form to obtain measures were observed. The thermometer was located one a table, the students wrote the value that the thermometer measured. Then they located it to different heights, they measured the temperatures and compared them. At the end the students investigated about the obtained differences and they analyzed the possible mistakes in the measurement's process.
  This same process was carried out with others meteorological instruments.
- The classroom likes laboratory
  Experimental activities were developed, creating a space open to the controlled experience, referred to meteorological phenomena to begin identification and differentiation processes among:
  - The wind chill.
  - The relationships between heat and temperature.
  - The presence of the atmospheric pressure.
  - The changes of aggregation state or phases of the water in the Nature.

Meteorological instruments were also built using materials and appropriate tools, these instruments were calibrated, the children observed their operation and they worked with observation and measurement's instruments and they obtained, in this last case, the measures.

- Pluviometer
- Weather vane
- Sleeve of wind
- Box of wind
- Thermometer
- Anemometer

- Barometer
- Psychrometer

*C) DESIGN OF AN INSTITUTIONAL PROJECT FROM THE CLASSROOM-WORKSHOP*

- Organization of the own weather station.
  The problem was revised and reconsidered, being established in the following way: "Is it possible to install a pluviometric station in Pujato?". When the problem was reviewing, consequently, the objectives were changed.
  The students could synthesize that to weather forecast was not an easy question, although the variables that affected of the weather in a certain moment and place could be measured.
- Field work.
  The children carried out surveys and interviews to the neighbors of the town. The students should bound, in a first instance, what data were necessary to discover, to determine to what population it will be directed, to leave to the street, to organize their time, to adapt their language (in function and style).
- Based analysis of the surveys.
  The data were gathered and registered, they were organized and represented in diagrams, charts and circular graphics and the organized information was described and analyzed.
  In all the moments in setting march and execution of the project, the dialogue like synthesis instance and reflection was used on results, also opposing difficulties, approaches to overcome them, question that were novel for them, relationship with devices observed in the community and fundamentally, to think if the initially outlined conjectures were validated through the different fulfilled activities.

**Activities - year 2001 -**

*A) EVALUATION AND SYNTHESIS*

First a revision of the concepts approached during the previous year was carried out about:

- Differences between weather and climate.
- Characteristic of the meteorological phenomena.
- Magnitudes linked with the meteorological phenomena: temperature, atmospheric pressure, humidity, wind speed, wind direction, formation of clouds, precipitation, fog.
- Instruments of the weather stations.
- Mass media that communicate the weather and weather forecast

Starting from this the study was deepened about:

- The atmospheric pressure and their relationship with the formation of the cyclonal centers and untilcyclonal.
- Formation of local winds. Characterization.
- Condition of the good time.
- Formation of clouds and classification. Direct observation. Obtaining of photographs. Photographic show.
- Point of dew. Icy. Fog. Wind chill.
- The optic phenomena. The halo and the crown. The rainbow. The color of sun, of the sky and of the clouds.

*B) FOCALIZED CONSULT*

A bibliographical investigation about the evolution of the meteorological services in the world and, especially, in our country was carried out. This work was supplemented with the projection of videos referred to the topic.

Surveys to the students of 1st and 2nd cycle of the Parochial School E.G.B. N°1345 were carried out, to know what representation they have about the form and the color of the clouds. This was discovered through drawings where the students illustrated clouds and they colored them.

Conclusion: that most of they draw a heap and they paint it of light blue color.

*C) GENERATION OF CENTERS OF INTEREST IN THE LOCAL COMMUNITY*

Photographic show: "Observing the clouds".

- Organization of the photographic show. During the month of November of the year 2000, the whole population of Pujato was invited, through mass media, to participate of the same one taking photographs of different types of clouds; at the same time the teachers suggested that they carry out the classification of the same ones and the teachers gave a date delivery limit, the month of March of 2001.
- Reception and categorization of the received photographs.
- Exhibition of the photographs. In this opportunity the whole population was invited to visit the photographic show that was carried out in the school during the month of June.

*D) LOOKING AT THE LITERATURE FROM THE METEOROLOGY:*
Starting from the make inquiries carried out the previous year of the beliefs related with the forecast of the time and rescued by the popular and folklore knowledge, an inquiry of the different meteorological phenomena was carried out, in different types of literary texts, for example, songs, ballads, poems, proverbs, stories, legends.

This was good to reinforce the knowledge and recognition of the oral literature of the region and of the country, where the meteorological phenomena were never absent of the argument of the traditional literary speeches, demonstrating, in this way that the state of the time and the nature have always been rich in mystery and popular beliefs and they have been related with the popular knowledge.

*E) THE PROFESSIONAL CONSULTATION*
A second visit to the Weather Bureau of the Airport Fisherton was carried out, where Mr. Rubén Darío Bersano informed us, in this opportunity, about the importance of possessing an automatic weather station. He also made reference under the care of the instruments that compose it and to the differences that exist between an automatic weather station and a manual station.

A series of interviews to companies and mass media of Pujato was carried out with the purpose of to know the importance that the weather have to them.

The questions that guided the same ones were the following ones:

1) Would you like consult the weather daily from Pujato?
2) Do you think that the weather can vary from a station located in Rosario to one located in Pujato? Why?
3) What data of the weather would you interest to consult relational with your work?
4) What data of the weather forecast would you interest to consult from meteorological station?
5) Do you think that the climate and the weather have varied in the last years? What can you tell us about this?
6) Do the human activities influence in the determination of the climate? Why?

After the interviews were carried out we concluded that to most of the companies and of the mass media of Pujato, would interest to consult the weather from Pujato, they also believe that these data can vary from a station located in Rosario to one located in Pujato. They also think that the climate and the time have varied in the last years, and they said this for the high temperatures that were registered during the winter of the present year.

*F) THE FIELD WORK LIKE RESOURCE OF SYSTEMATIC KNOWLEDGE*
Later on a survey was elaborated to know what meteorological instruments the families of Pujato have. For this the students were distributed with a plane of the town.

The survey that was carried out was the following one:

Do you have some meteorological instrument?
1. - PLUVIOMETER? ...............
Is it homemade?............ How did it manufacture it? ...................................................
Where is it located?...........................................................................................

2. - THERMOMETER?..................
Where is it located?....................................................................................................
3. - WEATHER VANE?.....................
Is it homemade?............ How did it manufacture it? .....................................................
Where is it located?....................................................................................................
4. - SOME DEVICE THAT INDICATES THE SPEED OF THE WIND?.......................
Is it homemade?............ How did it manufacture it? ..........................................
Where is it located?.................................................................................
5. - OTHER RELATED INSTRUMENTS?..........................................................................
6. - WHY DO YOU HAVE THESE ELEMENTS? FOR WHAT REASON DO YOU USE THEM?
..............................................................................................................

After to compile and to tabulate the data obtained starting from the survey, the students observed that the pluviometer is the meteorological instrument that most of the inhabitants of Pujato possess. In a smaller percentage the thermometer, the weather vane, instruments to measure the speed of the wind, barometers, hygrometers, sleeve of wind, maxim and minimum thermometer, floor thermometer appear.

Another of the questions to investigate starting from the survey was to the place where the instruments are located. With relationship to this point they could observe that the pluviometer is in a wall, roofs, garden or against some wall, and the thermometer, inside the house.

Another point to analyze was the why of the use of these instruments. Most of those interviewed responded that they have them from necessity, relating this with the labor activities. A minority only has them for curiosity.

*F) THE CLASSROOM-WORKSHOP LIKE LABORATORY*

- Use of built meteorological instruments the previous year: pluviometer, sleeve of wind, weather vane, thermometer, box of wind, anemometer, barometer, psycrometer to carry out observations and mensurations. Later on a heliograph was built, it was calibrated and it was put into operation.
- Training in the handling of an automatic weather station and manipulation of the same one.
- Comparison of the operation of the devices of the automatic weather station with the manufactured instruments.
- Comparison of the obtained data of some meteorological variables, the temperature for example, using the automatic power station and traditional instruments.

*G) OPENING TO THE LOCAL COMMUNITY*

The students registered the data corresponding to the weather daily: temperature, humidity, atmospheric pressure, wind speed, wind direction and precipitation. This registration carried out it to the 9.00 a.m. of the morning and at the 3.00 p.m.

The students were distributed in four groups to provide the weather report to the mass media of Pujato.

## CONCLUSION

This didactic experience was positive because it facilitated us to investigate the own reality of the class, where we also become apprentices every day with each student. As teachers, we had the necessity to appeal to several sources of information, included the visit and the advice with specialists in the topic and on the other hand, we perceive the necessity that these contents are not only approached by the students, but in the preparation of the formation of the teacher.

The teachers own admit that if the students are "taken out" of the classroom to study a content that is not treated habitually, the students are very motivated; in particular, the motivation was given by questions so simple as observing the sky and the different forms of the clouds, to listen the weather forecast every night, to leave to the street to interview people, to worry to get the necessary materials for the different activities. In this experience, the daily thing that usually for habit and comfort is always left aside, it became a learning object.

As teachers promoted the interaction between the scientific contents and the capacity of the students of approaching them, in function of their intellectual development and their representations. We try to cause in them continuous reflections on their form of arriving to the different conceptualizations, we meet ourselves to approach the contents with concrete and varied activities, specifying each task clearly, their functionality and what thing the students could learn with her. In this action road and accepting from our educational posture that the integration of the different thing is a challenge that is presented to the current society everything and not only to the school environment, we proposed in our daily work the integration and the attention to the diversity. Because we know that the students have different interests, necessities and lifestyles, experiences, learning rhythms, capacities, personal histories, cultural and social conditions, our challenge was to work with all them, from the heterogeneity, the difference and the plurality of senses, transforming each class of the workshop into an integrative and inclusive space.

From the Workshops of Science and Technology and during this educational experience contents of the different areas around the meteorological phenomena were integrated. These areas were: Technology, Natural Sciences, Mathematics, Social Sciences, Spanish, Artistic Educational: Plastic and Ethical Formation.

The classroom was always a healthy environment for the learning, facilitator of the intrinsic motivation, the autonomy and the self-esteem. The motivation given in the students and in the teacher generated an immediate initiative to set up a automatic weather station. Also the possibility that this offer would be offer to the whole local community.

The evaluation was developed in permanent and systematic form, supplementing different situations valuables, which were: the group's dynamic, the form of approaching the topics, the use of the time and of the space, the level of information, commitment and active participation, oral and written productions and presentation of the works.

Although these activities have been approached in complete form during a school cycle and in a certain context, these activities have allowed their orientation toward the search of new questions and procedures to work with the children in later stages. Also these activities can be approached by other teachers in other environments.

## BIBLIOGRAPHY:

BURROUGHS, W., CROWDER, B., ROBERTSON, T., VALLIER-TALBOT, E. y WHITAKER, R. 1999. Observar el tiempo. Editorial Planeta. Buenos Aires, Argentina.

BORRUT, J.M., CAMPS, J., MAIXÉ, J. M. y PLANELLES, M. 1992. La meteorología en la enseñanza de las ciencias experimentales una propuesta interdisciplinar e integradora. Revista de Enseñanza de las Ciencias, Vol10 Nº 2, 201-205

CAÑAS, A., DE TORRES, M. L., GUTIÉRREZ, M. S., LLAVONA, A., SORIANO, J. y TOMÉ, J. 1989. III Congreso Internacional sobre la didáctica de las Ciencias y de las Matemáticas. Revista de Enseñanza de las Ciencias, Tomo 2 166 - 168.

CANESTRO, ELSA. 1993. Experimentos sobre meteorología. Editorial Albatros. Buenos Aires, Argentina.

Diseños Curriculares Jurisdiccionales. 1997. Primer Ciclo Educación General Básica. Ministerio de Educación de Santa Fe. Santa Fe, Argentina.

Diseños Curriculares Jurisdiccionales. 1997. Segundo Ciclo Educación General Básica. Ministerio de Educación de Santa Fe. Santa Fe, Argentina.

FUENTES YAGÜE, JOSÉ. 2000. Iniciación a la Meteorología y a la Climatología Ediciones Mundi Prensa. Madrid, España.

GAY, AQUILES Y DOVAL, LUIS. 1996. Tecnología. Finalidad educativa y acercamiento didáctico. Prociencia. CONICET. Montevideo, Uruguay.

Manual de la UNESCO para la enseñanza de las Ciencias 1984. Ed. Sudamericana. Buenos Aires, Argentina.

PARKER, STEVE. 1995. Tiempo y clima. Editorial Sigmar. Buenos Aires, Argentina.

WATT, FIONA Y WILSON, FRANCIS. 1993. Tiempo y clima. Editorial Lumen. Buenos Aires, Argentina.

WATTS, ALAN. 1997. Manual del Tiempo. Ediciones Tutor. Madrid, España.

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# PUPILS' NEEDS FOR CONVICTION AND EXPLANATION WITHIN THE CONTEXT OF DYNAMIC GEOMETRY

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**Abstract**

This paper reports on task / worksheet based interviews conducted with 14 year-old pupils in order to determine their levels of conviction and their need for explanation within the context of dynamic geometry.

## Introduction

The study built on research by De Villiers (1991) but it was contextualized specifically within dynamic geometry. De Villiers (1991:261) pointed out that the role and function of proof in a mathematics classroom has been largely ignored and that proof is usually presented to pupils as a means of verification only. Hanna (1996 : 21-33) points out that proof has lately been "relegated to a less prominent role" and argues that pupils "must be taught proof". The purpose of this study was to determine pupils' needs for conviction and explanation within the context of dynamic geometry, and whether proof could be meaningfully introduced to novices as a means of explanation. Sketchpad was used here as a "mediating artifact" (compare Jones, 1997 : 121). Specifically, this study evaluated a worksheet that was developed as part of an on-going research programme based on distinguishing between the different functions of proof (see De Villiers, 1990). The material allowed the child to discover a solution to a problem by guiding the child through stages that are easy and practical. As the child progressed through the worksheets, the child was allowed to record his/her conclusions and conjectures and was led to an explanation (proof).

The research focussed on the following major research questions:

- are pupils convinced about the truth of the discovered geometric conjecture and what is their level of conviction ? Do they require further conviction?
- do they exhibit a desire for an explanation for why the result is true?
- can they construct a logical explanation for themselves with guidance and do they find it meaningful?

## Research methodology and overview

Seventeen 14 years old pupils were interviewed from Grade 9. These pupils were selected randomly by their computer studies class teacher, who chose every ninth pupil appearing in the attendance register. They were selected from a group of 153 pupils in February 1997. Grade 9 pupils were ideal for this study because the questions were suited to their level, and since they had not yet done any proofs in geometry. Interviews were audiotaped and analyzed.

The question, which the pupils had to work through, is given below.

> *Sarah a shipwreck survivor manages to swim to a desert island. As it happens, the island closely approximates the shape of an equilateral triangle. She soon discovers that the surfing is outstanding on all three of the island's coasts and crafts a surfboard from a fallen tree and surfs everyday. Where should Sarah build her house so that the total sum of the distances from the house to all three beaches is a minimum? (She visits them with equal frequency.)*

A dynamic sketch of the equilateral triangle was presented ready-made on Sketchpad to the pupils, since the task of constructing it for themselves was not relevant to the research questions.

### Pupils' needs and levels of conviction

The main purpose of this section was to establish how pupils convinced themselves of the truth of the discovered conjecture, as well as their levels of certainty. It took only a few minutes for pupils to convince themselves about the truth of the conjecture, namely, that Sarah could build her house at any point within the island (since the sum of the distances to the sides are constant). The researcher was surprised to find that most pupils (14) stopped within a few minutes of experimentation because they felt that there was no need to conduct further computer testing of the conjecture. The extract below demonstrates the high level of conviction that the pupil achieved in this dynamic geometry context.

| | |
|---|---|
| Researcher : | Okay Nirvana, you seemed to have moved it to a number of points. What is your observation? |
| Nirvana : | The distances are changing and the sum ....... |
| Researcher : | Which distances are changing ? |
| Nirvana : | All of them and the sum remains the same. |
| Researcher : | Do you think that this is the same throughout the triangle ? |
| Nirvana : | Throughout the triangle. |
| Researcher : | Do you think that if I moved the point to the corner there (pointing with the finger) then the sum will remain the same ? |
| Nirvana : | Yes ! |
| Researcher : | Are you convinced ? |
| Nirvana : | Yes ! |
| Researcher : | You don't want to try ? (The researcher was attempting to establish whether she was simply saying 'yes' to satisfy the researcher or did she really mean it ? |
| Nirvana : | I'll try........(after moving it around for a while) yes it remains the same |
| Researcher : | So, no matter where you moved it in the triangle, it will be the same ? |
| Nirvana : | Yes. |
| Researcher : | If I asked you how many percent convinced are you, what would you say? |
| Nirvana : | 100 % |

After the initial experimental exploration, the following levels of conviction were displayed:

- 12 (70.5 %) were 100 % convinced
- 2 ( 11.8 %) were 98 % to 99 % convinced
- 2 (11.8 %) were 70 % convinced
- 1 (5.9 %) were 55 % convinced

After further exploration (usually prompted by questions from the researcher), the following levels of conviction were displayed:

- 14 (82.3 %) were 100 % convinced
- 2 (11. 8 %) were 98 % to 99 % convinced
- 1 (5.9 %) was 90 % convinced

It was evident that the more pupils experimented the more convinced they became. The levels of conviction of all pupils were very high, and many achieved this level of conviction after just a few minutes of experimentation on the computer. In fact, their levels of conviction were much higher than that expected by the researcher. It is also possible that pupils might not have achieved these levels of conviction, so quickly and easily, if they had used only the pencil and paper construction and discovery method.

### Pupils' need for explanation (or understanding of why the result is true)

The purpose of this section was to try and establish whether pupils exhibited a need for explanation of the conjecture they had made. Do they want to know why the conjecture is true? Do they display a desire for a deeper understanding, independent from their conviction? The researcher found that the majority of pupils expressed a desire for an explanation despite already being convinced. In fact 16 of the pupils immediately said that they wanted an explanation and only one pupil took a while before saying that she would also like an explanation. The extracts below show the need pupils demonstrated for an explanation.

Researcher : Do you think, now that you are very convinced, ....is it necessary to know why this is the case ?
Rodney : Yes.
Researcher : Why do you want an explanation for this ?
Rodney : To satisfy my curiosity.

Researcher : Why do you think there is a need for an explanation ?
Karishma : Because I'm curious and I'd like to know what's going on.

Researcher : Why do you think there is a need for an explanation ?
Debashnee : Because I'm a curious person and I would like to find a solution for things. I would like to do the same for this.

Rhyam : I like to find out why things are taking place.

Higashnee : I would like to find out about it myself and know more about it than finding out from the computer.

Eventually all the pupils seemed to express some desire to have an explanation. This desire clearly did not emanate from a need to further verify the result as they already had very high levels of conviction. They seemed to want to 'understand' the problem which 'interested' them and which made them 'curious'. De Villiers (1991 : 258) similarly found that: "Pupils who have convinced themselves by quasi-empirical testing still exhibit a need for explanation, which seems to be satisfied by some sort of informal or formal logico-deductive argument". It seems that the pupils' need for an explanation arose out of finding the result surprising, with the surprise causing the cognitive need to understand **why** it was true (compare Hadas and Hershkowitz, 1998 : 26).

**Pupils' ability to construct a logical explanation with guidance**

Although the pupils were asked to attempt their own explanations, none of them were able to do so. A guided explanation was then given to them which required them to follow six steps in determining a possible solution (see Figure 1). The basic research question investigated here, was whether pupils could construct their own logical explanations with some guidance. It should again be noted that these pupils had not yet been exposed to the writing of proofs (explanations) for geometric statements. They were comfortable with the ease of the instructions because they could understand what was required. Figure 2 gives a typical example of one of the pupils' written work and an extract of the corresponding interview.

EXPLAIN
Here are some hints for planning a possible explanation. Read and work through it if you want, or try to construct your own explanation.
E1:Label all three sides as a and the distances from P to the sides AB, BC and CA respectively as $h_1$, $h_2$ and $h_3$.
E2:Write expressions for the areas of the triangles PAB, PBC and PCA in terms of the above distances.
E3:Add the three areas and simplify your expression by taking out a common factor.
E4:How does the sum in E3 relate to the total area of triangle ABC? What can you conclude from this?

**Figure 1**

Researcher : Now look at E4. I want you to write down this expression.
Nicholas : (after a while) I noticed that the big triangle also had half a in it. So I cancelled off the

half a from the big triangle and half a from the three small triangles.

Researcher : And what have we arrived at ?

Nicholas : The height of the three triangles ....when you add it up it gives you the height of the big triangle.

Researcher : What does this mean to you ?

Nicholas : No matter what the heights of the three smaller triangles are, it will always equal the height of the big triangle.

Researcher : So what does it mean in terms of Sarah's house ?

Nicholas : It means that no matter where she puts her house the total distances will always be constant.

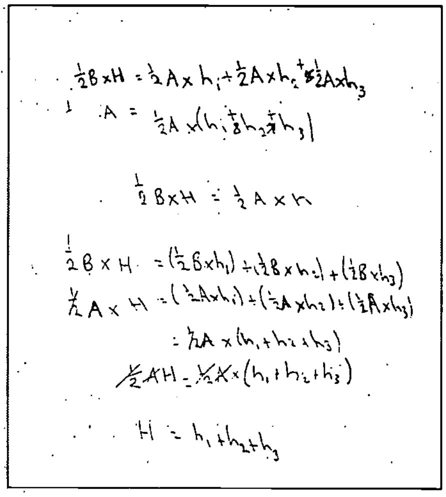

**Figure 2**

From the interviews it was evident that all the pupils were able to construct a logical explanation for the conjecture.

### Pupils' interpretation of the guided, logical explanation

Finally, it was attempted to establish whether the pupils had experienced the guided, logical explanation as meaningful. More specifically, did it adequately satisfy their earlier expressed needs for explanation and understanding? To attempt to establish this, pupils were asked whether the argument had satisfied their needs for explanation (or curiousity). Although all the pupils answered positively, and seemed quite satisfied, it is however very difficult to conclusively state that all the pupils had really found it meaningful (as they might have responded positively to please the researcher).

### Conclusion

The research indicated that pupils displayed a need for an explanation (deeper understanding) for a result which was independent of their need for conviction. Given such high levels of conviction one might expect that it should have made no difference to them whether there was some logical explanation for it or not. Yet they found the result surprising and expressed a strong desire for an explanation which was effectively utilized to introduce them to proof as a means of explanation (rather than verification). Furthermore, it was found that all pupils were able to construct an explanation with the given guidance and that they had felt that the argument satisfactorily explained **why** the result was true. Of course, proof has many other important functions, for example verification, discovery, systematization, and so on, which also have to be dealt with in the mathematics classroom. Activities focussing on these aspects are being developed and evaluated, some of which are appearing in De Villiers (In press).

## References

De Villiers, M. (1990). The Role and Function of Proof in Mathematics. Pythagoras. Vol 24, pp. 17-23.

De Villiers, M. (In press). Rethinking proof with Geometers' Sketchpad. USA: Key Curriculum Press.

De Villiers, M. (1991). Pupils' needs for conviction and explanation within the context of geometry. Proceedings of the 15th Conference of the International Group for the Psychology of Mathematics Education. Assisi (Italy), Vol 1, pp. 255 – 262.

Hanna, G. (1996). The Ongoing Value of Proof. Proceedings of the 20th Conference of the International Group for the Psychology of Mathematics Education. Valencia (Spain). Vol 1, pp 21 – 33.

Jones, K. (1997). Children Learning to Specify Geometrical Relationships using a Dynamic Geometry Package. Proceedings of the 21th Conference of the International Group for the Psychology of Mathematics Education. Lahti (Finland), Vol 3, pp 121 – 128.

Hadas, N. and Hershkowitz. (1998). Proof in Geometry as an Explanatory and Convincing Tool. Proceedings of the 22nd Conference of the International Group for the Psychology of Mathematics Education. Stellenbosch (South Africa), Vol 3, pp 25 – 32.

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# TOWARD A MODEL FOR EVOLVING SCIENCE STANDARDS: LEARNING FROM THE PAST, PRESENT, AND FUTURE ABOUT THE SHAPE OF THE EARTH

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**Abstract**

This paper looks at an approach that might foster the evolution of national science standards. It begins with a look at how textbooks from the 18th and 19th century and research on children's science concepts come to some consensus on the content related to the shape of the earth. It then looks at models in science education, psychology, and anthropology that build on the examples from textbooks and children's concept research. The science education model is then suggested as being useful in fostering the evolution of science standards.

## Introduction

Science standards have become critical in the development of science curriculum and instruction in many countries around the world (Ministry of Education, 1993; NRC, 1996; Queensland School Curriculum Council, 1999; Rutherford & Ahlgren, 1990). In the United States many individual states are developing science standards. (We expect other participants at this 2001 IOSTE meeting will provide additional examples of standards.) These standards are the culmination of an extensive process involving a wide variety of participants. As such the standards take on a stability that often contradicts the nature of science.

This paper supports standards as only one necessary component of science curriculum and instruction. However, without a model for evolution, standards become stagnant and limit future growth and development in science education. The questions are - What model can provide for curricular evolution? Where can we find stimulation for "new" curricula ideas?

We believe additional ideas are available in old textbooks and some research on children's science concepts. We use the explanation of the shape of the earth as our example of a science topic that might evolve because of additional ideas. We compare the explanations from 18th and 19th century texts with Nussbaum's (1979) research on children's concepts on this topic. We then look at and integrate three models from science education, psychology, and anthropology that might provide the frameworks to support the evolution of science standards, curriculum, instruction, and research on children's concepts.

### Comparing 18th and 19 century explanations of the shape of the earth with Nussbaum's research on the earth in space.

The shape of the earth is a common piece of science information. We take it for granted and assume children and adults understand this concept. With all the photos of the earth from space and the entertainment industry's films about space travel, who does not understand the spherical shape of the earth? Yet there are many children who do not conceptualize the spherical shape of the earth. More importantly, few adults can provide evidence or explanations for the shape of the earth.

Before we look at the explanations from old textbooks, it is helpful to look at Nussbaum's (1979) research on the earth in space. At a seminar in Indianapolis, Nussbaum, (1978) asked the participating students and faculty, "What basic information would you include to help a students understand the shape of the earth?" The majority of respondents thought "facts" like the shape and size of the earth, the amount covered by land and by water, and the composition of the earth's layers were basic. None mentioned ideas Nussbaum had drawn from his in-depth, probing interviews with the children such as up and down and how things would fall if dropped at various places "around" the earth. None of the participants thought the child's response that, "The earth is round and Columbus discovered it by sailing around the earth," was incorrect. They were surprised when this child's view of a round earth was round and flat like a disc or plate. As we look at the excerpts from 18th and 19th century textbooks please note that several of the ideas Nussbaum "discovered" were common in the old texts. We will discuss this convergence of old textbooks and research on children's concepts at the end of this section.

The older texts were written from the perspective that the shape of the earth was not always obvious to the reader. Before they would state a fact, such as the shape of the earth, the authors would provide broad, underlying concepts. Worchester (1831) begins by carefully defining a sphere, "Your ball is a globe or sphere. Everything, whether great or small, that is shaped like a ball, is called a *globe* or *sphere*. An apple, an orange, this great Earth on which we live, the Moon, the Planets, and the Sun are all shaped in nearly the same manner, and we therefore say they are *globular* or *spherical*" (Italics in original). He goes on to discuss what might also seem obvious, that people can only see a small part of the earth. "The Earth on which we live does not appear like a globe when we look at it; but it is so large, that we can see only a very small part of it," (Worchester, 1831).

Bingham, (1805) like many of the early textbook authors wrote in a question and answer format that was very common among books of that period. He brings up another interesting basic concept when he asks, "What is an artificial globe?" His answer, "A round body on which all parts of the earth are represented." It is interesting that he and several other authors of the older books made a point of distinguishing between the globe on which we live and the "artificial" globe we have in schools and homes. It is this concern for detail that we believe is ignored in the development of standards, which by definition have to be general and "scientifically" correct.

Ferguson (1756) represents the oldest book we reviewed. He provides an explanation of the problems people might have when using a globe as an analogy for the earth. "When we see a globe hung up in a room we cannot help imagining it to have an upper and an under side, and immediately form a like idea of the Earth; from whence we conclude, that it is as impossible for persons to stand on the under side of the Earth as for pebbles to lie on the under side of the globe, which instantly fall away from it down to the ground."

In a later book written for children, Ferguson(1817) responds to a question about the height of the sun at different times of the year with a discussion of up and down on the earth. "*High* and *low* are only relative terms; for, when the sun is at his lowest depression, with respect to us, he is directly overhead to some other part of the earth; for the earth is round like a globe, and on whatever part of its surface a person stands upright, he thinks himself to he on the uppermost side, and wonders how any one can stand directly opposite to him, on the undermost side of the earth or rather, how he can hang to it with his head downward, and not fall off to the lower sky."

It appears to us that Ferguson[1] was concerned about the types of questions skeptical observers would ask. In his earlier 1756 book he also approached this concept. "And having the Sky over our heads, go where we will, and our feet towards the center of the Earth, we call it *up* over our heads, and *down* under our feet: although the same right line, which is *down* to us, if continued thro and beyond the other side of the Earth, would be *up* to the inhabitants opposite to us."

Several of the authors presented a variety of explanations to help understand the shape of the earth. Again, using the question and answer format, Bingham, (1805) asks the about the shape of the earth in an interesting manner, "What reason do you have to suppose the earth is round?" The answers he provides are, "1. This shape is best adapted to motion. 2. From the appearance of its shadow in eclipses of the moon. 3. From analogy: all other planets being round. 4. From its having been circumnavigated many times."

[1] James Ferguson lived from 1710 to 1776. According to Ferris (1988), Ferguson began to study astronomy as an uneducated shepherd. He taught himself to read, became a teacher and wrote two popular astronomy books. We have used parts of these two books in this paper. His books had many editions, with several, including the example we used from 1817, published in the United States well after Ferguson died.

Jackson (1894), also uses a question and answer format. His answers to the same question about the shape of the earth start with an analogy to a common observation. "The same cause that makes the raindrop spherical, viz., *the mutual attraction of its particles*." He then goes on to discuss the attraction of gravitation. He states, "Every one knows that drops of rain are produced by invisible particles of cloud or vapor running together." According to Jackson it is precisely the same with the earth and other heavenly bodies.

He (Jackson, 1894) provides five different explanations as to why we know the earth is a sphere. But the explanations are not just listed as if they were obvious. The first is that, "the curvature of its surface may actually be seen." More importantly, "This convexity is found to be the same for the same distance, which could not be the case except upon a spherical body." Jackson then goes on to discuss methods for measuring the elevation of a middle target of three set up in a line. It is also interesting to note (end of next paragraph) that the curvature itself does not "proves" the earth is a sphere. Other shapes might produce similar curvature.

Jackson's second proof is circumnavigation. The third is the fact that "The Horizon seems both to enlarge and sink as we ascend above the surface; whereas, if the earth were an extended plain, our field of view would not change whatever our elevation. The horizon is always circular, which would not be the case if the earth's form differed very much from that of a sphere." He then goes on to propose a demonstration to prove his example. "Cut a small circular hole in a card, and place it upon different parts of a globe. Suppose an observer to stand in the very center of the aperture, in each position, the circle around him represents the horizon. If some other object be taken to represent the earth, as a cube or a cylinder, it will be seen that the hole in the card must be of a different form in order to fit different parts of its surface." His interest in knowing not only that there is a curvature, but that is it the same over the entire earth, raises the issue with the standard "proof" of a spherical earth obtained by watching the bottom of a sailing ship disappear in the horizon before the top. This observation would have to be made all over the earth and with ships moving in many different directions to show a spherical and not a cylindrical earth.

After the third explanation Jackson adds a typical comment, found in many older texts, questioning the information provided. He says, "It may be thought that the three proofs given above do not show *positively* that the earth is spherical — that it might be some other rounding form, like that of an egg, for example, without affecting the appearances described." So in addition to providing observational evidence, the old books ask the reader to make sure they can believe and justify the data. He then provides what he thinks are more direct proofs. "*The Weight of a Body* is very nearly the same at all parts of the earth's surface, which could not be the case if the earth were not nearly spherical, since the same body grows heavier the nearer it approaches (on the surface) the center of the earth." His final proof is based on the observation that during eclipses the earth's shadow is always circular. We have no idea why these several examples ignore explanations from the Greeks, both the change in position of the stars as you move north and south and the measurement of the size of the earth using the sun's shadow.

We believe these early authors knew they were writing for people with few sources of scientific information and little experience in the counterintuitive thinking required to understand science concepts. The authors also appeared to accept that the reader would be skeptical of a list of facts or information. They appear to have been trying to understand the readers' perspectives. This is the value of Nussbaum's approach to children's concept research. Rather than being satisfied to list children's errors, he probed and searched for the underlying principles the children were using to construct their explanations. That is why we believe Nussbaum found up and down, an issue for Ferguson in 1756, so critical. It is the idea of up and down that makes a spherical earth counterintuitive for some children. We also think the ideas of how jars of water and balls respond at different places on earth helped build a picture of the curricular issues critical to developing appropriate standards for all children. In looking at science standards we believe old textbooks provide one avenue for expanding the concepts and explanations to be included. But we also believe that research into children's science concepts (misconceptions, alternative frameworks, intelligently wrong concepts, mixed-conceptions, naïve conceptions) can also provide additional sources of ideas for the standards. However, the children's science concept research has to follow those approaches that work at eliciting the widest range children's concepts (Piaget, 1929; Novak, 1987; Pines, A.L, Novak, J.D., Posner, G.J. & VanKirk, J. 1978).

## Curricula Frameworks Built on the Wisdom of Elders, the Knowledge of Colleagues, and the Conceptions of Children

The fact that historical textbooks and children's science concept research have the potential to expand the content of science standards is only one part of an approach that would foster evolution of existing standards. Another component would be theoretical models which would help integrate the content into instructional models and frameworks. We describe the three frameworks we believe can help organize our thinking about curriculum, instruction, and research to foster evolution of science standards.

The first framework comes directly from science education research. Osborne, Freyberg and Tasker (1982), classify the science curriculum into four categories from the *official* through the *children's* curriculum. These categories provide locations for the "new" ideas from the old texts within the *official curriculum* and for children's science concept research and some old textbook material within the *children's curriculum*. This framework encourages feedback from children's ideas and old textbooks to inform and expand the dimensions of the *official curriculum* and create a dynamic, evolving *official curriculum*.

The second framework, which we believe validates the structure provided by Osborne, Freyberg, and Tasker comes from Gardner's (1993) study of creativity as exemplified through the lives of seven twentieth century individuals who changed their disciplines. A key theme in his work is "*the relationship between the child and the adult creator*." As with the curricula perspective, this approach is also build on the interaction between expert and novice understandings of the content.

Margaret Mead provides the third framework. In *Culture and Commitment*, (Mead, 1970. 1978), she describes cultural environments that differ in the speed with which they change. Her contribution is based on the understanding that elders, peers, and the younger generations (children) play very different but important roles in the evolution of culture.

### Categories of curriculum

In the design of the research that led to their popular book, *Learning in Science*, (Osborne and Freyberg, 1985) Osborne, Freyberg, and Tasker (1982) described four different categories of curriculum. These were:

| | | |
|---|---|---|
| "(i) | the official curriculum | (official transmitted) |
| (ii) | the teachers curriculum | (teachers' intentions) |
| (iii) | the actual curriculum | (teachers' actions) |
| (iv) | the students' curriculum | (students' received)" |

(Osborne, Freyberg and Tasker, 1982, Page 10.)

All four categories are critical if we are to continually improve curriculum. Professional organizations, state and federal agencies, school corporations, book publishers, and standards are devoted to concerns of the *official curriculum*. We believe that historical textbooks represent a rich source of new ideas for the *official curriculum*. Teachers, schools, and teacher education programs adapt the *official curriculum* to the *teacher's curriculum*, to meet the specific needs of students. Historical texts can also be a source of ideas for the *teacher's curriculum*. Lesson plans, teachers' journals, professional meetings and some professional development reflect examples of the *teachers' curriculum*. The *actual curriculum*, including the hidden curriculum, and the *students' curriculum*, what the students take away from instruction, are studied by some educational researchers and in some teacher education programs. Children's science concept research would be an example of the information related to the *students' curriculum*, as would the idea of "children's science" suggested by Gilbert, Osborne and Fensham (1982).

These categories of curriculum appear to imply a hierarchy. Some might think the *official curriculum* is most important since it has a long history and contains input from many "specialists." We believe Osborne, Freyberg and Tasker, (1982), treat the four categories equally. With van den Akker (1998), we believe the different representations are necessary when discussing and comparing curriculum innovations. We believe it is important to understand the different levels of the curriculum if there is to be any growth and development of science standards.

The *official curriculum* is important because it provides an overall conception of what is to be taught and usually includes the specific topics to be included at each developmental level. But, it is only the best approximation at the time it was written. The *official curriculum* should evolve as feedback is provided by the *teachers'*, the *actual*, and the *children's curriculum*. Teachers are usually more concerned with how the *official curriculum* can be made appropriate for their students. The *students' curriculum* provides us with information about how the children make sense of our instruction. It can be a source of new instructional ideas.

There are other classifications of curriculum and van der Akker (1998) presents a model with six categories: *ideal, formal, perceived, operational, experiential* and *attained*. We believe, for our purposes that his six can be abbreviated to the four we use. Van der Akker (1998) does bring up other considerations that are relevant to our discussions. For example, "what knowledge is of most worth for the science curriculum" and "how science curriculum programs and materials should be developed and implemented."

**Integrating mature science and childlike wonder**

A major component of the scientific enterprise involves creativity. As part of science, it should have a place within the development of the science curriculum. Gardner's *Creating Minds* (1993) provides a different way to validate our use of the curriculum framework of Osborne, Freyberg, and Tasker, (1982). In this book, Gardner (1993) studies seven individuals who had an impact on the twentieth century;Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Gandhi. He uses three organising themes to structure the book: 1. The relationship between the child and the adult creator; 2. The relationship between the creator and other individuals, and; 3. The relationship between the creator and work in a domain. These themes provide a different way to integrate the four classifications of the curriculum with children's science concepts and the concepts in old textbooks.

His observations about Einstein supports our emphasis on a broad understanding of the discipline enhanced by old textbooks and the child's perspective provided by interview studies. In order to change the direction of a discipline like physics around 1900, required, ".someone steeped in the findings of recent physics, but not yet too entrenched in its current points of view – a mind at once young and mature," (Gardner, 1993, P101).

Gardner includes both the idea that "adult creativity has its roots in the childhood of the creator," and that the "creators were able to maintain the wonder and openness of young children throughout their lives." From our perspective this provides a critical reason to continue to study the *children's curriculum*. While a few adults can maintain the curiosity of a child in some areas, most adults are frequently surprised by children's statements. It is interesting that Einstein knew Piaget and suggested that Piaget investigate children's intuitive notions, which Gardner calls Piaget's "most illuminating lines of research," (Gardner, 1993). It was this area of Piaget's research that formed the basis of many science education studies of children's concepts (Pines, Novak, Posner, VanKirk, 1978).

Gardner's organising themes provide an expanded idea of a discipline and are especially important in looking at the *official* and *teacher's curriculum* and how they might be affected by the *children's curriculum*. His work is also critical in relating creativity in several disciplines to creativity in science education. The creators in his study first mastered the work in their domain, as we would start with the *official curriculum*. However, the creators relationships with that domain became problematic and they began to create "new symbol systems." Our studies of children's science concepts should affect our perceptions not only of how children learn, but how we view the *official curriculum*. The old textbooks provide a broader range of ideas to consider as part of the *official curriculum*.

**Learning from each other**

Margaret Mead wrote *Culture and Commitment* at a time of perceived change around the world. She was trying to help us understand several factors of this change. We believe she provides additional support to the idea that we must be ready to learn from our elders, peers, and the younger generations (children). She describes three general types of societies. In societies with a very slow rate of change younger individuals almost always learn from those who are older and more experiences. This would represent the *official* and *teacher's curriculum*. In societies with a medium rate of change, as the early twentieth century, the young can still learn from the older generation, but they also learn important information from peers and officials such as teachers and other community workers. Here again the emphasis is on younger individuals adapting to the cultural "standard," although some change might occur. In more rapidly changing environments, there are many things young people can still learn from their elders and peers, but all individuals now need to also listen to the younger generation, not necessarily for answers but for questions. This we believe supports research into children's science concepts.

**Summary**

We understand that Gardner and Mead do not "prove" the curricular levels of Osborne, Freyberg, and Tasker are appropriate. But it is interesting that we can find psychological and anthropological categories that support those presented for science education. Curriculum, especially in science, is abstract and remains an elusive problem, claims van den Akker, (1998). But, he continues, "science curriculum change is complex but not impossible." We believe that the material in textbooks over the last two hundred and fifty years and children's science concepts can lead to a wider range of activities and open new understandings for ourselves and our students. This could encourage the implementation of Osborne and Freyberg's classification of curriculum as a model for curricular change.

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## References

Bingham, Caleb.A.M. 1805. *An astronomical and geographical catechism*. For the use of children. The eighth edition. Printed by David Carlisle, for Caleb Bingham: Boston

Cronon, William. 1983. *Changes in the land: Indiana, colonists, and the ecology of New England*. Hill and Wang: New York.

Ferguson, James. 1756. *Astronomy Explained Upon Sir Issac Newton's Principles and Made Easy to Those Who Have Not Studied Mathematics*. London, Printed for, and sold by the author at the Globe, opposite Cecil Street and the Strand.

Ferguson, James. 1817. *An easy introduction to Astronomy for young gentlemen and ladies*. Benjamin Warner: Philadelphia.

Ferris, Timothy 1988. *Coming of Age in the Milky Way*. New York: Doubleday.

Gardner, H., (1993). *Creating minds*. New York: Basic Books

Gilbert, J., Osborne, R., & Fensham, P. (1982). Children's science and its consequences for teaching. Science Education, 66(4), 623-633.

Jackson, Edward P. 1894. *The Earth in Space. A Manual of Astronomical Geography*. D.C. Heath & Co., Publishers: Boston

Mead, Margaret. 1970. *Culture and Commitment*. Natural History Press: Garden City, N.Y.

Ministry of Education. 1993. *Science in the New Zealand Curriculum*. Wellington, N.Z.: Learning Media.

Novak, Joseph D.1987. Proceedings of the second International Seminar Misconceptions and Educational Strategies in Science and Mathematics. Ithaca New York: Cornell University.

NUSSBAUM, J. 1978. Science education seminar for faculty and students. Indiana University School of Education. Bloomington and Indianapolis.

Nussbaum, J. (1979). Children's conceptions of the earth as a cosmic body: a cross age study. *Science Education*. 63(1): 83-93

Osborne, R., & Freyberg, P. (1985). *Learning in Science: The Implications of Children's Science*. Auckland, New Zealand: Heinemann.

Osborne, R., Freyberg, P. & Tasker, R. (1982) The research appendix: Working papers methodology: Learning in science project. ERIC Document Number ED228 083.

Piaget, J. (1929). *The Child's Conception of the World*. New York: Harcourt Brace.

Pines, A.L, Novak, J.D., Posner, G.J. & VanKirk, J. (1978). The clinical interview: A method for evaluating cognitive structure. Research Report No.6, Department of Education, Cornell University

Rutherford, F.J. and Ahlgren, A. (1990). *Science for all Americans*. New York: Oxford University Press.

Queensland School Curriculum Council. (QSCC). 1999. Science years 1 to 10 syllabus. Brisbane: Education Queesnland

van den Akker, J. (1998). The science curriculum: Between ideals and outcomes. In Fraser, B. J. & Tobin, K. G. (eds), *International handbook of science education*. Dordrecht: Kluwer Academic Publishers.

Worchester, S. 1831. *The young astronomer, designed for common schools*. Richardson, Lord and Holbrook: Boston.

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# 053 MULTIPLE MODEL OF TEACHING:BUILT - IN ASSESSMENT ON PERFORMANCE (BAP) A NEW APPROACH TO RETHINKING SCIENCE AND TECHNOLOGY EDUCATION

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## Abstract

Following author's consequent papers presented to 9TH IOSTE 1999 in South Africa and 1st IOSTE 2001 in Southern Europe on Meta-Model and Conforming Model of Teaching with Students Style of Learning, and as the result of the longtime study and research on learning and instruction, Multiple-Model of Teaching Approach with Built-In Performance Assessment was designed to be used in teaching and instructing science for all at different levels, grades, and academic subjects instead of current lecture domination. This model has become a base line for a series of follow up researches in the educational field under the author supervision.

The main characteristic of the new and completed model is as follow:

A. It has nine consequent classes of learning in an ascending hierarchy, which indicates the steps that a science teacher should take in time when teaching science subjects. Teacher starts each step with a question. Each question is accompanied with one or part of a model of teaching, a level of learning, a dimension of content and an assessment B. Joyce, M. Weil, and E. Calhoun's Models of Teaching (2000), and my idea on new models of teaching are used. Models of teaching, levels of learning, dimensions of contents and assessments are arranged from simple to complex.

B. Each step is accompanied by another question at higher level of learning, higher complexity level dimension of content, higher level of assessment, and higher complexity of model of learning until the complexity level of students learning grows up accordingly from Knowledge to comprehension, application, analysis, synthesis, and judgment. R. Gagne's Conditions of Learning (1965) and B. bloom's Taxonomy of educational objectives (1965) are particularly in use.

C. It uses the seven dimensions of intelligence i.e., verbal\linguistic, logical\mathematical, visual\spatial, musical\rhythmic, body\kinesthetic, interpersonal, and interpersonal intelligence. Howard Gardner (1983), a cognitive psychologist at Harvard University, introduced these terms in his book "Frames of Mind: The Theory of Multiple Intelligence".

The nine steps and its consequent questions are as followings:

1. Specific Response. The teacher asks," What do you see, hear, note? Make a `list of them."
2. Chaining. The teacher asks: " what belongs together?"
3. Concept Formation. The teacher asks: "what title suits the concept?"
4. Penetration into the Concept. The teacher asks: "What are the features that cause each case belong to the concept?"
5. Chaining the features. The teacher asks: "What are the common features or characteristics that cause the cases belong to the concept?
6. Rule Making. The teacher asks: "How do you define the concept on the pattern shaped through chaining the features?
7. Hypothesizing and Rule Using. The teacher asks: " With regard to the rule how do you hypothesize the belongingness of the new cases to the concept?
8. Problem Solving. The teacher asks: "How do you apply the rule for the different concepts?
9. Assessment and abductive thinking. The teacher asks: "How can you rationalize the rules using them for verification?

Many researches have been done on the application of this model in teaching different subjects and in different levels and the results are significantly amazing.

## Introduction

Even though teaching methods has a long history, but its complement models of teaching has improved distinctively in the last decade. According to Wiles and Bondy if we compare the philosophies and learning theories in terms of the method of teaching we can see an emerging continuum which, on the one hand, is quite controlling and directing and on the other hand, is quite non- directive and student orienting (wiles 2000)

Following author's consequent papers" Meta- Model Approach in Science and Technology" presented to the 9th IOSTE 1999 in South Africa and "the Conforming Model of Teaching by Students Style of Learning" presented to the 1st IOSTE 2001 in Southern Europe, and as the result of the longtime study and research on learning and instruction Multiple- Model of Teaching: Build - In Assessment on Performance (BAP) is added to the serial in order to assess students' performance informally.

BAP, similar to the other models of teaching in the serial, is designed as a new approach to complete the teaching elements of each model in the serial of multiple models. Through BAP, teaching and instructing is applicable in different levels, grades, and academic subjects instead of current lecture domination.

BAP, as the other models in the serial, purposefully meets the unique style of students learning and their conceptual systems. It, also, considers their development in five dimensions i.e. social, cognitive, personal, behavioral, and spiritual. Therefore, BAP looks toward upraising well-rounded whole individuals using group investigation, information and intellectual processing or learning to think by thinking, personal awareness, behavioral systems, and spiritual revelation.

The phases for implementation are so clearly designed that ordinary teachers could readily apply BAP without need to wait for changes in factors such as administrative supports, formal educational goals and objectives, students' previous knowledge, formal content and media, formal evaluation design and its implementation program.

BAP, Now, has supportive experiences of positive results in a scene of researches in different science subjects and can be introduced for global implementation in schools and higher institutions of learning. In this article BAP with its build – in assessment is introduced as an instructional technology on science education.

BAP approach in science and technology education is a conceptual framework that a teacher may form to teach the student how to learn. It is considered to be a flexible model of learning. BAP is formed from the distinct features extracted from models each representing a family models of teaching. BAP considers upraising well-rounded whole individuals through the process of learning activities using social interaction, information processing, individual awareness, behavioral systems and spiritual revelation.

## Curriculum –Based Assessment

Schools are relying heavily on assessments and measure everything from personality to intelligence. The problem is they do not meet the needs of individual students. BAP uses systematic and continuous or formative assessment with students, the results of the assessment is used for further achievement, and has safeguards built in for students' errors. Its assessment is authentic, useful for life skills, and can be used as portfolio for measuring students development in the five dimensions i.e. social, cognitive, personal, behavioral, and spiritual

Jones, T. Southern, and F. Brigham (1998) in their article, "Curriculum-Based Assessment: Testing What Is Taught and Teaching What Is Tested, "Describe several approaches to CBA in the literature, and J. Bondy and J wiles sum up features common to most CBA approaches as followings:

1. Academic standards are identified with completion indicators.
2. Frequent measuring of standards is built in to the process.
3. Those involved in the process share assessment results.
4. Such data is used to make defensible decisions about instruction.
5. Planning, instructional analysis, and instructional decision making are integrated into an institutional system

Using these five procedures, BAP focuses instruction on tasks to be evaluated. In this manner, curriculum and instruction are combined into a process that is more effective in meeting student needs.

A sample lesson in science education at the fifth grade in elementary school will give us the opportunity to highlight the important elements of BAP. The lesson is planned for insect life. In planning assessment for the lesson the teacher need to consider the followings:

- **Shaping teaching strategies to match the learner's development.**
- **"Optimal development occurs when the environment facilitates the conceptual work necessary for the person's conceptual growth" (Hunt, 1970b,p.4).**
- **Assessing the construct of conceptual level (CL).**
- **Exploring CL's implications for the identifications of optimal training environments.**
- **Deciding on selecting and modifying suitable models' of teaching.**

In this sample lesson the teacher notices that fifth grade students have already observed insects such as bees, flies, ants, but their observations have not been scientifically oriented.

**The overall objective of the Lesson**

The overall objective is made at the ninth level of hierarchic learning i.e., abductive thinking, making evaluation and judgment on the base of experiments, and assessments. It guides the selection of objectives at the lower levels of the model. A common mistake to be avoided in planning the lesson is to begin at the knowledge level and then try to "squeeze" the more complex types of learning from the responses. Rather, one should begin at the most complex level- abductive thinking - and then determine what needs to be learned to make problem solving possible.

Overall Objective: To be sure that the students have understood the scientific definition of insects, can hypothesizes the belongingness of the new cases to insects, and verify the prediction. The lesson objective includes specific objectives prepared as follow:

> " At the end of the lesson, I will expect you to make a list of the animals that you can see in your environment, classify them and give each a label, you are supposed to consider insects among other animals and draw a table based on a few common features you discover through analysis of each insects and then make an insect definition, draw that insect, use analogy (personal, direct and compressed conflict) for that definition and be ready to recognize an insect and distinguish it from other living beings on the basis of scientific prediction, argumentation based on the definition, and confirmation or recognition of the predictions based on the results of experiments and experiences."

Table 1 is a sample of how a teacher can make instructional design on BAP approach. Teacher's objectives indicate overt activities arranged in consequent phases according to the standardized operational procedure for assessment that has been designed using inductive model of teaching. There is, also, a comparison between Benjamin Bloom's "Taxonomy of Educational Objectives"(1956), or, levels of cognitive learning (i.e., knowledge, comprehension, application, analyses, syntheses, and judgment), R. Gagne's Conditions of Learning (specific responding, chaining, multiple discrimination, classifying, rule using, and problem solving), and the nine phases in BAP. Teacher's questions are designed consequently to improve the complexity level of students' cognition from knowledge up to judgment. Another aspect of this table, which is the distinct feature of BAP, is the Models of teaching that can be used on teacher volition. These models are several but a few of them have been indicated here as examples. The teacher can make decision on the kind of media and specify time contingent on circumstances.

These nine classes of learning form an ascending hierarchy; thus, before one can chain, one has to learn specific responses, identifying and enumerating the data relevant to a topic or problem. Chaining is assigning cases to classes denoting like functions, and in this way learning to distinguish insects from other animals. The result from this process is concept formation i.e., developing label for the category whose members have common attributes. Concept formation requires prior learning of chaining. Identifying critical features requires concept learned through classification (classifying the critical features) needs to have previous identification of the features. Definition requires previously established relations between features. Predicting requires applying definition formed through concept formation, to explain new phenomena or, predict consequences from conditions that have been established. Problem solving uses prediction that is ability to act on a concept that implies action, and application of the concept definition to a problem encountered before by the learner. Final assessment is, after all, used for "abductive thinking" which involves learning to handle previously learned levels. Assessments are taken place in a paradigm accompanying each step.

Indicating the pre-advance organizer on insect for learning, the teacher gives the following consequent direction orienting them to refer to sly and harmful animals:

1. Classify them based on the relations you can find out among them.
2. Make a list of the animals in your surroundings.
3. Give each class of animals a label (students are expected to label insect otherwise the teacher will offer this label to them).
4. Make a list of the distinct features of a few insects.
5. Make a table that shows relationship between the insects and their distinct features.
6. Make definition on insects.
7. Predict the belonging of an unfamiliar animal to insect.
8. Rationalize the prediction on the definition on insect.
9. Make an observation or experiment to verify yourPrediction.

## STUDENTS' ACTIVITIES

**Step 1-** Students 'at the first phase' make a list of living beings first individually, and then in groups and finally in the class as a whole. At this stage of the lesson the teacher can use the group investigation model of teaching. He /She can ask the students to collect information through studying different books, observing living beings or their pictures and talking with authorities before coming into the classroom and then put the information collected on the board. (The teacher himself/herself can use a collection of live insects or dried ones or their pictures. The teacher or the formal curriculum are only one source of information and the student is learning the skills necessary for processing information independently) The level of learning and assessment at this stage is knowledge.

**Step 2-** Looking at the list of at least 40 living beings identified and enumerated, and on the basis of the relationships that they can observe among them, the students group them all into categories whose members have common attributes The level of learning and assessment at this stage is comprehension.

**Step 3-** After classifying the living beings according to the common attributes found out among them, the students develop labels such as reptiles, mammals, and insects for each category (Up to this point, the concept of insects is formed in their minds and in fact, according to Bloom's classification, they've come up to the level of classification and understanding in terms of cognition; and through their preoccupation with the learning task, to the level of attention and response in terms of emotions and finally to imitation and repetition in terms of psycho-motor domain)

**Step 4-** Having the concept of insects in their mind, the students focus on one specific insect and make a list of the features which distinguish it from all other living beings included in other categories

If the students aren't familiar with this pattern, the teacher can tell them that having eyes or breathing are not distinctive features of insects. The students will be able to say that having three pairs of legs and one pair of feelers and three distinct parts of the body are specific features of insects. In fact the pattern used at this stage of the lesson is concept formation. The level of learning and assessment at this stage is analysis.

**Step 5-** now, students with due attention to the list of features that they have made and the common relation among them, can make a table. (For example Table 2) The level of learning and assessment at this stage is synthesis.

**Step 6-** Now, with due attention to the common features in the table, the students can define insects. All students define insects as living beings, which have three pairs of legs, one pair of feelers and a body made up of 3 distinct parts. (At this stage, the level of learning is synthesis to which the students get through analysis and tabulation)

**Step 7-** Now, during the remaining part of the time available, the teacher will mention the name of some living beings, and the students, based on the definition given to insects, will predict whether they belong to the category of insects or not. The level of learning and assessment at this stage is evaluation or judgment

| | Teacher Objective For Assessment | Level On Learning | Teacher Question | Models of Teaching | Time and Media Expected |
|---|---|---|---|---|---|
| 1 | Students' specificResponse (Making a List) | Knowledge | What Do YouSee? Hear?Note? | Advanced organizer,GroupIn vestigation. | On teacher volition |
| 2 | Chaining (Grouping) | Comprehension | What BelongsTogether? | Group inquiry,Attaining Concept | """""""" |
| 3 | Concept formation(Giving Labels) | Application | What Do You Call This Group? | SynecticsConcept Attainment | """""""" |
| 4 | Identifying CriticalFeatures.P enetration into the Concept. | Analysis | What Is the Critical Feature of Each Sample? | Attaining conceptSynectics | """""""" |
| 5 | Chaining theFeatures. ClassifyingThe Critical Features. | Syntheses | How Can You Make A Table Of Them? | SynecticsGroup Investigation | """""""" |
| 6 | Rule Making. Giving Definition. | Syntheses | Give A Definition | SynecticsGroup Investigation | """""""" |
| 7 | Predicting (hypothesizing and Rule Using) | Judgment | Does this Belong ToThe Concept? | Deductive | """""""" |
| 8 | Problem solving.Supporting thePrediction. | Application | How Can YouConfirm It? | InquiryAbductive | """""""" |
| 9 | Assessment andabductive thinking.Making Experiments | Application | How Can You Prove It? | Mastery learning | """""""" |

**Table 1-** Application of BAP in a lesson

**Step 8-** the students prove their prediction based on the definition.

**Step 9-** now the students can make final assessment and approve or reject their inclusion in the class of insects. The levels of learning at this stage exceed synthesis and reaches judgment. In fact, they have generalized the definition and applied it.

As it was specified first, the aim of the lesson is exposed on the board and the aim itself will indicate and guide all teaching steps. The different elements of teaching for each of the sequential objectives are determined in advance on the basis of the facilities. The students themselves collect the general familiar information from their immediate environment, previous experiences and learning, study or observation, and bring them to the classroom. In the classroom, the information is processed through management information system process or any other system, which is mentioned in Table 1.

## Assessment

Assessment and through it the evaluation of students achievement, all through these steps, joins with observation of students' achievement and is inseparable part of teaching. In each step, the teacher identifies what the students already know and tries to complete it before shifting to the next step. The teacher can specify the time, media, and the required content for each objective in advance. In fact there should be a lesson plan in which all teaching elements including the aim, cognitive and behavioral objectives, sequence, assessment, content, media, and procedures are mentioned.

| Insects' Features | 3 Pairs Of Legs | 3 Distinctparts Of The Body | 1 Pairs Of Feelers |
|---|---|---|---|
| Bees | + | + | + |
| Fly | + | + | + |
| Ant | + | + | + |
| Spiders | 4 pairs | 2 distinct parts | None |

**Table 2-** the features necessary to be mentioned for defining insects

Teachers are expected to teach through BAP as a learning pattern and provide the student an opportunity to practice it so that they can use it independently in learning new things

## References

Behrangi, M.R.., (2001) Conforming Model of Teaching by Students' Learning Style: preparing future citizens Science and Technology Education: 1st IOSTE Symposium in Southern Europe Paralimni. Cyprus 29th April-2nd May, 2001

Behrangi, M. R..,(1999) Meta Model Approach in Science and Technology, 9th Symposium of the International Organization for Science and Technology Education (I0STE) 26June-2July1999,Durban, South Africa

Bloom, B.S., et.al, (1956) "Taxonomy of educational objectives. Handbook 1:Cognitive domain, New York: Mckay

Bondi, Joseph & Wiles, Jon., (2000). Supervision: A guide to practice Prentice Hall

Jones, Eric Southern, Thomas, and Brigham, Fred. "Curriculum-Based Assessment: Testing What Is Taught and Teaching What Is Tested," Intervention in School and Clinic 33, 4(March 1988): 239-246

Gagne, R. (1965) The Conditions of Learning. New York: Holt, Rinehart &Winston.

Hunt, D. E. Joyce, B., Greenwood, J. Noy, J. Reid, R., & Weil, M.(1981) Student conceptual level and models of teaching. In B. Joyce, L., peck, & C., Brown, (Eds.), Flexibility In Teaching. White Plaine, N.Y: Longman.

Joyce,B, Weil, M., & Calhoun, Emily, (2000) Models of Teaching (6th. ed.). Allyn & Bacon

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# INSTRUCTIONAL EFFECTS ON UNIVERSITY STUDENTS' EPISTEMOLOGICALDEVELOPMENT

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**Abstract**

Research evidence indicates that students' scientific epistemological beliefs play an important role in determining their learning orientations towards science and the ways of organizing cognitive structures of scientific knowledge. Previous research also suggested that reasoning abilities are associated with epistemological development. The issue of whether epistemological growth is developmental in its nature or affected by instructional methods constitutes, however, an ongoing debate in the literature. In this study, we examined the possible effects of different instructional strategies on learners' epistemological development. Specifically, the study investigated the effects of teaching critical-thinking principles on university students' epistemological development, and whether these effects had any relation to the teaching strategy. Ninety-five first- and second-year university students were randomly assigned to three different training sessions (45-minutes duration). In the first session, subjects were taught general critical thinking principles in a de-contextualized way. In the other two sessions, one being a variation of the other, subjects were taught critical thinking principles situated in a real-world context. Epistemological development was measured in terms of the difference of subjects' performance on a pre- and post-test measuring two variables representing (a) view of knowledge and (b) justification of beliefs. Statistical analyses of the data, using a doubly multivariate repeated measures design, showed a statistically significant effect related to justification of beliefs ($F = 6.552$, $p < .05$) and a significant effect related to view of knowledge ($F = 4.504$, $p < .05$). Post-hoc comparisons did not reveal, however, any significant differences among the subjects assigned to the three instructional strategies in terms of their performance on both measures. The results of the study indicate that even short training on critical thinking principles affected students' view of knowledge and their approach in justifying beliefs. Efforts should be intensified to design and implement appropriate teaching materials and strategies of longer duration conducive to facilitating students' epistemological development. Orchestrated efforts towards this direction should also address the development of reasoning and critical-thinking abilities and their relationship with epistemological development. Education in science and technology should pay more attention on developing future citizen's ability to judge evidence and draw conclusions from the scientific point of view in conjunction with their epistemological development.

## Introduction

The emergence of information age, the birth of global economy, and the new ways of communication continuously transform our physical, social, political, economic and cultural environments, and shape accordingly our understandings and our views of scientific and technological literacy (STL). A concept of STL must put emphasis on the functional aspects of science and technology as they relate to human welfare, economic development, social progress, and the quality of life. Thus, if STL is an implied aim of science teaching, then it should provide a balance among content, methods and processes of science, the nature of science, and the interaction between science, technology, and society. Evidently, the development of students' reasoning, problem-solving, decision-making, and critical-thinking abilities as well as their epistemic growth should be important issues when designing and implementing science and/or technology curricula.

Previous research on students' scientific 'misconceptions' or 'alternative conceptions' also contributed substantially to our understanding of the ways that learners' prior knowledge highly influences how new knowledge is constructed. The organizing role of prior knowledge and understandings in gaining new knowledge and skills should include, however, other aspects of knowledge structures and patterns of reasoning, such as epistemological and attitudinal variables. For example, there is research evidence indicating that students' scientific epistemological beliefs play an important role in determining their learning orientations towards science and the ways of organizing cognitive structures of scientific knowledge. There is also evidence indicating the importance of scientific epistemological beliefs on conceptual change (Posner et al., 1982). Research evidence (Perry, 1970; King & Kitchener, 1994) also suggested that reasoning abilities are associated with epistemological development.

Evidence also exists showing that epistemological beliefs and reasoning or critical-thinking are somehow connected. Brabeck (1983), for example, provided evidence that critical thinking and reflective judgment are different constructs but they are highly correlated. Kuhn (1991) also concluded that epistemic beliefs and reasoning skills are connected.

Personal epistemological development and epistemological beliefs are thus becoming a growing area of research interest, and intensive research efforts are directed towards investigating the way individuals come to know, their beliefs about knowing, and the manner in which such epistemological premises are related to the development of cognitive processes of thinking and reasoning. The issue of whether epistemological growth is developmental in its nature and the extent to which it could be affected by instructional methods also constitutes an ongoing debate in the literature.

In a recent review of the literature, Hofer and Pintrich (1997) concluded that most of the researchers, who have studied epistemological development (e.g., Perry, 1970), seem to suggest that epistemological growth is developmental in nature. Hence, epistemological development has been studied for the most part in terms of stage models, and how and when epistemic growth progresses from one stage to another. Nonetheless, no systematic research efforts have been devoted so far in the examination of the effects of instructional experiences on epistemic growth. The way teachers in science classrooms explain scientific ideas and organize information could influence students' epistemological beliefs and their learning perceptions. It is implied that the learning environment created in science classrooms may contribute in shaping students' perceptions of how science is practiced and how new knowledge is constructed.

In the present study the results of employing different instructional strategies were compared in an attempt to establish possible links between epistemic growth and instruction. Specifically, the study investigated the effects of teaching critical-thinking principles on university students' epistemological development, and whether these effects had any relation to the teaching strategy.

## Theoretical Framework

King and Kitchener (1994) proposed the most extensive developmental scheme for assessing epistemological beliefs. They developed the reflective judgment model to describe how individuals reason about ill-structured problems. The model was constructed based on 15 years of interview studies with high school students and adults of all ages. During the interview, participants were first asked to state and justify their point of view about the specific issue at hand. Subsequently, they were asked six questions specifically designed to tap assumptions about how they viewed knowledge and how they justified their beliefs. The data obtained from the interviews were then analyzed by employing a seven-stage rubric that was specifically developed.

In this research study, the seven-stage model of epistemological development (King & Kitchener, 1994) was reduced into a three-stage model by: (1) collapsing the three pre-reflective stages into one stage, that of Absolutist Thinking; (2) collapsing the two quasi-reflective stages into one stage, namely, Relativist Thinking; and (3) collapsing the other two stages into one stage, that of Reflective Thinking. A person's stage of epistemological development was then evaluated in terms of performance on a test measuring two variables: (1) View of Knowledge; and (2) Justification of Beliefs. The first construct consists of one's view of knowledge, 'right versus wrong' knowledge, and legitimacy in viewpoints, and the second construct consists of the concept of justification, use of evidence, and the role of authority in making judgments. In this scheme, 'view of knowledge' and 'justification of beliefs' are rather interrelated, and any advancement in one of them leads to an advancement of the other.

In the pre-reflective stage individuals perceive knowledge as certain, and consider that answers to all questions are acquired through experts, parents, and authorities in general. It is thus implied that beliefs need no justification or that they are also justified through an authority figure. Quasi-reflective thinking recognizes that one cannot always know with certainty. Knowledge is considered to be subjective and contextual. Thus, thinking is also contextual and relative to one's experiences. Consequently, "What is known is always limited by the perspective of the knower" (King & Kitchener, 1994, p. 62). Beliefs are filtered through a person's experiences and are justified by giving reasons and evidence idiosyncratic to the individual. It is not until stages 6 and 7 that reflective thinking starts to emerge. At this stage, knowledge is the outcome of the process of rational inquiry leading to a well-informed understanding. Beliefs are justified by evaluating evidence and arguments from different perspectives leading to a reasoned judgment, which is considered as the best plausible understanding of an issue on the basis of all available sources of information. At this stage, critical inquiry and probabilistic justification guide thinking and knowledge construction with awareness that all conclusions may be reevaluated.

Reflective thinking bears an almost direct correspondence with the nature of science. At a level of generality, the nature of science refers to the epistemology of science, or science as a way of knowing that includes the values and beliefs inherent in the development of scientific knowledge. Recent science education reform documents (AAAS, 1993; NRC, 1996) and science education research (Lederman, 1999) identified the general aspects of the scientific enterprise that tap on the basic characteristics of reflective thinking. Scientific knowledge is empirically based, that is, based on and/or derived from observations of the natural world, and it is always theory-laden and subjective. Consequently, science is the product of human inference, imagination, and creativity. Scientific knowledge is always socially and culturally embedded, and it necessarily involves a combination of observations and inferences. It is thus probabilistic in nature and subject to change upon accumulation of new evidence taking into consideration that observations are necessarily constrained by our perceptual apparatus and are inherently theory-laden.

## Methodology

### The Context of the Study

Ninety-five first- and second-year university students were randomly assigned to three different training sessions (45-minutes duration). In the first session, subjects were taught general critical thinking principles in a de-contextualized way. In the other two sessions, one being a variation of the other, subjects were taught critical thinking principles situated in a real-world context. Epistemological development was measured in terms of the difference of subjects' performance on a pre- and post-test measuring two variables representing (a) 'view of knowledge' and (b) 'justification of beliefs'. In more detail, the three teaching strategies were PreTeach, Infusion, and Immersion. PreTeach was designed based on traditional/didactic instructional tactics (Reigeluth, 1983) such as presentation of content, examples, and practice, to teach participants principles of good critical thinking. These principles include analysis of the problem, generation of alternative solutions, development of the reasoning for each solution, decision about which is the best solution, and evaluation of one's thinking based on certain criteria. On the other hand, Infusion and Immersion were designed based on constructivist principles (Duffy & Cunningham, 1996) of teaching and learning, and focused more on the process participants followed to construct their own critical thinking principles within the context of collaborative problem-solving. Infusion aimed at both making critical thinking principles explicit to the learners, as well as helping them to contextualize those principles in a specific situation. Learners were placed in a problem-based learning activity with a real-world problem, and general critical thinking principles were made explicit to them only after they were asked to reflect on their thinking process and develop their own principles. Immersion aimed at teaching students general principles of critical thinking executed or contextualized in a problem-solving situation with a real-world problem. General critical thinking principles *were not made explicit* to the learners, as they were with PreTeach and Infusion. Instead, students' ideas of critical thinking principles were first solicited, and, then, through Socratic questioning, students were challenged to reflect on and evaluate the principles they had constructed.

The context within which this study took place was that of collaborating with others to solve an ill-defined problem, i.e., a problem that could be solved in many different ways. Students were randomly assigned in dyads, and then each dyad was randomly assigned to one of the three teaching interventions (i.e., PreTeach, Infusion, Immersion). There were two research sessions training and transfer. At the beginning of the training session, each participant's epistemic beliefs were measured, and then participants had been taught about critical thinking principles. During the transfer session each dyad was asked to discuss the issue "Should drugs be legalized?" and prepare an outline for a paper that presented their joint position on the issue. At the end of the session, each participant's epistemic beliefs were again measured.

In both occasions, participants' epistemic beliefs were measured using a questionnaire with five open-ended questions. Form A and Form B of the questionnaire were used for the pre- and post-test. The questions in the pre-test were related to the article "Are our values shaped by the mass media?", while, in the post-test they were related to another article titled "Should drugs be legalized?" The five questions were adapted from Kitchener's (1994) reflective interview questions. The first question measured participants' perceptions of how important they thought the two controversial issues were. The other questions addressed either participants' views of the nature of knowledge or their beliefs of how knowledge should be justified.

Obviously, the approach for evaluating epistemic growth intentionally tried to avoid "certain blanket generalizations about the nature of knowing and learning, generalizations that do not attend to context" (Elby & Hammer, 2001, p. 555). Epistemological knowledge does not consist of declarative beliefs that are stable across contexts and people can express them if asked the right questions. For example, the notion that scientific knowledge is tentative and evolving does not necessarily apply equally across all scientific knowledge, but it depends on contextual nuances. Thus, the approach followed took into consideration the contextual dependencies of students' beliefs about knowledge and attempted to avoid 'mis-measuring' their epistemological stances.

## Results

Analysis of participants' answers was conducted by employing the three-stage rubric that was developed by reducing the Kitchener's (1994) seven-stage model of intellectual development. A trained rater independently graded 25% of each form of the questionnaire (48 out of 190), and Pearson r inter-rater reliabilities were calculated. The reliabilities for 'view of knowledge,' 'justification of beliefs,' and overall were .79, .74, and .82 for Form A, and .88, .70, and .80 for Form B, respectively. The range of these reliabilities guarantees sufficiency in dealing with instrumentation validity.

Table 1 shows descriptive statistics of students' scores related to 'view of knowledge' and 'justification of beliefs' for each teaching strategy, and Table 2 presents the inter-correlations among pre- and post-test measures of students' 'view of knowledge' and 'justification of beliefs'.

**Table 1**: Descriptive Statistics of Students' Scores. Related to View of Knowledge and Justification of Beliefs

| | Treatment | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-teach | | | Infusion | | | Immersion | | | Total | | |
| | Mean | SD | n | Mean | SD | n | Mean | SD | n | Mean | SD | n |
| View of Knowledge | | | | | | | | | | | | |
| Pre-test | 2.17 | .30 | 30 | 2.28 | .41 | 34 | 2.13 | .36 | 31 | 2.19 | .37 | 95 |
| Post-test | 2.28 | .43 | 30 | 2.28 | .39 | 34 | 2.23 | .42 | 31 | 2.26 | .41 | 95 |
| Justification of Beliefs | | | | | | | | | | | | |
| Pre-test | 2.30 | .75 | 30 | 2.18 | .80 | 34 | 2.13 | .76 | 31 | 2.20 | .77 | 95 |
| Post-test | 2.48 | .50 | 30 | 2.56 | .66 | 34 | 2.42 | .67 | 31 | 2.46 | .61 | 95 |

**Table 2:** Inter-correlations Among Pre- and Post-test Scores on 'View of Knowledge' and 'Justification of Beliefs'

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| View of Knowledge-pre (1) | 1.000 | .182 | .150 | .162 |
| Justification of Beliefs-pre (2) | .182 | 1.000 | -0.017 | .005 |
| View of Knowledge-post (3) | | | 1.000 | .543** |
| Justification of Beliefs-post (4) | | | | 1.000 |

In general, post-test scores on students' 'view of knowledge' and 'justification of beliefs' were higher than pre-test scores for every teaching condition. Nevertheless, only the Pearson r correlation between students' post-test scores on 'view of knowledge' and post-test scores on 'justification of beliefs' was significant at $p. < .01$. This seems to imply that these two variables rather develop in synchrony. This interpretation is not totally justified, because the same variables, as they were measured by the pre-test, were not significantly correlated. Moreover, there was not any significant correlation between pre- and post-test measures of either the 'view of knowledge' or the 'justification of beliefs'.

Table 3 shows the results of the repeated measures MANOVA for 'view of knowledge' and 'justification of beliefs'.

**Table 3:** Repeated Measures MANOVA for View of Knowledge and Justification of Beliefs (n=95)

| Source of Variance | SS | df | MS | F | Level of Significance |
|---|---|---|---|---|---|
| Between-Subjects Effects | | | | | |
| Intercept | 1968.032 | 1 | 1968.03 | 4447.435 | .000 |
| Teaching method (A) | .629 | 2 | .31 | .710 | .494 |
| Error | 40.711 | 92 | .44 | | |
| Within-Subjects Effects | | | | | |
| View of Knowledge (B) | 1.012 | 1 | 1.012 | 4.504 | .037** |
| Interaction (A x B) | .023 | 2 | .012 | .051 | .950 |
| Error | 20.664 | 92 | .225 | | |
| Justification of Beliefs (C) | 2.559 | 1 | 2.559 | 6.552 | .012** |
| Interaction (A x C) | .145 | 2 | .072 | .185 | .831 |
| Error | 35.931 | 92 | .391 | | |
| Interaction | | | | | |
| B x C | .823 | 1 | .823 | 3.666 | .059 |
| A x B x C | .634 | 2 | .317 | 1.413 | .249 |
| Error | 20.652 | 92 | .224 | | |

** Statistically significant at $p. < .05$

The main effect related to the between-subject independent variable was not significant, that is, none of the three training sessions was significantly more effective in promoting students' 'view of knowledge' and their 'justification of beliefs'. Students' pre- and post-test scores related to either 'view of knowledge' ($F = 4.504$, $p < .05$) or 'justification of beliefs' ($F = 6.552$, $p < .05$) were, however, significantly different. The interaction effects between treatment and either one of the two within-subjects variables were also not significant. Post hoc comparisons did not show any statistically significant effect related to any one of the three training conditions.

## Discussion

Kuhn (1970) argued that paradigm shifts in scientific thinking occur or do not occur depending on social factors that determine how evidence is interpreted or what counts as compelling evidence. Similarly, students' epistemologies might act as obstacles or catalysts for conceptual development. Science education should not ignore that the fallibility of science is a quality inherent in the nature of science that should be fully explored, understood, and shared not only with our students but also with the public in general. Evidently, students should come to understand scientific knowledge as fundamentally tentative and evolving, rather than certain and unchanging. They should view scientific knowledge as subjective, in the sense that it reflects scientists' perspectives, rather than objectively inherent in nature. They should also view scientific knowledge as a coherent, hierarchical system of ideas, not a simple collection of facts. Thus, they should conceptualize learning science as making sense of new ideas for themselves rather than receiving and accumulating information from authorities. "Scientific knowledge is simultaneously reliable and tentative. Having confidence in scientific knowledge is reasonable, while recognizing that such knowledge may be abandoned or modified in light of new evidence or re-conceptualization of prior evidence and knowledge" (NSTA, 2000).

The results of this study suggest that teaching methods and educational experiences can have a significant effect on learners' epistemological development. Even a short training on critical-thinking principles affected students' views of knowledge and their approach in justifying beliefs. There was an overall effect attributable to training, but there was no evidence associating significantly better results with any one of the three training conditions. Students exhibited a significantly improved performance in their' 'view of knowledge' and their 'justification of beliefs,' as these variables were measured by students' answers to the five-question questionnaires and evaluated by employing the three-stage rubric, but none of the employed teaching approaches was superior than the others from this respect, and any claims about the kind of teaching that could be more effective are not tenable.

The cumulative evidence from this study clearly tends to support, furthermore, that 'view of knowledge' and 'justification of beliefs' do not develop in isolation. Any improvement in terms of 'view of knowledge' is somehow associated with improvement in terms of 'justification of beliefs' and vice versa. Teaching critical-thinking principles proved to positively affect both 'view of knowledge' and 'justification of beliefs'. Post-measures of these constructs were also positively and significantly correlated, while pre-measures of them were not. This inconsistency contradicts, to a certain extent, the hypothesis of concurrent development of 'view of knowledge' and 'justification of beliefs'.

In summary, there are indications that research on epistemological development is promising. Efforts should be intensified to design and implement appropriate teaching materials and strategies of longer duration conducive to facilitating students' epistemological development. Orchestrated efforts towards this direction should also address the development of reasoning and critical-thinking abilities and their relationship with epistemological development. Education in science and technology should pay more attention on developing future citizen's ability to judge evidence and draw conclusions from the scientific point of view in conjunction with their epistemological development.

But, as with all research findings we need to be careful about how we interpret the findings of the study. What we cannot infer at this point in time is whether these belief changes are enduring or whether some students are simply more adaptable than others are. More research studies are needed to investigate the effects of instruction on epistemic growth. It also seems necessary to avoid relying exclusively on surveys, but rather to contextualize interviews more deeply, use more naturalistic (observational) methods, and take into account the results from different contexts and approaches as a way of triangulating our results. This research study provides preliminary evidence that epistemological growth may not be just developmental but also linked with educational experiences teachers provide in the classroom. Future efforts should also focus less on ranking the students' epistemologies and more on identifying productive epistemological resources that can be triggered by different contexts or evaluation approaches.

Research should also pay more attention to the productivity of an epistemological belief and avoid blanket assertions that do not account for contextual dependence (Elby & Hammer, 2001). Any belief may prove as productive only if it generates behavior, attitudes and habits of mind that lead to cognitive engagement and mental effort for an in-depth understanding of a phenomenon. For example, it might not be productive for elementary school students to view as tentative the idea that the earth is round or that the day-night cycle is attributable to the earth's rotation around its axis, but it might be productive to take a more tentative stance toward light phenomena or theories of light. Kuhn (1970) suggested that individuals view the world from within a certain paradigm or conceptual framework shared by their community. In a sense, individuals live in a phenomenal world mediated by a shared language and comprehended from within a conceptual framework of inter-subjective meanings. They then usually attempt to comprehend new knowledge and phenomena from within the conceptual entities that make up their phenomenal world.

Elby and Hammer (2001) suggest that students' epistemological endowment "consists not of articulate beliefs, but rather of epistemological resources- often implicit, often inarticulate- that can be triggered in different combinations by different contexts" (p. 566). Research should be intensified and coordinated in order to identify productive epistemological resources that students can employ to become better learners and feel more comfortable to face the dramatic changes that accompany our era. Obviously, this is the beginning of a prosperous line of research taking into account that the effects of instructional methods have remained largely unexplored within the domain of epistemological development.

## Bibliography

AMERICAN AASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. (1993). Benchmarks for Science Literacy: A project 2061 report. New York: Oxford University Press.

BRABECK, M. (1983). The relationship between critical thinking skills and the development of reflective judgement. Journal of Applied Developmental Psychology, 4, 23-34.

DUFFY, T. M., & Cunningham, D. J. (1996). Constructivism: Implications for the design and delivery of instruction. In J. H. Jonassen, (Ed.), Handbook of research for Educational Communications and Technology (pp. 170-198). New York: Simon & Schuster Macmillan.

ELBY, A., & Hammer, D. (2001). On the substance of a sophisticated epistemology. Science education, 85, 554-567.

HOFER, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. Review of Educational Research, 67, 1, 88-140.

KING, P. M., & Kitchener, K. S. (1994). Developing reflective judgment: Understanding and promoting intellectual growth and critical thinking in adolescents and adults. San Francisco: Jossey-Bass Publishers.

KUHN, D. (1991). The skills of argument. Cambridge, England: Cambridge University Press.

KUHN, T. S. (1970). The structure of scientific revolutions. (2nd ed.). Chicago: The University of Chicago Press.

LEDERMAN, N. G. (1999). Teachers' understanding of the nature of science: Factors that facilitate or impede the relationship. Journal of Research in Science Teaching, 36, 916-929.

NATIONAL RESEARCH COUNCIL (1996). National science education standards. Washington DC: National Academic Press.

NSTA position statement on the nature of science. (2000). NSTA reports, Vol. 11 (6).

PERRY, W. G. (1970). Forms of intellectual and ethical development in the college years: A scheme. New York: Holt, Rinehart, and Winston.

POSNER, G., Strike, K., Hewson, P., & Gertzog, W. (1982). Accommodation of scientific conception: Toward a theory of conceptual change. Science Education, 66, 211-227.

REIGELUTH, C. M. (Ed.). (1983). Instructional-design theories and models: An overview of their current status. Hillsdale, N.J: Lawrence Erlbaum Associates.

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# CHAOS IN THE SCIENCE CENTER: A MULTIMEDIA EXHIBIT

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**Abstract**

This work describes an interactive exhibit for demonstrating chaotic phenomena and concepts of dynamical systems. It was conceived to address the general public in science centers and science museums. The exhibit has three items: (a) a system with two uncoupled double pendulums which allows the observation of the chaotic movements in each of them (when launched from appropriate initial conditions) and also the different trajectories into which each of them evolve; (b) an optical scattering system where a laser light beam is directed to a set of three cylindrical mirrors positioned at the vertices of an equilateral triangle. The laser beam may or may not be multiple scattered depending on its incidence point, revealing the sensibility of the system to the initial conditions; (c) a multimedia software with a text on deterministic chaos, dynamical systems, atractors and suggestions for further readings and activities. The software also has interactive simulations with graphical resources that reproduce the behavior of the equipment in detail and under controlled conditions, intended to demonstrate the power of the physics concepts and mathematical methods used to deal with this kind of system. The software can be operated by the general public of the museum at a multimedia kiosk installed near the exhibit and can also be executed through the Internet. Two units of the exhibit were built: one is at Estação Ciência, a science, technology and culture diffusion center of University of São Paulo, in São Paulo, SP, and the other is at the Instrumentation, Demonstration and Experimentation Laboratory of the Physics Department at Federal University of Santa Catarina, in Florianópolis, SC. Both institutions are opened to the general public, have programs for attending scheduled school groups and develop teacher training programs. This paper presents the basic ideas underlying the phenomena that can be demonstrated with the installation, design and construction details, algorithms used in the simulations and strategies for the use of the exhibit in the context of science centers and science museums.

## 1. Introduction

### 1.1. Chaotic phenomena and dynamical systems

Chaos is present in many natural and systems: variations in predator and prey population in an ecosystem have chaotic features; the stock market has sudden fluctuations, unexpected and impossible to forecast using economical models; the rhythm of a sick heart are aperiodical and complex in certain critical situations.

Since the 70´s, beginning with the pioneer works of Edward Lorentz, Mitchell Feigenbaum, Stephen Smale, James Yorke and others, a whole conceptual and mathematical framework was developed to deal with systems that display chaotic behavior. This opened a whole new frontier in science with an impact considered by many as comparable to that of the quantum theory.

The subject was greatly appreciated by educated people from the general public. James Gleick [GLEICK, 1990] wrote a best seller book that would tell the history of this development almost as a thriller. The subject deserved dedicated issues from science popularization magazines [LA RECHERCHE, 1989; SBPC, 1992]. Closely related to chaos, fractals were materialized in the form of exotic images in a great book [LAUWERIER, 1991] and were extensively explored in a special section in many issues of *Scientific American* [DEWDNEY, 1989-1990]. Today it is possible to find a great number of Internet sites with interactive applets for fractal generation, exploring its aesthetic appeal. Books with more technical introductions proliferated [HO-KIM et al., 1991; DEVANEY, 1992] and specialized scientific journals created specific sections for papers on chaos and complex systems. The subject is now part of standard classical dynamics books [JOSÉ and SALETAN, 1998].

However, like quantum mechanics and relativity, fundamental structures of the contemporary view of nature, deterministic chaos is unknown to the general public. And, like quantum mechanics but in a much more explicit level, chaos is present in a multitude of daily situations, from meteorology to physiology. Our motivation for developing the exhibit was the desire to give the general public the opportunity and stimulus to think about it. Also, the experiments were chosen in an attempt to show that two apparently disconnected phenomena - the movement of a pendulum and the scattering of light - do have something in common: the deterministic chaos. The text and simulations added to the exhibit meant to stimulate the visitor to think about the possibilities of science, to have a glimpse of the ability science has shown in dealing with regular and irregular phenomena and the connection of all that with the beauty of geometry. The goal is to awake, mainly in the young science center visitor, the perception of these relationships.

**1.2. Science popularization and science centers**

It is a consensus that a country's scientific and technological activity is directly linked to its economical development perspectives [UNDP, 2001]. In order to pursue this development, huge investments in the nation's science and technology system are necessary. And the most important part of this system is the people who are running it and who can benefit from it. It should thus be a priority to arouse in a great fraction of the young population the desire to follow scientific carriers and offer them conditions to be successful in case they choose this path. To effectively create the stimulus and the conditions, there must be a great, systematic and continuous investment in the various components of the educational system. In the industrialized countries — and more recently in many emerging countries — one important strategy has been the creation and upgrade of science museums and science centers.

Science museums and science centers offer the possibility to enhance the participation of scientific and technological knowledge in everyone's life, specially children and teenagers, in a attractive, pleasant and often unforgettable way. Really active libraries and science centers, in association with efforts to enhance the participation of the great public in a society's cultural life, develop a sustaining mesh that supports and extends the contact the students can establish with the whole universe or formal knowledge even out of school.

Science centers and science museums are vigorously proliferating in many parts of the world [PADILLA, 2000]. In Brazil, however, with a few honorable exceptions, this is a quite new activity, even if compared to Latin-American neighbors. Three of the largest Brazilian institutions (Estação Ciência, of University of São Paulo, in São Paulo, SP, Science and Technology Museum, of the Catholic University in Porto Alegre, RS, and the Life Museum of Oswaldo Cruz Foundation, in Rio de Janeiro, RJ), received, altogether, an estimated 600,000 visitors [ABCMC, 2001]. Meanwhile, Maloka, in Bogotá, Colômbia, had one million visitors during its first year of activity [NOHORA, 2000]. In Mexico there are more than a dozen museums with more than 200,000 visitors per year, and the whole system receives more than 5 million visitors per year [PADILLA, 2000].

The Brazilian Association of Science Centers and Science Museums, in a recent inventory [ABCMC, 2001], found approximately 120 institutions of all sizes in Brazil. To give an idea of their resources, only 20 of them have an e-mail address or an Internet site. We engaged in this project with the desire of stimulating and increasing the participation of the scientific community in the effort to popularize science and to appreciate of this type of institution.

A few words about the institutions involved in this project: Estação Ciência (Science Station) is the science, technology and culture diffusion center of University of São Paulo, in São Paulo, SP. It is located at a crowded neighborhood, very close to a suburban train station. It was created 14 years ago by a Federal Government agency, the National Council of Scientific and Technological Development (CNPq), which a few years later transferred its control to the University. Estação Ciência has about 5,000 square meters and about 25,000 visitors per month. More than half of the visitors are students from public and private elementary and high schools. The science center has a large portfolio of services: courses for the general public, teacher training programs, movie and video sessions, educational materials for schools, cultural events such as music and theater shows and so on.

The Instrumentation, Demonstration and Experimentation Laboratory (Labidex) is a much smaller science center linked to the Physics Department of Federal University of Santa Catarina (UFSC), in Florianópolis, SC. Labidex has about 60 experiments and receives about 3,000 visitors per year, basically all of them students from public and private schools. Labidex also gives support to Basic Physics disciplines offered by the Physics Department to many courses of the University, especially to undergraduate teacher formation courses ("licenciatura") and graduate courses in science education.

## 2. Equipment Description

### 2.1. Double Pendulums

Double pendulum exhibits are found in different versions in a few science museums (Museu de Ciência e Tecnologia, in Porto Alegre, RS and Museo Interativo Mirador, in Santiado, Chile, for instance). The system we built is similar to the one described by Shinbrot and collaborators [SHINBROT et al., 1992], added a few support and safety structures, so it could operate properly in the context of a busy science museum.

One of the distinctive characteristics of the equipment is the use of two identical double pendulums, put side by side. Both can be released simultaneously from equivalent positions. This allows comparison of movements, greatly enhancing the potential of the equipment.

Figure 1 shows a schematic view of the system. There are two double pendulums symmetrically fixed to a cylindrical iron column. The column is rigid enough to deem the pendulums uncoupled. The pendulums are made of aluminum bars with ball bearings articulations. The total length of the pendulums is about 46 cm. The iron column is soldered to an iron plate bolted to a very heavy wooden table 105 cm long and 40 cm wide. In order to protect the visitors, 8 mm tempered glasses 70 cm high surround the exhibit, except for one small side, where the glass is 35 cm high in order to give the visitor access to the pendulums. The pendulums are manually released and although this introduces some loss of precision in the definition of the initial position, it does not interfere in the quality of the demonstration.

An information and instruction illustrated sheet is positioned near the equipment. The sheet stimulates the visitor to compare two different situations. In the first one, the two pendulums should be launched from equal heights, in the small oscillations regime (low energy). In this regime it is quite clear that the pendulums has a periodical and predictable behavior and that small differences in the initial position or between them and in the pendulums themselves (friction, for instance) do not make the trajectories evolve far apart in the long run. In the second situation, the pendulums are released from higher positions (high energy). Observing the system for fractions of seconds is enough to convince us that the trajectories will evolve quite differently and that the movement is completely unpredictable.

Most visitors at Estação Ciência and all visitors at Labidex are groups accompanied by guides. At Estação Ciência, the guides are undergraduate students of many areas. At Labidex, they are invariably undergraduate Physics students. Training courses were delivered for the guides after the installation of the equipment. During the training courses, the guides were oriented to do more than what is written in the information sheet: the pendulums should be launched from successive positions with crescent energy, but always in the small oscillations regime; the visitors should be stimulated to pay attention at the regularity, predictability and synchronicity of the their movement; the pendulums should then be launched from a high energy situation that will lead to chaotic movement and the visitors asked to make predictions, considering what they had seen before, about what will happen.

The guides were also oriented to discuss other concepts with the visitors. For example, that chaos is not only in the nature of the object, but also in its dynamical situation: the double pendulum may or may not show chaotic behavior, depending on the conditions it is launched (essentially of the energy). It is also possible to discuss energy conservation and transfer: if the forearm rotates rapidly, the center of mass of the whole pendulum makes a slow oscillatory movement; a few instants later most of the rotation energy previously in the forearm is transferred to the center of mass movement and the whole system oscillates rapidly.

Observing the visitors it is possible to see that the pendulums movement has some quasi-hypnotic property: people launch them over and over and observe their revolutions and oscillations with fixed eyes, as if they were seeing a skilled gymnast playing at asymmetric bars.

**2.2. Chaotic scattering**

The chaotic scattering experiment that integrates the installation was based on the design proposed by Bercovich and collaborators [BERCOVICH et al., 1991]. Adaptations were necessary in order to allow visualization of the phenomenon, as well as the use of the equipment under the typical conditions of a science museum.

Figure 2 presents a schematic view of the equipment. It consists basically of a helium-neon laser that can be moved by the visitor and a scattering system made of three cylindrical mirrors surrounded by a screen.

The helium-neon laser was chosen instead of a cheaper semiconductor laser due to its higher power output and to the size and shape of the light spot. Its durability under rough conditions is also expected to be greater (semiconductor lasers heat and degrade quickly if turned on for a long time).

The laser is installed over a brass block. Through the block runs a steel screw that drives the movement in a direction perpendicular to that of laser emission. The laser, its high voltage power supply and the moving block are isolated from the visitors by an 8 mm tempered glass box. The box has small apertures through which the power cable, as well as the laser beam and the screw can pass. The screw is couple to a wheel that the visitor turn to move the laser. The range of the movement is about 8 cm, half the side of the triangle formed by the scattering centers.

The scattering centers are cylinders 10 cm diameter and 5 cm high coated with a reflector material. The cylinder centers are placed in the vertices of an equilateral triangle, 18 cm apart. One of the sides of the triangle is perpendicular to the direction of incidence of the laser beam. In the equipment installed at Estação Ciência, the cylindrical mirrors are brass rings coated with chromium. Special care must be taken in machining the cylinders and polishing the surface, before and after the application of the chromium coat. The equipment in UFSC has brass rings wrapped in an aluminized polyester film 0,05 mm thick. In both cases the reflection coefficient is high enough for a good visualization of the phenomena.

The cylinders are fixed to a wooden circular platform 32 cm diameter and 2,5 cm high. The platform has a white formica finish. A strip of formica 9 cm wide and long enough to cover 270 degrees was put around the platform as the projection screen. The remaining 30 degrees allow the entrance of the laser light beam. Over the set of mirrors there is a red acrylic sheet 3 mm thick intended to protect the mirrors and enhance the contrast between the red laser light and the white formica. Extreme care was taken during design work to avoid flaws that could lead to accidental or deliberate delivery of laser light to the visitors eyes.

The corresponding information and instruction illustrated sheet stimulates the visitor to note the different patterns of light drawn on the screen as the laser moves. The device reinforces the idea of the sensitivity to small differences in initial conditions. There are situations where only one or two reflections occur before the light beam escapes to the screen. In such situations, the trajectories of different parts of the beam are not very different, producing a small spot somewhere in the screen. There are also situations of multiple scattering (tens of reflections), and the small initial differences in the position of incidence of the laser beam in the mirrors are amplified in such a way that the original beam is scattered all over the screen.

**2.3. Text**

The text, entitled "The Faces of Chaos" has two parts: a conceptual one that presents some fundamental ideas on deterministic chaos, dynamical systems and fractals and atractors, and a second part with orientations for the use of the simulations. The text also contains references to articles, books and Internet sites related to the subject.

The conceptual part has four sections:

*Deterministic chaos.* In this section there is a brief definition of deterministic chaos, a transcription of a famous citation by Henri Poincaré about determinism, a comment on the sensitivity some systems have to the initial conditions and finally an illustrated numerical example of the baker's transform.

*Manifestations of Chaos.* After mentioning many situations where chaos is present (to predispose the reader to see it in situations of his or her daily life), the text presents the problem of populations in ecosystems, followed by the mathematical model proposed by Robert May and the logistic map, annotated.

*Dynamical systems.* After a brief introduction on how physics deals with models for representing reality, there is a brief illustrated presentation on the simple and the double pendulum, introducing the idea of small oscillations and normal modes of vibration. There is a conceptual introduction to differential equations and their connection with determinism in classical mechanics. The text also brings comments on non-linearity and its relationship with the sensitivity to initial conditions. Finally, there is an introduction to phase space with the classical example of the simple pendulum, first without and them with damping, introducing the idea of atractors.

*Atractors and fractals.* This section establishes the relationship between phase space, atractors, periodical systems, fractals and chaotic systems, emphasizing the relation between chaos and the infinite complexity of a fractal. Some fractals are presented (the Koch curve and the Mandelbrojt set), with instructions for their construction. Finally, there are a few words about fractals in nature.

An effort was made to write the text to the general educated public not familiar with the concepts or the mathematics underlying the phenomena. For example, it explains what is a differential equation but does not show one; illustrates the normal modes of oscillations of the double pendulum but does not present their equations. The reading requires a bit more attention and engagement if the reader decides to reproduce numerically the baker's transform and a sample sequence of the logistic map. At a certain point, the text invites the reader to go a bit beyond his or her comfort zone and presents the equation (in the complex domain) and the algorithm to get the Mandelbrojt set.

The text, accessible at a multimedia kiosk between the devices, certainly is not an easy one for most of the visitors. Our hope is that it will function as a support for teachers, accompanying adults and students willing to dedicate some time to it. The visitors are also informed (by the orientation sheets and by the guides) that the text is also reachable through the Internet.

**2.4. Simulations**

The simulation of the double pendulum was accomplished through integration of the system differential equations. It is a classic problem frequently found in classical mechanics textbooks. The differential equations can be derived quite easily using hamiltonean formalism. They are highly non-linear differential equations that cannot be analytically integrated. In the simulations we used the differential equations as derived by Shinbrot and collaborators [SHINBROT, 1992] and numerical integration, which gives a time series, or trajectory, for the angular coordinates and respective time derivatives (angular velocities). The numerical integration is done using a fourth order Runge-Kutta method [PRESS et al., 1992] using the strategy proposed by Stump [STUMP, 1986]. The use of hamiltonean formalism with the Runge-Kutta method allows a simple monitoring of the error: if the error is negligible, the energy, a natural quantity in the hamiltonean formalism, is constant, so monitoring the energy is monitoring the error.

Figure 3 presents an image of the double pendulum simulation screen. The lateral buttons grant independent positioning of the arm and forearm, start, stop and continuation of the movement and access to the main text. Due to the high volume of computations needed in the numerical integration, the program first calculates 40 seconds of movement, and then shows it on the screen. The small delay introduced by this procedure is compensated by the feeling of reality given to the movement.

In addition to the pendulum window, there are also two charts with more sophisticated information directed to a more demanding visitor or to a teacher who wants to go further. One of the charts show the paths of the "elbow" and the "hand" of the pendulum (red and blue dots indicated in the figure). The other chart is a bit more challenging: it shows the angles the "elbow" and "hand" form (relative to the vertical position) as a function of time. The text has comments on this and the guides were trained to guide the visitors in the interpretation of each chart.

The simulation of the chaotic scattering does not present great conceptual difficulties. The beam is divided into many smaller beams and their trajectories are followed through the scattering system, using simple optics reflection laws. The recording of the trajectory ceases when it reaches the screen.

The visitor can use the lateral buttons to move the laser, and its position is indicated in a scale. The movement can be done in different step sizes (1 mm, 3 mm and 10 mm). The beam width is 3 mm, approximately the same as the real one. The simulation is an important aid because it shows the rays along their paths, which cannot be seen in the real device.

The software was designed to allow the simulation of many different configurations (different number, size and positions can be ascribes to the scattering centers) and to generate statistical data and charts for a few variables of the system. These possibilities are not available for the general public but have been used in academic investigations.

Exhibits designed for a science center like Estação Ciência have to be extremely sturdy. They are potentially exposed every day to 1,200 children who do always use the equipment the way the designers wanted them to. Most of the people consider the visit an entertainment and behave accordingly — with euphoria; vandalism is also quite frequent.

The user interface for the simulations was designed for operation in a multimedia kiosk with lateral buttons or touch screen video monitors. This avoids visitors contact with keyboards and pointing devices, sure sources of problems in large science centers.

## 3. Conclusion

Two units of an exhibit for demonstrating chaotic phenomena were built to be displayed at science centers and science museums, which are institutions for entertainment and non formal learning that have been recognized as an important support to the formal school system and as an effective strategy to awake and stimulate young people for scientific and technological carriers, essential to a nation's development.

The goal was to present to the visitors some aspects of chaos and complex systems, considered by many one of the great scientific developments of the 20th century. We also hope being able to stimulate the visitors to integrate the apparently unconnected contents (mechanical movement, light propagation and reflection) under a big category (chaos and dynamical systems) and to show that even chaotic systems can be treated with the powerful conceptual tools borrowed from mathematics and physics.

Obviously, we do not expect to substantiate, in the context of a science center or museum, the explicit acquisition of this knowledge, but we do expect to create a general impression that can eventually be associated to other stimuli. A reasonably long text with references to publications and Internet sites offer to a more demanding visitor good opportunities to reach a deeper comprehension of the phenomena. The text and the simulations are also available through the Internet.

The devices seem to be robust enough for the rough environment of a big science museum and has attracted an attention comparable to other exhibits in the institution.

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**REFERENCES**

BERCOVICH, C., SMILANSKY, U., FARMELO, G. P., *Demonstration of Classical Chaotic Scattering*, Eur. J. Phys., 12 (1991), p. 122-128.

DEVANEY, R. L., *A first course in chatic dynamical systems: theory and experiment*, Addison-Wesley, 1992.

DEWDNEY, A. K., *Computer/Mathematical Recreations*, Scientific American, aug. 1985, dec. 1986, jul. 1987, sep. 1980, nov. 1987, feb. 1989, jul. 1989, may 1990.

GLEICK, J., *Caos: a construção de uma nova ciência*, Editora Campus, 1990.

HAMBURGER, E. W., BERTOLETTI, J., RIBAMAR, J. (directors of the cited science museums), *personal comunication*, december 2001.

HO-KIM, Q., KUMAR, N., LAM, C. S., *Invitation to Contemporary Physics*, World Scientific, 1991.

JOSÉ, J. V., SALETAN, E. J., *Classical dynamics: a contemporary approach*, Cambridge University Press, 1998.

*La Recherche*, no. 209, abril de 1989.

LAUWERIER, H., *Fractals: Images of Chaos*, Princeton University Press, 1991.

NOHORA, E. H. *Maloka: un nuevo horizonte para Colombia*, in: Curso para Treinamento em Centros e Museus de Ciência, EC-USP, São Paulo, 5 a 10 de julho de 2000.

PADILLA, J. *Museos e Centros de Ciencia en México*, in: Curso para Treinamento em Centros e Museus de Ciência, EC-USP, São Paulo, 5 a 10 de julho de 2000.

PRESS, W. H., TEUKOLSKY, S. A., VETTERLING, W. T., FLANNERY, B. P., *Numerical Recipes in C: The Art of Scientific Computing*, Cambridge University Press, 1992.

SBPC, Revista *Ciência Hoje*, Sociedade Brasileira para o Progresso da Ciência, Vol. 14, no. 80, 1992.

SHINBROT, T., GREBOGI, C., WISDOM, J., YORKE, J. A., Chaos in a Double Pendulum, Am. J. Phys., 60 (6), 1992.

STUMP, D. R., *Solving classical mechanics probolems by numerical integration of Hamilton´s equations*, Am. J. Phys. 54 (12), 1986.

[UNDP, 2001], UNDP (United Nations Development Programme), *Human Development Report 2001: making new tecnhologies work for human development*, Oxford University Press, 2001.

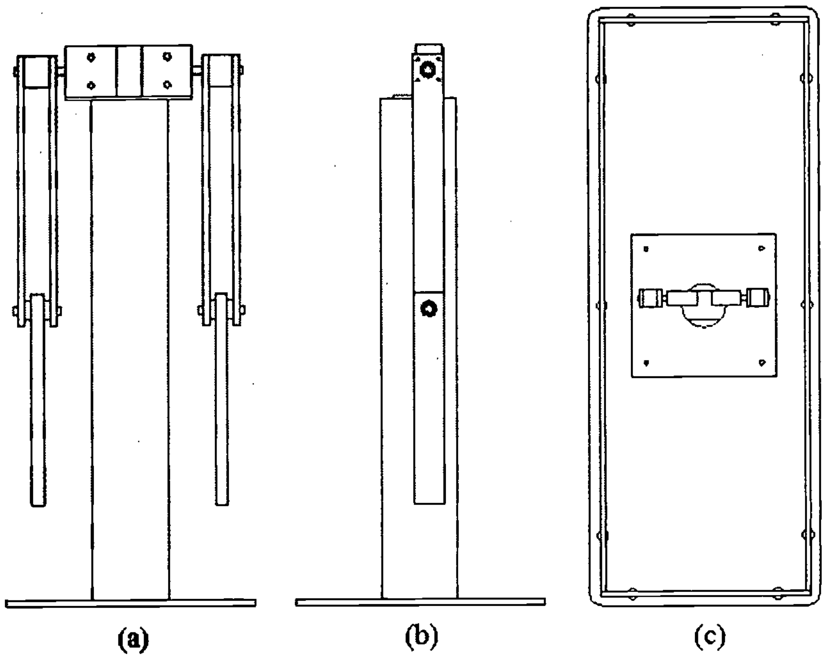


**Figure 1.** The double pendulum. (a) and (b) Frontal and lateral views, respectively; (c) top view of the pendulums and the table and protection glasses (in a reduced scale).

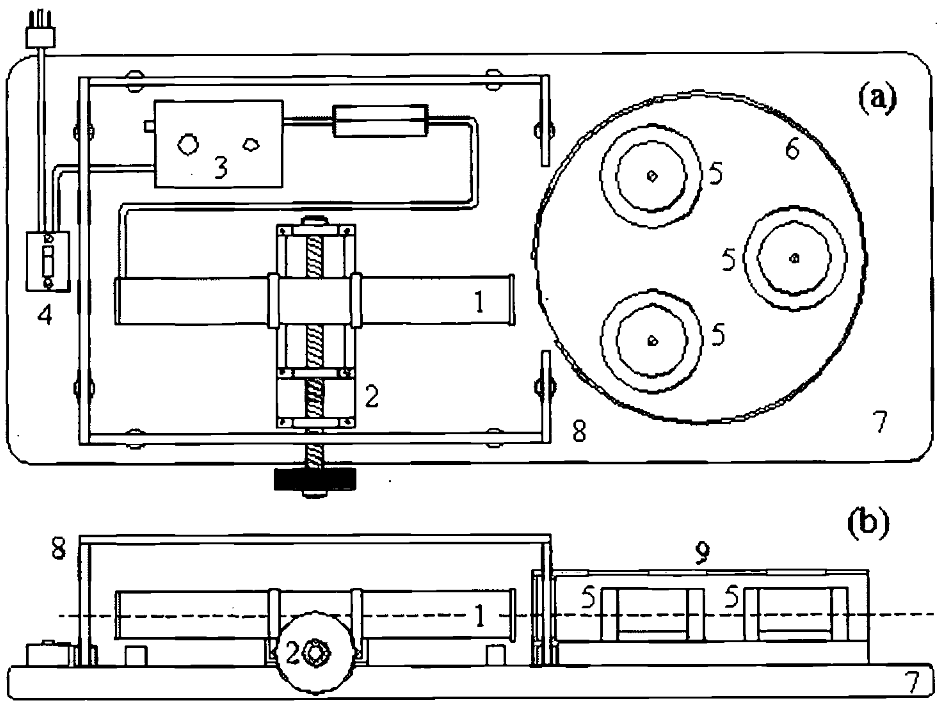


**Figure 2.** Chaotic scattering device. (a) Top view; (b) lateral view. 1. Laser; 2. linear table for support and translation of the laser; 3. laser high voltage power supply; 4. on-off switch; 5. cylindrical mirrors; 6. projection screen; 7. base; 8. glass box; 9. red acrylic cover.

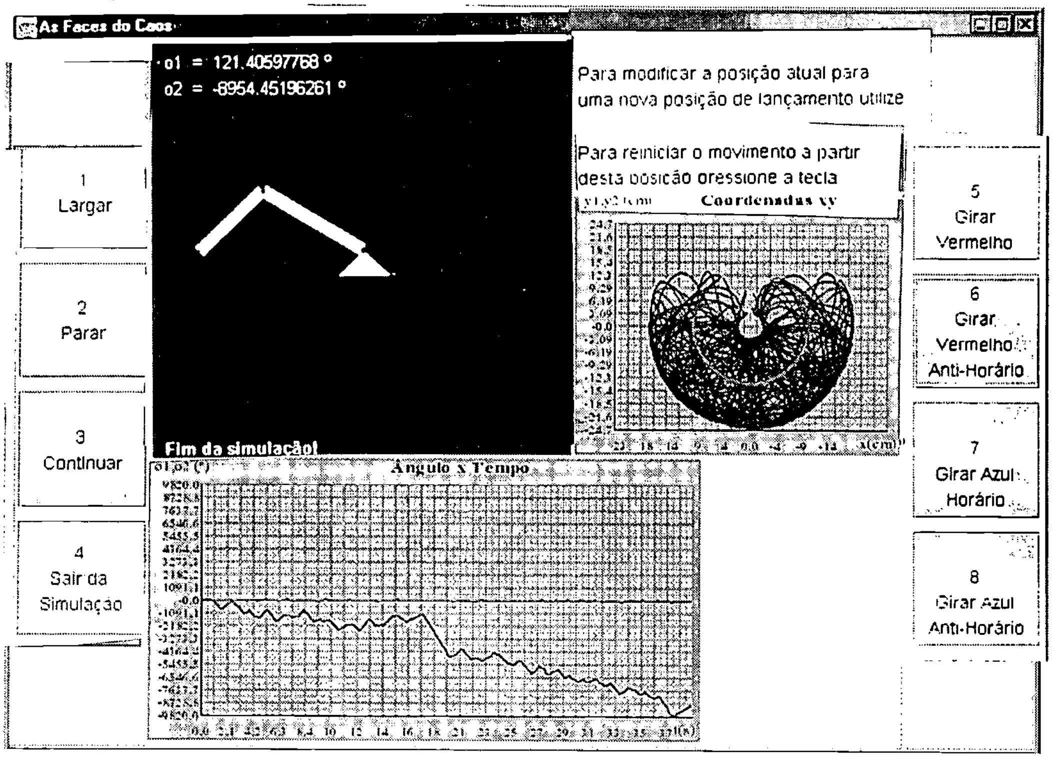


**Figure 3.** Simulation of the double pendulum. The user can choose the initial position of the arm and forearm independently using the side buttons. See text for explanations.

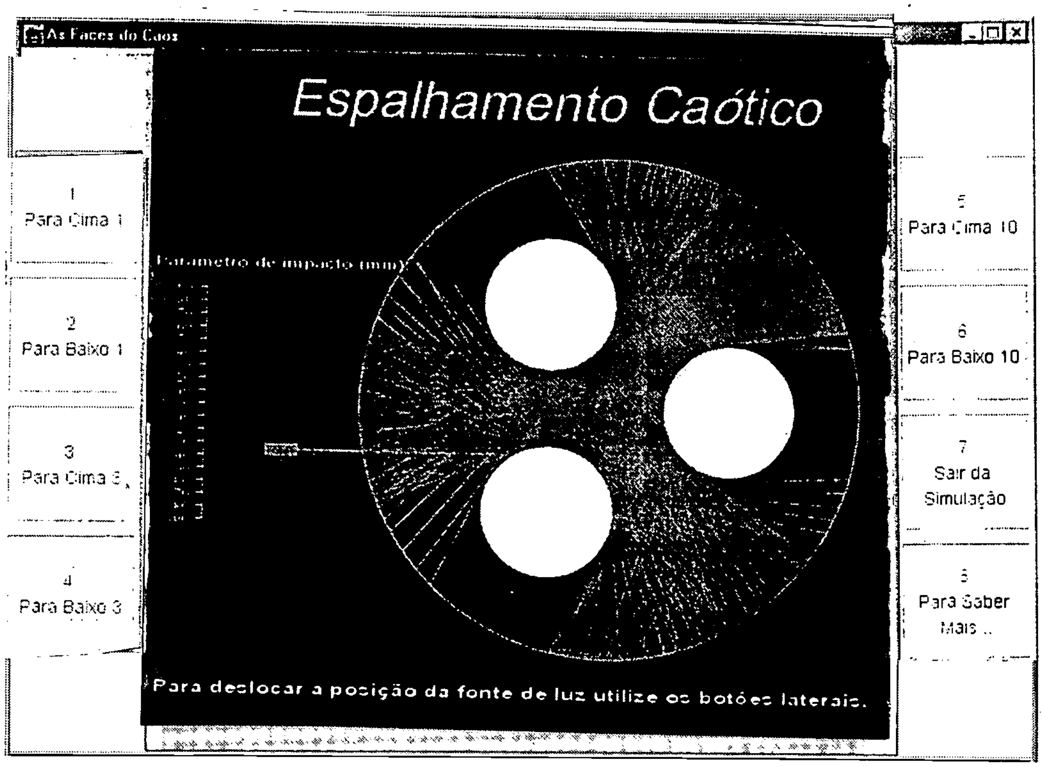


**Figure 4.** Simulation of the chaotic scattering. The user has three options for stepping the laser (1 mm, 3 mm and 10 mm).

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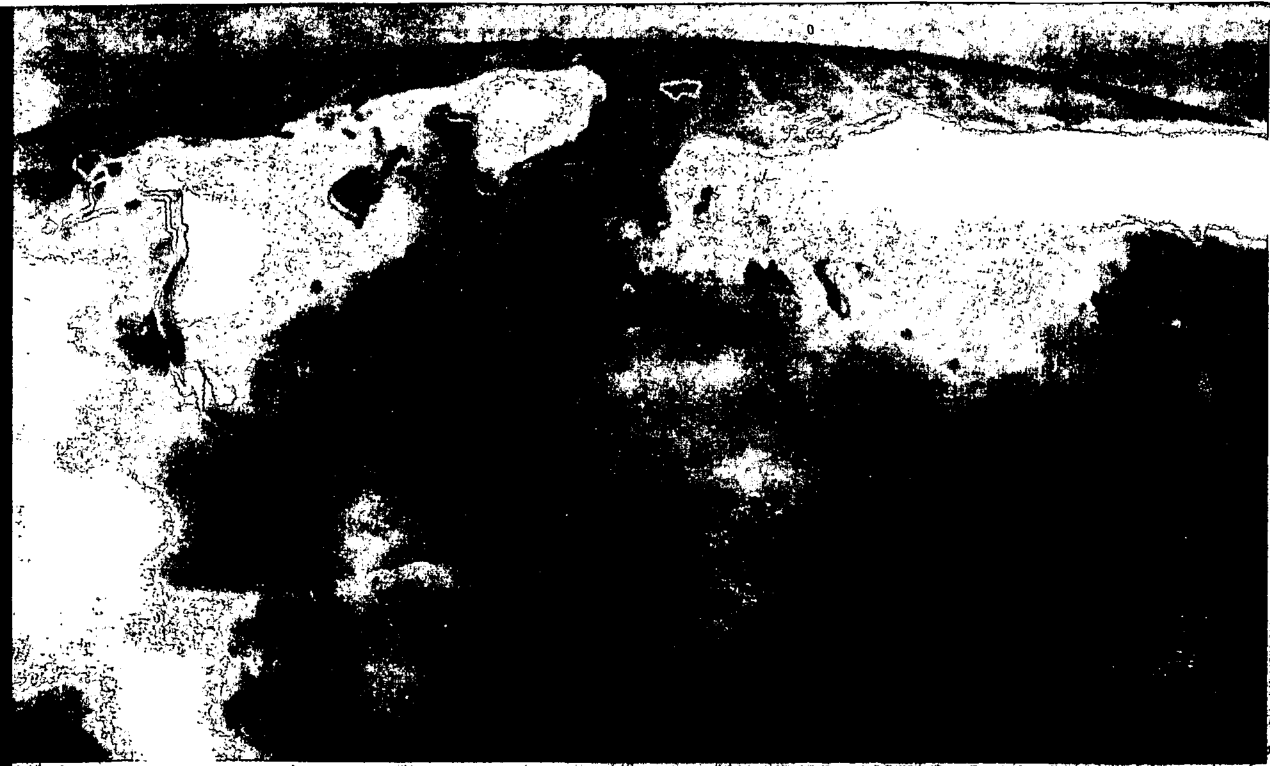

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# INTERNATIONAL ORGANIZATION FOR SCIENCE AND TECHNOLOGY EDUCATION (IOSTE)

## X Symposium Proceedings


editors

Nelio Bizzo, Clarice Sumi Kawasaki, Laercio Ferracioli, Vivian Leyser da Rosa




volume 2

# Rethinking Science and Technology Education to Meet the Demands of Future Generations in a Changing World

## International Organization for Science and Technology Education

10th Symposium Proceedings

## VOLUME II

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In 1979, an informal network for exchanging information on world trends in science education was established. In 1984, this group became IOSTE, a formal organization with membership in over 50 countries which is dedicated to advancement of science and technology education around the world. IOSTE is officially recognized by UNESCO as a non-governmental organization.

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## FOREWORD:

### RETHINKING SCIENCE AND TECHNOLOGY EDUCATION TO MEET THE DEMANDS OF FUTURE GENERATIONS IN A CHANGING WORLD

**BRAZIL, 2002**

In June 1999, the IX IOSTE Symposium assembly voted that Brazil ought to be the host of the next symposium. Since then, a great deal of work has been undertaken in order to meet two major guidelines of IOSTE. On the one hand, we wanted to attain excellency by gathering a group of science educators that have been meeting in the last years. On the other hand, we wanted to have an impact on public schools as much as possible. For the first time in IOSTE symposia, we included a special program for teenagers, which was called "*IOSTEen*", broadcasted in a TV open signal by the Ministry of Education. We shared the common belief that science and technology are related to the understanding of the natural world and the changes introduced to it by deliberate human action, as well as that education plays an important role in preparing future generations to be conscious of the complexities involved in scientific enquiry and in the judgment of planned changes. This is what 500 educators had in their minds during the period from July 28 to August 2, 2002, in the beautiful town of Foz do Iguaçu in Paraná, Brazil.

All educators recognize that societies throughout the world are becoming increasingly diverse and complex. Citizens live in a technologically dominated society, where equity in social relationships, respect for the environment and sustainable development are yet to be achieved throughout the world. Science and technology education, therefore, have very significant roles to play in the socio-economic development of communities in a global environment.

In addition, we were planning a symposium while the Organization for Economic Cooperation and Development (OECD) was performing a horizontal assessment in 33 countries of the world (PISA 2000). It is acknowledged that assessment plays a key role in designing and monitoring changes in education. However, many people believe that it is time to re-appraise the role of assessment in a variety of educational situations, and this issue had to be addressed in the conference. We have noted that several papers deal with this subject, and that a morning session was entirely devoted to the theme.

Education in science and technology is an essential process, which must take the diversity in societies into consideration and relate this diversity to sustainable development. Students need to be able to evaluate evidence and draw conclusions from a scientific point of view. They must be able to critically grasp the extent to which scientific uncertainty allows predictions. As citizens, they should be able to evaluate possible technological solutions, based on their knowledge of the natural world and its complexity. Many papers are devoted to this theme, and two morning sessions were devoted entirely to the theme. In one of them, science teachers preparation was addressed, and in another, we planned to debate the tense relationship between academic and vocational perspectives in science education.

We believe that the two volumes which you have in your hands, and which represent the proceedings of IOSTE X Symposium, bring relevant contributions to the role of science and technology education, at a time in which much attention has been placed on "Education for All". We wanted to go further and offer a relevant contribution for those who are looking for a deeper understanding of the possible roles played by science and technology education in providing a relevant education for all citizens. There has been a strong history of rewarding academic excellence in science education, even at the expense of relevance for all. However, for the new century we believe there is a need to find ways to combine both. If educators are not able to do so, the so called "*post modern perspectives*" can seduce many people, creating an apparently equally legitimate alternative, driving out of the scientific field many who could possibly understand the real contribution science and technology can bring to populations in a proper way.

How is it possible to provide a strong science and technology background for those students wishing to pursue these subjects at a higher level, while at the same time provide an appropriate and rewarding science and technology experience for all students? In other words, how can we increase public awareness of science, and encourage problem-solving and decision-making activities in students rather than to portray science and technology as knowledge subjects where success is largely measured by memorizing facts?

We believe that many clues to these questions can be found in these proceedings, which include papers in five core-areas:

1-Science, Technology and Society: how can we educate citizens to live in a sustainable environment, providing basic needs for all, with a deep ethical concern.

2-Content Areas: science and technology education have connections to traditional content areas (e.g. Biology, Chemistry, Physics, and Geology), and may bring a number of different areas together. Many articles deal with contents, either taken as subjects or skills or competencies, aimed at improving pupils skills and knowledge, including many examples from science textbooks used worldwide.

3-Teaching Practice: Different teaching methods have shown a variety of usefulness in formal and non-formal education. Eliciting students' ideas and designing learning environments have been part of the strategies aimed at improving students' capacities to evaluate evidence, to distinguish theories from observations and to assess the level of certainty that can be ascribed to 'scientific' claims. Those interested in these subjects will find very interesting articles in these proceedings.

4-Assessment: re-appraising the role of assessment in a demanding and changing world is essential. There are papers in the proceedings which describe the problems which are encountered when standardized assessment procedures are applied in different sociocultural settings.

5-History and Philosophy of Science: several papers show how history and philosophy of science can play important roles in understanding students' ideas. History and philosophy of science can be used in a series of contexts when designing activities aimed at improving pupils' skills and knowledge.

Last, but not least, a great effort has been made to follow the format that IOSTE proceedings traditionally have had, but we have tried to improve on this format by adding indices of authors and of keywords. The result is, we believe, an outstanding group of articles, which bring together in almost 1000 pages the state-of-art in science and technology education in many countries.

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# 056 THE TEACHING OF BUSINESS ADMINISTRATION USING BUSINESS GAMES

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**Resumo**

O desenvolvimento de novos *software* de ensino, no atual mundo virtual, provoca novas formas de transmissão do saber. O seu uso em sala de aula (ensino presencial) ou em outros locais (ensino à distância), revoluciona antigos métodos existentes nas seculares escolas, como o uso da lousa ou mesmo dos livros. A utilização dos Jogos de Empresas, baseados em computador, no ensino se amplia, eles seguem as constantes evoluções dos computadores, suas interligações em rede (Internet) e das avançadas linguagens de bancos de dados desenvolvidas num ambiente gráfico cada vez mais amigável. O ensino seguindo esta evolução utiliza esta ferramenta didática, cria novas situações para alunos e professores. Principalmente nesta época, onde temos o "*dever de repensar a educação para enfrentar as demandas deste mundo globalizado em mudança*" (10º IOSTE). A educação demanda novos posicionamentos, se atualiza com os estudos andragógicos (ensino voltado para os adultos) e novas atitudes que os alunos e professores assumem num ciclo de aprender-pesquisar-ensinar-aprender constante. Fazendo a transposição do saber científico em um conhecimento aprendido pelos alunos, tendo a telemática um importante papel nessa ação. Neste contexto, aborda-se neste trabalho o ensino de Administração (educação profissional) o qual tem a característica de transmitir o conhecimento através de um conjunto de disciplinas de diferentes áreas do saber, de forma estanque e segmentada, aplicando-as na gestão de um negócio, que exige visão integrada e significativa. Estuda-se como ocorre a integração destas disciplinas vistas no curso de Administração em uma aplicação de Jogo de Empresas

## 1. Introduction

The use of new telecommunications and information technologies continues to change education. More and more, theory and practice merge in the classroom (physical presence) as well as in self-study programs (remote systems). Old teaching methods are thus transformed and applied in conjunction with new computer techniques.

Following this trend, teaching at the college and university levels is extending the use of new hardware technologies (notebooks and networks) and programs, such as word processors, presentation spreadsheet software. All are taken for granted in classrooms that use information technology.

Accordingly, over time, education must move closer and closer to the actual situations that graduates will encounter in the job market. It must be assured that the different areas of knowledge (disciplines) which makeup an undergraduate education are relevant and meaningful to the formation of future professionals who are able to compete. This is especially true when teaching business administration, which has the characteristic of transmitting knowledge using a group of diverse disciplines in an isolated and segmented manner.

This raises a question – How can institutions that teach business administration transmit knowledge to future business managers in an integrated and meaningful manner? To answer this question, this paper studies the broadening of the use of business games in undergraduate and graduate courses, considering that they combine concepts from segmented and isolated disciplines of college study and apply them to business management, where an integrated and meaningful view are required.

The objective is to demonstrate that the Business Game is an efficient tool for teaching business administration in both the academic and business areas. To accomplish this, aspects of this teaching method will be studied. It will study the use of computer games as a teaching tool while observing the environment created in the classroom among student groups that are working and studying under the direct supervision of a professor.

## 2. Business games and simulations during training

Games are understood to be one of the human activities that require physical and mental effort from participants, and which are organized by a body of rules that govern their development (in time and space) for a specific purpose (Huizinga, 1993, p.33). The act of playing creates a feeling of tension and happiness which motivates people to make daring decisions (or adopt bold attitudes) whose consequences are not real, but which simulate reality.

Simulation is the construction of models that imitate real situations, in order to use these same to create training, teaching, or research experiences. One variation on this theme involves computer-human simulations in which interaction creates environments for educational or scientific investigation purposes.

Such simulations or business training experiences can be seen as a learning process through which individuals are prepared to perform work-related tasks better. It is important to emphasize that a training game should have a learning objective; clear definitions for behavior; a competitive element among participants; a high degree of interaction; and should end with a well-defined result (Kirby, 1995, p. 16).

Business training is a way to develop competencies in individuals so that they can become productive, contributing to the objectives of organizations, as well as their personal development. The use of games, simulations, structured exercises, dramatizations, role playing, and situational experiences is intended to facilitate learning processes, instill concepts, as well as to implement new skills and attitudes.

Correspondingly, a game is an activity that is governed by a body of rules and procedures that are intended to reach a specific objective in an entertaining manner. Simulation is the construction of a model that imitates a real situation through which experiences can be had for research or training purposes. When the joining of games with business simulations is applied in education, the creation of training games is permitted and the same can be used to experience management situations, teach concepts, make decisions, and study individual behavior in these situations. If we take a look at Business Games, it can be seen that all of these concepts are present.

The first Business Games that used computers appeared in 1955 (U.S. Air Force). They took advantage of military training experience (strategies) to study battlefield simulations applied to business.

Since then, Business Games have been used for business training and academic courses. Today, there are various types of games for industries, banks, stock markets, international trade, motor vehicle dealerships, and supermarkets, among others. This activity is currently growing through the use of personal computers with multimedia resources (sound, images, and films), such as the business game on CD that is supplied to businesses by Microsiga or games designed for the Internet, such as Challenge by Sebrae (the Brazilian equivalent of the Small Business Administration).

The term normally adopted in Portuguese (*Jogo de Empresas*) is derived from the English name, Business Game, and the same may also be called a business simulation, management simulation or exercise, business simulation or activity, or even business management simulation.

Depending on the focus or the model analyzed, games can be classified as follows:

- **Mixed games:** combine organizational and behavioral components;
- **Functional games:** focuses on a specific function within a company;
- **Organizational games:** focuses on various functions within a company;
- **Business competitor games:** in addition to the items mentioned above, includes business competitors;

- **Market or structural games:** include situations involving all organizational areas, as well as the economic environment.

Accordingly, a Business Game can be defined as a simulation (virtual) of a business environment where the participants act as executives of a company, managing resources and evaluating, as well as analyzing hypothetical business scenarios and the possible consequences that result from the decisions made. (Marques Fº, 2001, p. 135).

## 3. Adult education

Education, which in a broader sense especially seeks to form citizens who are aware of their environment, is comprised of teaching which represents the educational process in action and by learning which is a consequence of this process. Didacticism is a tool that stimulates learning through a teaching method, which encompasses a group of techniques that drive the learning itself.

Learning with its cognitive, affective, and social aspects seeks changes in attitudes and the acquisition of skills. It occurs through means, such as experience, theory, simulation, or behavior. The teaching process includes the stages of planning, orientation, and control of a student's learning.

In 1926, Eduard C. Lindeman (USA) studied the teaching of adults in the book *The Meaning of Adult Education,* which latter assumed a supporting role in the research of other authors. In the fifties, Malcolm Knowles adopts the term andragogy (from the Greek *aner* – adult, *agogus* – conduct, guide) as the most adequate to express "the art and science of helping adults to learn" (apud Oliveira, 2000).

Knowles constructs an andragogical education model in opposition to the pedagogical model that must be considered when using Business Games in higher education or business training, since such work is mainly done with adults. The model of teaching-learning situations that adults tend to present is summarized (Krischke, 2000) in the characteristics below:

They
- are impatient readers who demonstrate strong motivation and a desire to learn;
- pursue various goals and purposes with respect to learning;
- require stimulation and importance must be given to the task being executed;
- bring life experience with them and are capable of giving and receiving;
- require social interaction and wish to enjoy the same;
- fear failure when taking part in a learning situation;
- have generally had bad experiences in school;
- reveal any individual thinking style which is unique and individual, with its own rhythm;
- have well defined needs, pursue concrete objectives, and they accelerate learning.

Consequently, it can be seen that andragogy is education that focuses on adults who seek knowledge that will be used immediately after it is learned. An adult learns dynamically through the significant and consequential problems that are put before them. Such learning generates more complex questions that may or may not be for immediate use.

These andragogical studies (contemporary) set forth a much more richer position for higher learning and even for business training. It can be affirmed that andragogy does not counterpoise pedagogy, but is instead complementary, since depending on the moment in time, whether with the teaching of adults or children, they must always be present.

Television in education also provokes changes in a teacher's posture, as well as the teaching process itself, through the use of this technology. In addition to constant updating (in terms of equipment and programs), readjustment of a teacher's methods is also required. Teachers take on a new role, that of a "pedagogical mediator".

The student assumes a position as an active participant in this process; he is no longer a passive repeater. The teacher also assumes a new attitude. Even though he does assume the role of a specialist with knowledge to communicate on occasion, for the most part he fills the role of teaching facilitator/partner, working in a team together with the students, striving for the same objectives. When a teacher uses new technologies, he becomes an advisor/segment manager for the learning process, integrating intellectual, emotional, and managerial instruction. "The teacher is a researcher at work who learns in practice and through research, teaching what he learns and achieving through learning-research-teaching-learning". (Moran, 2000, p. 30-46). The role of the teacher is broadened from simple informer who dictates content to learning advisor and manager of research and communication who coordinates the teaching process, its progress, and rhythm.

A concept called didactic transposition can be identified in this teaching process mediated by technology and supported by systemic models. The concept which was created by Michel Verret (sociologist) and discussed by Yves Chevallard (1985) in the book *La Transposition Didatique* (apud Samagaia, 2001) demonstrates the transposition that occurs with knowledge when it is transferred from the area of science to the school and sounds an alert in relation to the importance of the fact that this process be comprehended by educators. This being, providing to students scientific knowledge with a cognitive relevance or transforming a piece of knowledge (produced by a scientist) into a piece of schoolhouse knowledge that is taught by teachers and learned by students.

Perrenoud (1999, p. 65) relates didactic transposition, which is centered on a situation-problem pedagogy (a new didactic contract) in which the role of the student is to get involved, take part in the collective effort to implement a project, and construct new competencies, to the construction of competencies in individuals. This allows trial and error, voicing of doubts, opening thinking, acquisition of awareness of ones individual learning, memorizing, and communicating processes, making it a contemplative process. This construction of competencies in education is understood as the ability to utilize a group of cognitive resources (knowledge, skills, information, etc.) to pertinently and efficiently resolve a series of situations (Perrenoud, 1999, p. 7).

These concepts and today's classroom with information technology drastically alter the position of the teacher who assumes a new role – that of a pedagogical/andragogical mediator. Where the two new elements in the classroom, the computer and programs, takeover the teaching process, executing this portion of the didactic transposition and attributing to the teacher different and new responsibilities.

All of this education technology creates a new learning environment and one of the tools of this environment is the Business Game. The teacher, advisor, or mediator, regardless of the name, all have a common objective, which is to process (with knowledge) a specific raw material (the student), using a tool (technology) into a new product (a good professional) for the market (labor place). In this case, the processor of this transformation (didactic transformation) is a catalyst (in the case of a pedagogical mediator).

## 4. Teaching business administration

The Brazilian Ministry of Education, through various laws, establishes the minimum content and duration of undergraduate programs. A summary of these requirements, which includes objectives, a profile of the graduate, and the skills and content required can be found in the National Test for Business Administration Programs (*Provão* – Brazil 2001). The above-cited document divides subjects into three groups:

- **G1 – basic and required subjects**: Accounting, Law, Economics, Statistics, Philosophy, Computer Science, Mathematics, Psychology, Sociology;
- **G2 – subjects required by the profession**: Management theories, Marketing Management, Personnel Management, Budget and Financial Management, IT Management, Production Management, Raw Material and Asset Management, Organization, Systems, and Methods; and
- **G3 – emerging issues**: Ethics, Globalization and the New Economy, Ecology and Environment, as well as Information Technology.

When the list of subjects offered by schools in Business Administration programs is surveyed, a wide variety of names that are different then those used by the Ministry of Education are found. After analyzing only three schools of Business Administration with four or five year degree programs, a list of eighty-eight different courses was arrived at (Marques F., 2001, p. 157).

This diversity of names for courses and content demonstrates to students and the teachers themselves the diversity of areas of knowledge that are taught in college programs. This even causes a certain degree of confusion or preoccupation with respect to the actual need for some of these subjects in a Business Administration curriculum

One of the ways to demonstrate to students the importance of learning such diverse subjects and concepts is to assure that they are applied in practical cases that have importance and relevance.

The Business Game supplies this condition, allowing all subjects to be worked with to a greater or lesser degree. This can be seen in Table 1, which was compiled using a questionnaire filled out by a group of fourth year Business Administration students at the end of the Business Strategy Game course given at the Faculdade de Administração de Empresas do Estado de São Paulo (FAESP).

In this survey, among other questions, students were asked about the degree of applicability of each subject in the business game. The results can be found in the "Points" column, which was calculated by assigning weights to the quantity of answers given. These weights were used to differentiate the choices made by students between "agree slightly x0" and "highly agree x7" based on the Lickert scale or attitude scale (Marconi and Lakatos, 1982, p. 94) using the following formula:

$$\textbf{Points} = (x0 * 0) + (x1 * 1) + (x2 * 2) + (x3 * 3) + (x4 * 4) + (x5 * 5) + (x6 * 6) + (x7 * 7)$$

By observing Table 1 it can be noted that the subjects, Holistic Management (sixth place) and the General Theory of Management (tenth place), were considered by the students to be the most important, directly opposing the opinion of the author who considers the same to be conceptual subjects. The subjects ordered from 1 to 15, which correspond to approximately fifty percent (50%) of course-of-study subjects, represented sixty-one point seven percent (61.7%) of those mentioned by students and those ordered from 16 to 29 represented thirty-seven point three percent (37.3%) of those mentioned.

It should be noted that the subject of "Economics" was only considered in fifteenth place (15th). Notwithstanding, it should have placed better due to its use in business games that involve a specific market. This could be a sign of the need for reinforcement of aspects of microeconomics with students.

Another interesting finding is that items like Communication Expression, Ethics in Business, Psychology, Sociology, and Law related subjects got low points, contradicting the main skills required by a professional, which according to Borrás (et al. 1999) are initiative, high moral/ethical standard, capability to work in a group, and leadership.

**Table 1** – Tabulation of student answers - Business Administration program

| | Subjects | Points | | Subjects | Points |
|---|---|---|---|---|---|
| 1 | Budget and Financial Management | 159 | 16 | Organization, Systems, and Methods | 130 |
| 2 | Business Games | 159 | 17 | Information System Management | 125 |
| 3 | Strategic Planning | 157 | 18 | Personnel Management | 124 |
| 4 | General Accounting | 155 | 19 | Capital Markets | 118 |
| 5 | Cost Accounting | 150 | 20 | Communication and Expression | 114 |
| 6 | Holistic Management | 149 | 21 | Ethics in Business | 112 |

| | | | | | |
|---|---|---|---|---|---|
| 7 | Marketing Management | 147 | 22 | Advanced Topics Seminar | 106 |
| 8 | Production Management | 146 | 23 | Philosophy and Living | 99 |
| 9 | Financial Management I | 145 | 24 | Psychology | 90 |
| 10 | General Theory of Management | 141 | 25 | Scientific Method | 83 |
| 11 | Computer Science | 137 | 26 | Sociology | 74 |
| 12 | Raw Material and Asset Management. | 135 | 27 | Business Law | 67 |
| 13 | Mathematics | 132 | 28 | Tax Law | 55 |
| 14 | Statistics (General and Applied) | 131 | 29 | Public and Private Law | 51 |
| 15 | Economics | 130 | | | |

Source: (Marques Fº, 2001, p. 128).

Analyzing the subjects in Table 1 above together with their points, the content dealt with in each one (Teaching plans), and in relation to their utility for a business game, the subjects encountered in groups **G1** to **G3** can be rearranged as follows:

- **Basic**: Mathematics, Statistics, Computer Science, Portuguese, Communication and Expression;
- **Conceptual**: Law, Economics, Philosophy, Management Theories, Sociology, Psychology, and Systems.
- **Professional**: Planning, Materials, Production, Marketing, Finances, Accounting, Human Resources.
- **Management**: Business Creation and Development, Business Management, Small Business Management, Leadership and Decision Process, Entrepreneurship, Industrial Organization, Business Management Games.

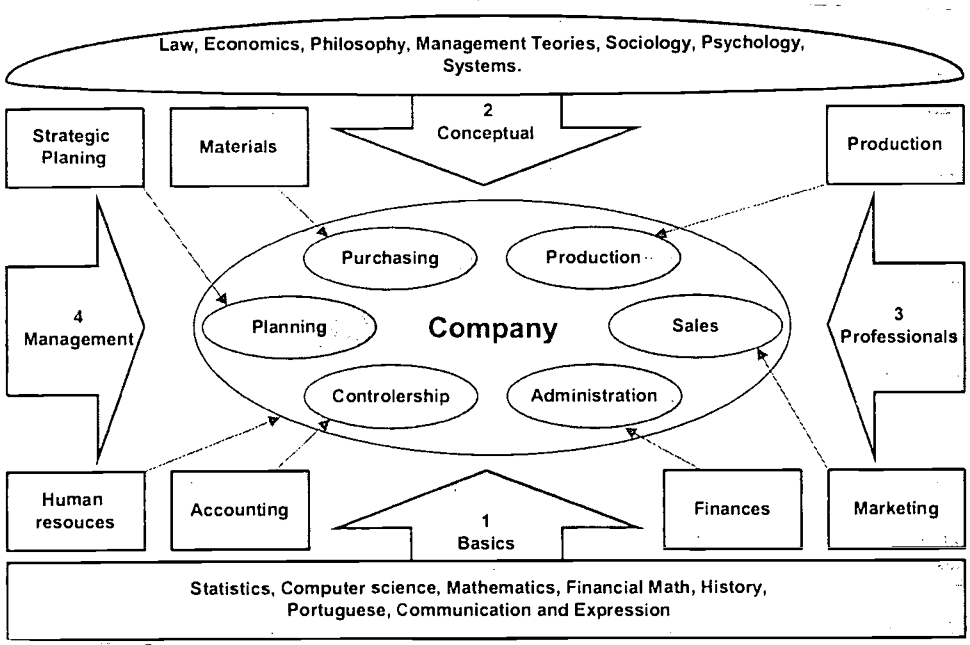


**Figure 1 – Subjects relating to areas of a Company**
Source: based on the content of each subject and its use in business (Marques, Fº, 2001, p. 100).

One application of these subjects is seen in "Figure 1" where the 1) **basics** (at the base of the figure) serve as support for the action of a business' management; 2) **conceptual** subjects act as a cover comprising more general matters; 3) **professional** subjects are directly applicable in specific areas or in the company as a whole;

and finally 4) **management** which is mainly intended to complete the teaching of administration and decision making to future managers.

The arrows in "Figure 1" represent the interconnections among the subjects in a Business Administration program and the internal areas of a business. These interconnections can be prioritized in accordance with their degree of applicability, as follows: **low** (basic and conceptual subjects); **intermediate** (subjects that involve a company as a whole - HR management), or **high** (subjects that are more 'professional' and which involve specific areas of a company – strategic planning, purchasing, production, sales, administration, or accounting).

These subjects are equally present in a company's relationship with other entities in its environment, such as suppliers, competitors, customers, banks, government, unions, shareholders, and employees.

A Business Game that is used in a Business Administration program can, for example, simultaneously use concepts involving economic theory, strategic planning, production planning, marketing, finances, accounting, controllership, among many others, all in accordance with the game's focus or the emphasis that the teacher wishes to give to student studies.

It is important to note that the main focus of a Business Game is on a company's manager staff (intermediate), meaning at a **tactical** or **managerial** level as represented in "Figure 2", since **strategic** areas (business direction) executed by top management and **operations** (tasks executed by technical staff) involve specific activities that are not always considered in this type of game.

Higher education can be perceived as being organized in groups of subjects with basic/required or professional/complementary ends. These subjects with origins in diverse areas of knowledge are segmented and ordered to facilitate the teaching process. One proposed grouping (basic, conceptual, professional, and managerial) is arranged in accordance with their utility for a business manager.

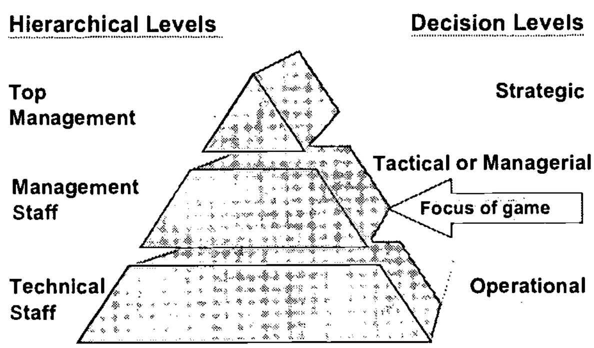


**Figure 2 – Decision levels and the company hierarchy**
Source: prepared by the authors

### 5. Teaching objectives using games

The combination of Business Games with teaching models for adults and the connection of this type of learning with the learning process is presented in Bittencourt's comments (2001): Through experience, the business game permits professionals to gain access to concepts, theories, and practices using the model that contemporary andragogy recommends – executing with involvement, interaction, and commitment, achieving as a consequence learning and growth. Furthermore, to attain these objectives of learning and growing, several steps should be followed.

To use the games for educational purposes, the first step is to establish clear objectives for the activity and link them to what will be done. These objectives, when aligned with the requirements of higher education, can be set forth as the goals that will comprise the pedagogical plan for a program of study or course using games.

To link business games to your objectives, the second step is to make students execute tasks that connect the technical content learned to the practical portion of the games that will be used. This is a difficult task, because it requires that both the teacher and the student remember concepts worked with in other subjects. One way to solve this problem is to inspire students to research these concepts, connecting them to the difficulties encountered in the simulated companies.

Other pedagogical objectives can be created in accordance with the type or focus of the game. For example, Risky-Business (2001), a company that markets games, claims that the use of this type of didactic-pedagogical tool has proven useful for users to:

- learn and improve their capacity to manage functional areas of the company;
- learn and improve their strategic management capabilities;
- improve their capacity to work as part of a team;
- achieve a global understanding of their organization;
- improve the quality of management decisions made;
- improve their ability to direct;
- be able to successfully lead individuals who are under their responsibility.

A teaching plan should formalize the pedagogical project, establishing teaching methods, required strategies, and the concepts that will be worked with. Connections can be established between subjects that are part of the Business Administration curriculum and areas worked on in a Business Game, applying the following degrees of usefulness: low (conceptual subjects), intermediate (basic subjects), or high (professional and management subjects).

## 6. Final comments

The use of games in undergraduate programs or for business professionals is normally planned in conformity with the desired objectives. A sixteen-hour course can be given in two consecutive days, in five consecutive half days, or in five weekly half-day classes. As can be noted, the dynamics are modified with each class strategy. In the first, the rapidness of decisions is a decisive factor for the results of companies and conceptual assimilation is reduced. In the second and all other cases, the time available for reasoning is longer, giving participants the opportunity to review or absorb concepts (Marques Fº & Pessôa, 2000).

Sixteen class hours is considered to be the minimum. Additional time can be used to study additional theoretical topics, depending on whether it is an undergraduate, graduate, or business training course.

Another factor is the number of individual participants with each company. If this number is less than three, the synergy expected in relation to the transfer of knowledge and experience might not occur. If the number is greater than five, it is possible that a participant could be left out. It is recommended that groups be made-up of individuals with diverse business profiles, such as production, marketing, administration (accounting), and finance, creating a simulated organizational chart.

Finally, individual behavior is different in this type of class and it is possible to note the following:

- The teacher does not need to give lectures;
- The teacher does not need to perform a roll call;
- The teacher is only sporadically active in class;
- Students do not skip class and arrive on time;
- Students are always motivated (by the pressure of the game);
- Students speak quietly and remain at their work stations in an orderly manner;
- Students perform diverse tasks outside of class;
- Evaluations using written tests are unnecessary;
- Student groups keep their strategies to themselves and do not "cheat";
- All are preoccupied with the objective and the end of the activity;

- When the class ends (game), students wish to continue;
- Students learn the content passed along in their own way, in an entertaining manner.

In this type of class, everyone always wins, since those who participate in the activities, those who help their colleagues, those who attempt to clear up doubts, those who study alternatives, those who understand the work model, are the ones who gain knowledge, making the teaching effective. The winners are actually everyone who learns!

Accordingly, the business game allows curricular integration and a multi-discipline approach that is diversified, integrated, and systematic in relation to all other college disciplines. Thus guaranteeing the formation of professionals with integrated and meaningful viewpoints who are qualified to work in a constantly changing globalized market.

## 7. References

BARTON, Richard F., (1973). **A Simulation and Game Manual**. Petrópolis: Vozes, 285p.

BITTENCOURT, Francisco, (2001) **A Business Game**. Available at <http://www.institutomvc.com.br/insight23.htm> Accessed June 2, 2001.

BORRÁS, Miguel A., (1999). Aires et al. Human resources as a key factor for development of the national agribusiness: the agro-industry production case. In: **Management & Production**. v.6, n.3, p: 282-291, Dec. 1999. Universidade Federal de São Carlos.

BRASIL, (2001). Ministry of Education. Ministerial Order no. 010 of Jan. 4, 2001. Sets forth details on the National Test for Business Administration Programs. **INEP- Instituto Nacional de Estudos e Pesquisas Educacionais**. Available at <http://www.inep.gov.br/enc/provao2001/diretrizes/Administração.htm>. Accessed Jan. 24, 2001.

HUIZINGA, J., (1993). **Homo Ludens: the game as an element of culture**. 4.ed. São Paulo: Perspectiva, 243p.

KIRBY, Andy, (1995). 150 **Training Games**. São Paulo: T&D, 320p.

KRISCHKE, Jeannine L., (2000). Andragogy. In: XI Santa Caterina State Congress on Human Resources ABRH-SC – Santa Caterina State Chapter of National Human Resource Association. 2000. Joinvile. **Electronic files...** available at <http://www.mlim.com.br/~abrhitj/andragogia.htm> Accessed Dec. 14, 2000.

MARCONI, Marina de A. (1982). LAKATOS, Eva Maria. **Research Techniques**. São Paulo: Atlas, 205p.

MARQUES Fº, Paulo A.; PESSÔA, Marcelo S.P. (2000), Business Games for Production Management. VII. In: Production Engineering Symposium of the Universidade Estadual Paulista, Bauru. **Electronic files...** Available at <http://www.bauru.unesp.br/acontece/anais2000.html>. Accessed Nov. 30, 2000.

MARQUES Fº, Paulo A., (2001). **Business Games: a strategy for teaching management and decision making.** São Paulo, 2001. 175 p. Dissertation (Masters Degree in Production Engineering) Campus Bacelar - Universidade Paulista.

MORAN, J. M. (2000). Teaching and innovative learning with audio-visual and television technologies. In: MORAN, J. M. et al. **New technologies and pedagogical mediation**. São Paulo: Papirus. 173p. p: 11-65.

OLIVEIRA, Ari Batista de, (2000). **Andragogy**. Available at <http://www.terravista.pt/Meco/4678/andragogia.htm>. Accessed Dec. 18, 2000.

PERRENOUD, Philippe, (1999). **Constructing competencies beginning at school**. Porto Alegre: Artmed, p.90.

RISK-BUSINESS, (2001). RB **Business Simulator**. Available at <http://www.riskybusiness.com>. Accessed Jan. 8, 2001.

SAMAGAIA, Rafaela R. et al., (2001). **Didactic Transposition: a train to the stars.** Universidade Federal de Santa Catarina - Centro de Ciências Físicas e Matemáticas. Available at <http://www.fsc.ufsc.br/~inspb/transp3.html> Accessed Nov. 5, 2001.

**Keywords**: Business Game, Simulation, Management Teaching.

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# [1] COMPLEMENTARY EPISTEMOLOGIES OF SCIENCE TEACHING: AN INTEGRAL PERSPECTIVE

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**Abstract**

Within the science education community, alternative epistemologies of teaching and learning have jostled historically for supremacy. For over 20 years, science education has been a site of considerable struggle between adherents of the competing epistemologies of 'objectivism' and 'constructivism'; recently, proponents of 'personal constructivism' and 'social constructivism' have locked horns. In this paper, we argue that, in the interest of creating greater equity of access amongst students to a much richer encounter with science, science teachers should consider adopting an 'integral perspective' on these divergent epistemologies.

First, we illustrate the unhelpful antagonism that exists between proponents of these highly influential but divergent epistemologies of science teaching and learning. Next, in seeking a means of moving towards epistemological pluralism, we argue that a mode of reasoning is needed that differs from the established Cartesian binary and dualist thinking which tends to fuel a discourse of competition between theories. From the perspective of constructive postmodernism, we propose 'dialectical complementarity' as a potentially productive way of considering unity-in-diversity amongst opposing epistemological perspectives. Then, in an attempt to overcome the obstacle of literalism, which tends to reinforce notions of difference, metaphor is presented as a frame of reference. The centrality of metaphor to both cognition and science, and its power in supporting a multi-perspective dialogue, is established. The metaphorical bases of both constructivism and objectivism are illustrated, with special attention given to the way in which concepts of 'understanding' and 'making sense' are metaphorically structured.

Finally, we illustrate the viability of adopting an integral perspective on science teaching with a brief account of a doctoral research study into the scientific literacy of a class of junior high school students. From the extensive literature on scientific literacy, a set of complementary but distinctive metaphors was developed: 'student-as-recruit', 'student-as-judge' and 'students-as-scientists'. Each metaphor is aligned with one of the three epistemologies of teaching and learning discussed in the paper. The three-metaphor set was employed as an interpretive framework to examine the quality of students' access to science. Over the period of a year, the student as recruit metaphor was found to prevail and to exclude students with specific learning styles. Students were also tracked through the school day into their other subjects where some of the excluded students were observed to be highly engaged learners. We conclude that the judicious adoption in school science of all three metaphors may enhance students' equity of access to science and provide a richer experience of the nature of science.

## Introduction

Over sixty years ago, Dewey (Garrison, 1995) reflected that the history of educational theory is marked by opposition. It seems that this is true also of recent educational history where 'paradigm wars' are well established between proponents of the disparate epistemologies of objectivism and constructivism (and between those who favour one form of constructivism over another). Clearly, each of these epistemologies serves contrasting purposes in science education, with constructivism currently in the ascendancy in the Australian national curriculum framework

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However, relentless competition amongst theories may promote a tendency for science education to move through cycles of ideas, only to return, ultimately to the starting point, resulting in teachers becoming cynical about the latest curriculum development 'fads' (Fullan, 1993). It may also contribute to a sense, especially amongst teachers, that educational researchers do not or cannot contribute significantly to 'real' educational issues within schools.

These are significant reasons for science educators to consider establishing an integral perspective which endeavours to unite otherwise disparate energies (Settelmaeir & Taylor, 2002). In this paper, we first consider divisive antinomies amongst proponents of single epistemologies, such as objectivism, personal constructivism and social constructivism, and contrast this with a call for epistemological pluralism. Next, in the interest of generating more inclusive science teaching aimed at enhancing equity of student access, we present an argument for uniting these seemingly divergent epistemologies. This involves:
1. using dialectics (rather than dualism) as a mode of reasoning, and
2. using metaphor (rather than literalism) as a frame of reference.

**Privilege or Pluralism?**

For over 25 years, the thesis of constructivism has challenged science teachers' traditional understanding of their classroom role as transmitters of objective knowledge. Proponents argue that the 'anti-thesis' of objectivism evokes an outmoded image of knowledge as an entity progressively accumulated and stored in memories and books. They argue that an objectivist view of learning often uses, implicitly or explicitly, inappropriate metaphors of knowledge transfer, such as a conduit metaphor or education as a pipeline. The constructivist reform movement calls for pedagogical priorities to be redirected towards enabling students' to make sense of their learning experiences.

Science education research has responded by developing teaching strategies for eliciting students' prior knowledge, producing cognitive conflict and utilising different purposes of writing. Continuing developments in constructivist theory have highlighted the social context of learning, and the instructional focus is now shifting onto language, values and patterns of relationships among students. From a critical perspective, social constructivism highlights the disenfranchisement of students under objectivism, and looks for evidence of the benefits of more socially inclusive modes of teaching and learning (Taylor, 1998).

Undoubtedly the notion of a superior educational theory has an appealingly parsimonious quality. However, as Dewey reflected, the rancour that develops around the aggressive-defensive posturings of proponents of either side can be counter-productive. The science education literature is replete with the competitive voices of proponents of single epistemologies of teaching and learning. For example, from an objectivist perspective, Kragh (1998) argued against constructivism by claiming the latter to be 'philosophically unsound', having 'weak empirical support', being 'subversive to honesty and critical thought in general' and constituting 'a frontal attack on the entire edifice of science' (p.242). On the other hand, Guba and Lincoln (1989) claimed, from an avowedly constructivist perspective, that the objectivist paradigm 'needs to be replaced' (p.43).

This contestation is not confined to the apparently antinomic theories of objectivism and constructivism. Favouring social constructivism, Gergen (1995) argued that the way earlier forms of (cognitivist) constructivism depicted the mechanism of communication was a 'pitiful accomplishment' (p.28). O'Loughlin (1992) advanced this rhetoric in claiming 'that the universalist, rational, disembedded thought valued by Piagetian [personal] constructivists is...ideologically bound and must be rejected in favour of a more suitable ideology' (p.809). Defending personal constructivism, Fosnot (1992) countered that the social constructivist model is 'nihilistic, culturally relative, and dangerous' (p.1189).

In science education there is, however, an emerging agenda for epistemological pluralism, that is, for multiple epistemologies (or theories of knowledge, ways of knowing) to be regarded as useful, complementary, and mutually perspective-building ways of informing us about student (and teacher) learning. But if we are to become a more pluralistic and tolerant community, we need good reasons for doing so. Calabrese-Barton and Osborne (1998) point the way with questions about more inclusive science teaching:

- How can historically marginalised students become involved in science?
- How can we shape practice and curriculum to address the needs of diverse learners?

Contemporary calls for 'science for all' are directing teachers to account for differences amongst students in cultural background, language and gender (Aikenhead, 2000). Indeed, an ethic of inclusivity demands a fresh approach to providing science for all students, and it is our belief that a complementary perspective on the utility of contrasting epistemologies may help to achieve this elusive social goal.

## Complementarity

Postmodern curriculum theorists (Pinar & Reynolds, 1992; Slattery, 1995) warn that the philosophy of modernity has restricted our (Western) ability to reason by privileging Cartesian binary and dualistic thinking. When 'confronted' by contradictions inherent in oppositional aspects of reality – male and female, body and soul, thinking and feeling, person and world, light and dark, good and evil, immanence and transcendence, particularization and generalization, theory and practice - we automatically resort to well established modes of reasoning. The first is domination and/or destruction, in which we try to control or eliminate the oppositional pole. This is evident in the contestation amongst proponents of opposing epistemologies in science education.

The second is dialectic in which we attempt to transform both poles of a contradictory set of metaphors into a higher level of understanding. The classical form of (Hegelian) dialectic is to pursue perfect society or ultimate truth by debating thesis and antithesis until a new synthesis emerges as a point of departure for a further dialectic. However, little purchase is provided for honouring the integrity of the thesis or antithesis or of the unique connectedness of these parts to the overall whole.

On the other hand, constructive postmodernism views the world as complementary and organic, and recognizes that the strength of the whole is derived from a respect for the contribution of each part (Slattery, 1995). In the symbolic circle of the yin and the yang, masculine and feminine principles of light and dark blend together in a permanent dance of continuous improvisation. The notion of 'dialectical complementarity' focuses on the relationship between the seemingly opposing parts; and conceives the relationship as more akin to a sacred dance than a power struggle. It allows us to seek unity-in-diversity without either rejecting one of the parts or merging the parts into a new synthesis.

From a postmodern curriculum perspective, dialectically complementary epistemologies - objectivism, personal constructivism, social constructivism (amongst others) - provide a set of unique ways of engaging students in science classes to understand (or make sense of) the natural world (or constitute dialogically their relationship with it). As we shall argue, each epistemology provides a different focus for learning, a different means of engaging in the process of learning, and a different set of possible learning outcomes.

At a meta-level, this integral perspective provides opportunity for students to learn about the nature of complementarity itself, that is, the endless philosophical (and socio-political) 'dance' between contrasting epistemologies, within science and without, down the ages and across cultures. Thus, through reflection on the (mostly invisible) epistemological framing of their own learning in/about science, students may experience something of the richness, complexity and contingency of the scientific worldview shaping both their cultural identities and their sense of individual agency for shaping the natural world.

However, our argument for an integral perspective cannot rest solely on the principle of complementarity. There is another obstacle that we need to deal with: the tendency towards literalism that fuels the antagonisms we have witnessed earlier.

## Metaphor

If, during a conversation, one speaker exclaims, "I see", when she actually means, "I comprehend", and the other turns to gaze in the same direction, then effective communication is restored only when the second person realises the metaphorical nature of the first person's comment and the inappropriate literalism of their own initial interpretation. Equally, if one chooses to use in a metaphorical sense the terms 'objectivism', 'personal constructivism' and 'social constructivism', then communication will be difficult with those who use them in a literal sense. Indeed, we believe that a complementary view of these epistemologies is impossible if a literal view persists, especially one that entails a 'competing theories' notion of their relationship.

Through the lens of the literal we are presumed to see things as they 'are' and where they 'belong', yet many (perhaps most?) of our concepts have metaphorical structurings because of the embodied structuring of mind. Many everyday commonsense expressions about our understanding – 'that's a clear argument', 'what's your outlook?', 'I've got the picture' - constitute a metaphorical mapping of our sensorimotor based knowledge about human vision onto the domain of understanding or knowing. Whenever we conceptualise aspects of mind in terms of expressions such as 'grasping ideas', 'reaching conclusions', 'being unclear', or 'swallowing a claim', we are using metaphor to make sense of what we do with mind. Indeed, we utilise a variety of metaphors that structure the way we conceive of mind: 'mind as body system', 'mind as builder', 'mind as computer', 'mind as container', 'mind as machine' and 'mind as person'. Some of these metaphors give rise to incompatible perspectives, yet each has a certain viability and currency in its usage (Lakoff & Johnson, 1999; Lakoff & Nunez, 2000).

Metaphor is central also to science. 'Science'- to know, derives etymologically from a root word meaning 'to cut' - a 'knowing through cutting' (Klein, 1971). To say that scientists have been 'cutting into the fabric of the universe' is using metaphoric language to suggest that they have been doing experimentation or theorisation about the nature of the universe. However, to say that they are conducting 'scientific research into the nature of the universe' has a literal resonance which masks the metaphoric origins of the term 'science', thereby rendering it as a 'dormant' metaphor. Thus 'science' comes to be viewed no longer as a metaphor but as a literal term conveying a precise meaning.

Not only the origins of the concept, but the ongoing practice of science relies strongly on metaphor. 'Plum-pudding', 'solar system', 'wave' and 'cloud' have all been applied metaphorically, successfully or unsuccessfully, to the phenomenon labeled 'atom'. Diametrically opposed ways of conceiving of phenomena can and do co-exist because of fundamentally different metaphors. The wave-particle duality model of light is a classic example.

Metaphor is central also to the communication of scientific ideas. The register of science makes use of nominalising active processes. Verbs used to describe processes, such as 'moving', 'refracting', 'gravitating', are transformed into nouns, thereby creating (fictional?) entities such as 'motion', 'refraction' and 'gravity'. This linguistic process has been termed 'grammatical' metaphor (Halliday & Martin, 1993). The metaphorical basis of language and thought means that metaphor is not just an important conceptual tool, but doubly-buried in the register of scientific English in its expressions and grammar. This implicit use of metaphor tends to make the scientific register seem like a foreign language, all the more bewildering because it seems in many respects to be familiar.

A hallmark of metaphor is that it dispenses with the proprieties of literalism and takes the risk of merging elements and discourses that are supposedly incompatible. The metaphorical impulse might thus be described as dialogic (Seitz, 1999). It is the discursive, risk-taking, merging-of-the-incompatible nature of metaphor that, we believe, provides it with the credentials to help facilitate multi-perspectival dialogue amongst proponents of the epistemologies of objectivism, personal constructivism and social constructivism. In bringing our argument to a conclusion, we next consider whether there may be some inherent quality in objectivism that precludes us from considering it in other than a literal sense.

### Metaphors of Constructivism & Objectivism

When Kelly used the term 'construct', he referred to the action of building things that were apprehendable by the senses, such as bricks and wood, and carried it over to building thoughts. As such, it is clearly metaphorical

(Spivey 1997). An appeal of the metaphors of constructivism – making sense, constructing - is their dynamism, suggesting that mind is actively involved in manufacturing something.

The term 'constructivism' has attracted numerous modifiers, and two of these are of interest here. Personal constructivism can be rooted either in the work of Kelly or Piaget, with their different nuances, yet each branch focuses on the process of learning as the internal activities of individuals concerned with making sense of phenomena. Personal constructivism has a realist ontology, yet emphasises that learners construct understandings to make sense of this real world. The term 'personal' modifies the metaphor to suggest that the construction occurs primarily in individual students' minds.

Social constructivism arises from numerous sources, including Vygotsky's sociocultural theories (Berk, 1994) and the new sociology (Berger & Luckman, 1966). The term 'social' modifies the metaphor to indicate the interpersonal nature of knowledge construction, in which sense making is mediated by culture and language, and reality is constructed socially. Thus, social constructivism has a relativistic ontology.

Objectivism has as its root a noun, 'the object'. The focus on the reality of the object led to a 'carrying over' of the idea into the realm of philosophy. In objectivism, the object is pre-eminent and must be studied rigorously for people to slowly, progressively, communally and objectively discover the underlying reality. Objectivity relates to repeated and reproducible empirical measurements, facts independent of observers, perpetually confirmed laws and falsifiable theories about phenomena. A basic assumption of objectivism is that communities of scientists can be confident that, by utilising certain standards of methodology and integrity, they can come to increasingly more accurate knowledge about phenomena in the world; to see them more clearly.

In science education the roles of objectivism and constructivism are similar; they provide understanding about knowledge and how students come to know about the phenomenal world. It is interesting to note that, for these erstwhile opposing perspectives, their central concepts – knowledge, knowing - are understood in terms of 'seeing' metaphors.

'Understanding' is an objectivist metaphor associated with taking a (sensory) position from beneath, with the implication of looking up (at the underside) of something. It is possible that 'to make sense' meant originally to have a variety of sensory inputs providing corroborative information about a phenomenon, for example, a heavy-looking rock that proves difficult to lift. Cognitive conflict may occur if we see a large chunk of rock floating on water, as that wouldn't make (coherent the information from each) sense. Therefore, 'making sense' probably meant literally that there was coherence and corroboration amongst the senses. The term was then applied metaphorically to mean a coherence of logic, and so filled a semantic void that existed prior to the use of such a term.

The term 'point of view' is a metaphor for 'opinion'. The viewing point determines the view, yet the phrase has come to mean 'the view itself'. Originally, however, the implication was that understanding depends (perspectively) on where one stands, and is therefore more closely allied to constructivism. However, 'to come at it from another angle', another expression of how to understand something, gives greater weight to the object in view, as if a partial circumnavigation is required in order to reach a different vantage point. Here, the emphasis on the object is more closely related to objectivism.

Under the umbrella metaphor of 'the object' come metaphors related to truth, such as 'uncovering' facts and making 'discoveries' of knowledge. Bernstein (1985) defined objectivism as the basic conviction that there is or must be some permanent ahistorical matrix or framework to which we can ultimately appeal in determining the nature of rationality, knowledge, truth, reality goodness or rightness. Key elements of objectivism include: a realist ontology; a belief that humans can attain objective truth, at least in an intellectual community marked by integrity; and, therefore, a belief in the objectivity of the Western Scientific Canon.

If science educators presently holding a commitment to a single epistemological perspective are willing to accept the metaphorical basis of not only their own epistemology but also of alternative epistemologies, then a complementary notion may gather momentum.

## Students of Science: Mostly Recruits, Rarely Judges or Scientists

Recent research utilizing metaphor as an interpretive framework investigated the development of 'scientific literacy' in junior high school science (Willison, 1999). The framework consists of three emergent metaphors which encapsulate a large range of divergent epistemologies of scientific literacy in the research literature: 'student-as-recruit', 'student-as-judge' and 'students-as-scientists'. Each metaphor gives rise to a distinctive view of pedagogical goals and the discursive classroom roles of teacher and students.

The metaphor of student-as-recruit emphasizes students accessing and appropriating classroom-science (by which we mean traditional science content and skills), and is most closely aligned with the epistemology of objectivism. Students work in labs on prescribed 'cook-book' tasks, designed primarily to illustrate scientific theory and develop important practical skills associated with doing science. The purpose of this form of teaching is to recruit students as trainees into the professional field of science.

Student-as-judge is a metaphor that emphasises individual students' evaluation of the knowledge claims of classroom-science. Ultimately, students are persuaded one way or the other about the validity of a scientific claim, however to be recognised as participating in this manner they need to manifest some type of judgement. For example, a student's critical exclamation, 'I told you science is stupid. You never know if you are right', constitutes a judgement about a classroom-science notion being delivered by the teacher that did not make sense to the student. The focus of this metaphor is on the sense-making activity within the mind of the individual student, and is aligned with the epistemology of personal constructivism.

Students-as-scientists is written in the plural because the metaphor emphasises social (constructive) processes in the formation of scientific literacy. This metaphor is demonstrated when students develop their own knowledge claims about phenomena and attempt to persuade others about the validity of their claims (Sutton, 1993). Developing their own knowledge claims involves asking their own questions, devising their own experiments, producing their own results and conclusions, and engaging in reflective discourse on the viability of their knowledge and the way it was generated.

A year of participant-observation in a Year 9 junior high school science classroom situated in a government-controlled inner-metropolitan school in Western Australia revealed that students were engaged almost solely in enacting the role of recruit, occasionally as judge and rarely as scientists (Willison, 2001). In relatively closed investigation tasks, problem, method and solution were largely predetermined. Although this is not necessarily a bad pedagogic approach, it can be problematic if it excludes other possibilities. In this research, students learned (implicitly) to ignore their 'errant' methods and 'ill-fitting' observations in order to ensure that they were assessed by the teacher (and their peers) as having confirmed classroom-science canonical knowledge and to have conformed closely to its standard discourse practices.

On occasion, a student was seen to be functioning in the role of student-as-judge, especially when judging the classroom-science to be at odds with his/her own lifeworld experiences. For example, Shelly had observed her father welding and had noticed how the welding material had 'shrunk' into the gap after being heated. From this experience she inferred that metals shrank when heated (as magnesium also appears to do when burnt), and she applied this tenacious understanding to 'explain' the famous heated 'ball and ring' experiment. However, her science teacher failed to probe her alternative ideas when she offered them in class discussion. After much frustration, Shelly eventually 'accepted' the classroom-science canon that metals expand when heated, although further research revealed that she did not believe her teacher or fellow students, and had concluded that "Science is stupid, 'cause you don't know if you're right!".

A more epistemologically astute teacher may have encouraged Shelly to voice her alternative ideas, along with those of other students, and managed a discussion about their viability, perhaps discovering appropriate life-world contexts in which students' alternative ideas make good sense. As Aikenhead (2000) argues, a 'science for all' ethos would actively promote 'concept proliferation', thereby enriching students' worldviews, rather than necessarily replacing commonsense views with those of classroom-science. A concept replacement model constitutes an unhealthy enculturation into a scientistic worldview. Moreover, if the teacher encourages students to judge the classroom-science, for example, by identifying perceived deficiencies then fewer students may become alienated from science. Conversely, when alternative student understandings "are not treated as candidate challenges to accepted scientific knowledge but as erroneous and explained by external factors, the teacher suggests that science offers an unfailing accurate and thorough description of the world as opposed to providing the means of participating in the scientific construction of reality" (Costa, 1993). Such a non-inclusive approach might not seem helpful to a student who is struggling to make scientific sense of phenomena.

On one occasion during the year, students were involved in an open investigation into parachutes which presented an opportunity to enact the role of students-as-scientists. Shelly seized the opportunity, designing, conducting and reporting persuasively her own experiment. Because parachutes were of interest to her out of school, she designed a unique investigation into the relationship between parachute shape and time of fall, keeping constant surface area, weight and drop height. Most students chose to investigate the simpler relationship between drop height and time of fall (suggested by the teacher). Although she was constrained to work individually, Shelly displayed some important hallmarks of the students-as-scientists role inasmuch as she (i) developed a genuine and relevant research question, (ii) enjoyed ongoing freedom of experimental design, (iii) generated empirical data and accounted for invalid readings, and (iv) reported pursuasively about her knowledge claims in terms of classroom-science criteria (controlled variables, use of mathematical equations, repeat trials, and a null hypothesis).

It is important to note that Shelly's success as a scientist was dependent on her skills as a successful recruit. Bordieu and Wacquant (1992) have argued that "historians and philosophers of science, and especially scientists themselves, have often observed that a good part of the craft of the scientist is acquired via modes of transmission that are thoroughly practical" (p.223). Thus, utilising the students-as-scientists metaphor may help facilitate student learning of classroom-science knowledge, thereby enhancing the role of student-as-recruit.

From this research we conclude that greater scope in the science class for enacting the roles of student-as-judge and students-as-scientists might provide meaningful learning activities for a much greater range of students as well as enabling students to develop richer (more complex) understandings of the nature of science. A teacher who utilises purposively and judiciously all three metaphors would be allowing objectivism, personal constructivism and social constructivism to inform, in a complementary manner, educational processes in the classroom.

## Conclusion

In order to respond to Dewey's (Garrison, 1995) call to approach conflict in education from 'a level deeper and more encompassing', the notion of 'theory' may be better backgrounded, because it tends to evoke a competitive and mutually exclusive standpoint. In science education, research under the auspices of objectivism, personal constructivism and social constructivism have collected/generated their own data, fortified their respective research programs and refuted competing theories. The competition between each is understandable when 'theory' is the underlying conception of these influences on our understanding of learning.

We have argued here that metaphor is a conceptual framework that has the capacity to facilitate an integral perspective, by allowing divergent epistemologies to be perceived as complementary; as united in diversity. Regarding the use of fundamentally different metaphors that give rise to fundamentally different mathematics, Lakoff and Nunez (2000) argue that "each mode of metaphorical understanding has different uses. And each is precise in its own terms..But you do not have to choose. As long as you keep your metaphors straight, you can use whichever is most useful for a given purpose" (p.374). We propose the view that objectivism, personal constructivism, and social constructivism are metaphorical in origin and substance, that each is significant, and that together they are not mutually exclusive, but rather can provide different viable and valuable understandings about science teaching and learning (and the nature of science).

In making explicit the metaphorical bases of these divergent epistemologies, and arguing for a mode of reasoning involving dialectical complementarity, we hope to contribute to a more productive dialogue amongst the proponents of single epistemologies in the science education community. We pose the following question to fuel this dialogue: can an integral perspective better inform the science education community about epistemological processes involved in teaching and learning science, and thereby facilitate an increasing equity of access amongst students to a richer experience of the nature of science?

## References

AIKENHEAD, G. (2000). Renegotiating the culture of school science. In R. Millar, J. Leach & J. Osborne (Eds.), Improving science education (pp. 245-264). Buckingham, UK: Open University Press.

BERK, L.E. (1994). Vygotsky's theory: The importance of make-believe play. Young Children, 50(1), 30-39.

BERGER, P.L. & LUCKMAN, T. (1966). The social construction of reality: A treatise in the sociology of knowledge. London: Penguin Books.

BERNSTEIN, R. (1985). Beyond objectivism and relativism: Science, hermeneutics and praxis. Philadelphia, PA: University of Pennsylvania.

CALABRESE-BARTON, A., & OSBORNE, M.D. (1998). Marginalised discourses and pedagogies: Constructively confronting science for all. Journal of Research in Science Teaching, 35(4), 339-340.

COSTA, V.B. (1993). School science as a rite of passage: A new frame for familiar problems. Journal of Research in Science Teaching, 30(7), 649-668.

FOSNOT, C.T. (1993). Rethinking science education: A defense of Piagetian constructivism. Journal of Research in Science Teaching, 30(9), 1189-1201.

FULLAN, M.G. (1993). Change forces. London: The Falmer Press.

GARRISON, J. (1995). Deweyan pragmatism and the epistemology of contemporary social constructivism. American Education Research Journal, 32(4), 716-40.

GERGEN, K.J. (1995). Social construction and the educational process. In L. P. Steffe & J. Gale (Eds.), Constructivism in education (pp.17-39). Hillsdale, NJ: Lawrence Erlbaum.

GUBA, E., & LINCOLN, Y. (1989). Fourth generation evaluation. London: Sage.

HALLIDAY, M.A., & MARTIN, J.R. (1993). Writing science: Literacy and discursive power. London: The Falmer Press.

KLEIN, E. (1971). Klein's comprehensive etymological dictionary of the English language. Amsterdam: Elsevier.

KRAGH, H. (1998). Social constructivism, the gospel of science and the teaching of physics. Science and Education, 7(3), 231-43.

LAKOFF, G., & JOHNSON, M. (1999). Philosophy in the flesh: The embodied mind and its challenge to Western thought. New York, NY: Basic Books.

LAKOFF, G. & NUNEZ, R.E. (2000). Where mathematics comes from: How the embodied mind brings mathematics into being. New York, NY: Basic Books.

O'LOUGHLIN, M. (1992). Rethinking science education: Beyond Piagetian constructivism towards a sociocultural model of teaching and learning. Journal of Research in Science Teaching, 29(8), 791-820.

PINAR, W.F. & REYNOLDS, W.M. (Eds.). (1992). Understanding curriculum as phenomenological and deconstructed text. New York, NY: Teachers College Press.

SEITZ, J. E. (1999). Motives for metaphor: Literacy, curriculum reform, and the teaching of English. Pittsburgh, PA: University of Pittsburgh Press.

SETTELMAIER, E. & TAYLOR, P.C. (2002, July). Bridging the gap: Integral philosophy and educational research in the seventh moment. Paper presented at the Xth annual conference of the International Organisation for Science and Technology Education, Foz de Iguacu, Brazil.

SLATTERY, P. (1995). Curriculum development in the postmodern era. New York, NY: Garland Publishing.

SPIVEY, N.N. (1997). The constructivist metaphor. San Diego, CA: Academic Press.

SUTTON, C. (1993). Figuring out a scientific understanding. Journal of Research in Science Teaching, 30(10), 1215-1227.

TAYLOR, P.C. (1998). Constructivism: Value added. In B.J. Fraser and K.G. Tobin (Eds.), International handbook of science education. Dordrecht, The Netherlands: Kluwer Academic Publishers.

WILLISON, J.W. (1999). Who writes the recipes in science: Possibilities from four years of action research with students and their scientific literacy. Research in Science Education, 29(1), 111-126.

WILLISON, J.W. (2001). Classroom factors affecting student scientific literacy: Impressionistic tales and their interpretation using a metaphoric framework. Unpublished Doctoral thesis. Curtin University of Technology, Perth, Western Australia.

**Keywords:** Epistemology, Pluralism, Constructivism, Objectivism, Dialectic, Science Education, Science Teaching, Metaphor

**058**

# SCIENCE LITERACY IN SOUTH AFRICA: TOWARDS CRITICAL EDUCATIONAL STUDIES

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## Abstract

This paper explores both theoretical and methodological underpinnings for the reconstruction of the South African science curriculum deriving from the critical educational studies of Freire, Giroux and Apple. The South African science curriculum needs far greater changes than simply altering a syllabus; it needs to be underpinned by radical and critical educational studies to ensure that it serves emancipatory interests and empowers the historically disadvantaged students. Critical education involves problem posing in which all involved are challenged to reconsider and recreate their prior knowledge and to extend their thinking (Shor 1987:180). Freire argues that the form and content of knowledge, as well as the social practices through which it is appropriated, have to be seen as part of an ongoing struggle over what counts as legitimate culture and forms of empowerment (Aronowitz and Giroux 1986:156).

Freire insists that knowledge is neither static nor neutral. It is continually created and recreated as people reflect and act on the world:

> Knowledge...necessitates the presence of subjects confronted with the world. It requires their transforming action on reality. It demands a constant searching...In the learning process the only person who really learns is s/he who ...re-invents that learning (Freire 1973:101)

The central categories of Giroux's (1981:114-116) formulation of the dialectic - totality, mediation, appropriation, and transcendence - detail the various dimensions of a Freirean critical knowledge of reality. Totality, according to Shor (1987:183) involves understanding any fact or situation in its historical, socio-economic, political and cultural context. Therefore critical knowledge involves uncovering the limits and possibilities of our actions for transforming the world. We use our knowledge to reconstruct society so that it is free of alienating and oppressive social institutions and life forms (Giroux 1981:122). The dialectical of critical educational studies has much relevance to the current South African educational context since it points to the connection between critical knowledge and emancipatory social change.

## Historical context

Education was used as an instrument of repression by the apartheid regime. The unequal provision of educational resources was reinforced by a curriculum that promoted white supremacy. Unfortunately, education in South Africa continues to bear the indelible imprint of apartheid South Africa. What needs urgent attention is the systemic disadvantage faced by black learners. Systemic problems are simply reduced to lack of efficiency, cost-effectiveness, accountability, coherence and language issues.

## Current context

South Africa's education system is currently in a crisis. The need for graduates has risen by a staggering 2000% over the past three decades, but the current system cannot rise to this challenge. The National Plan for Higher Education released in 2001 ignores the HIV/aids crisis and its synergy with student numbers. A key feature of the Plan is the reduction of the number of students in the humanities, and an increase in the sciences. An unfortunate legacy of the past that is denied is the lack of qualified teachers in black schools in the fields of maths and science education and the lack of suitably qualified academics in previously disadvantaged tertiary institutions to offer programmes in mathematics, science and technology. The increased intake of students in the humanities in many institutions must be seen against this backdrop.

After six years of democratic governance, conditions in black schools remains appalling and fundamental inequities between white and black schools remain entrenched. The schools are plagued by low teacher morale, maladministration and corruption, limited funding for development and a general lack of confidence in the public education system. The government is addressing some of the issues though the ambitious plan called *Trisano*, announcing the end of illiteracy by 2004 and an evaluation of the South African Qualifications Authority. The national Minister of Education has failed to rally support among critical stakeholders and has come into conflict with the South African Democratic Teachers' Union, the Congress of South African Students and the Congress of South African Trade Unions.

The President's invitation to Cuban science and mathematics educators to teach in South Africa is problematic. The invitation ignores the capacity that exists in many or our institutions that have established science and maths education units precisely to respond to the challenge to expand and upgrade science and maths education in schools. A more significant intervention would be to put into our schools the science graduates who presently roam the streets unemployed and the many good teachers who were driven out of the system as a result of the government's poorly conceived and badly managed voluntary severance package policy.

Figures relating to the participation and attainment of learners in maths and science are alarming. Participation rates in maths and science at higher grade, as reflected in matric results from 1997 to 2000, are around 20%. The pass rate in these crucial subjects consistently falls below 5%. The result of the poor pass rate is that the country's ability to train enough young people in the sciences is reduced. The direct consequence is that the economy is starved of the skills necessary for growth and sustainability. Reasons for this state of affairs, according to the Ministry of Education are the dysfunctionality of many public schools and the large number of unqualified or under-qualified maths and science teachers. An interesting point is that the ministry maintains that there is nothing wrong with the learners. The following steps have been taken to address the problem:

- upgrading of teachers in these subjects;
- exploring ways of utilising retired or unemployed teachers;
- co-operating with other governments in upgrading teachers;
- recruiting matriculants to get them trained as teachers;
- working with universities and technikons in advancing this process; and
- implementing maths and science-dedicated school projects.
  (Mangena 2001: 4)

Related issues that need to be considered are improvement of the management of the curriculum, subject knowledge, materials development, the role of language in science teaching, curriculum theories and assessment strategies. This paper is underpinned by a reflection of my experiences with theoretical strategies for curriculum development within the context of critical educational studies.

## Critical educational studies

This paper proposes that the teaching of Science would be best served by working within a critical paradigm, having as its objectives the goals of critical educational studies (Apple, 1996, contends that the term 'critical pedagogy' is limited). McLaren (1989:182) explains that critical educational studies supports a dialectical understanding of schooling that:

> ...enables the educational researcher to see the school not simply as an arena of indoctrination or socialisation or a site of instruction, but also as a cultural terrain that promotes students' empowerment and self transformation. (1989:167)

The cardinal aim of critical educational studies is to conceive of education as an arena of contestation that examines how and why knowledge is the way it is, why some forms of knowledge appears more powerful than others and how the student's daily experiences reflect certain constructions of knowledge. It requires activities that encourage meaning construction, to develop their understanding of the process whereby meanings are made, to interrogate the relationship between knowledge and power, and to actively promote critical thinking skills in science teaching. Within post-colonial contexts, critical educational studies is most relevant in examining how social, historical and political factors influence teaching and learning and how power relations in the institution and society influence meaning construction. McLaren (1989) notes the following questions that are relevant to teaching within the paradigm of critical educational studies:

a. How do the selected texts construct knowledge?
b. Do they promote stereotypical views that reinforce racist, sexist and patriarchal attitudes? And if so, how do they do it?
c. How do we treat the knowledge that working-class students bring to the class?
d. Do we unwittingly devalue such voices and marginalise these students?

Giroux (1992:73) maintains that by taking into consideration these issues, the teacher is empowered to actively promote a politics of *difference* instead of being trapped within the dominant 'appropriate knowledge' that the establishment sanctions. Such an approach is concordant with curriculum reconstruction that redefines the relationship between the margins and the centre - the dominant canon and excluded knowledges - and offers the opportunity for a politics of *voice* (Giroux 1992:73).

Critical educational studies provides a variety of useful modes of analysis to challenge traditional educational ideology that considers educational institutions as transmitting agents of objective knowledge. This position is challenged by presenting theories of the hidden curriculum and theories of ideology that identify the interests underlying specific forms of dominant knowledge like the canon of traditional western science.

Freire's critical approach enables the student to counter subjective knowledge. It is based on one basic assumption: the 'ontological vocation' of a person is to be a subject who is capable of acting upon and transforming the world:

> ...the conviction that every human being, no matter how ignorant or submerged in the culture of silence he may be, is capable of looking critically at his world in a dialogical encounter with others. Provided with the proper tools for such encounter, he can gradually perceive his personal and social reality as well as the contradictions in it, become conscious of his own perceptions of that reality, and deal critically with it. (1971a:13)

The Freirean concept of *critical consciousness* involves the combination of coming to an awareness of contradictions expressed as 'limit situations' (serving the interests of some, limiting the actions of others) <u>and</u> understanding that these contradictions exist not so much as obstacles preventing action but challenges stimulating appropriate action - the oppressed then identify themselves as critically reflecting subjects *in* the world and *with* the world.

Two strands of Freire's philosophy of critical consciousness forms the basis of critical educational studies: ***dialogue***, a vocation to become more fully human, and ***praxis*** (critical reflection and action upon the world). Since action cannot be separated from reflection, and critical education develops critical knowledge, Freire views education as vital in helping people to become subjects involved in liberatory social change (Shor 1987:184). Although Freire's works have direct reference to the oppressed in various Third World countries, his focus on problem-posing in contrast to problem-solving - together with his commitment to dialogical rather than 'banking' education - is also relevant for curriculum reconstruction in South Africa, especially in view of the need to counter the 'culture of silence' that was characteristic of apartheid education.

Critical theorists like Giroux and McLaren make extensive use of Freire's works in their discourse on curricular reconstruction. They maintain that critical educational studies as a form of cultural politics speaks to a form of curriculum theory and application that stresses the historical, cultural, and discursive in relation to classroom materials and teaching practices. It enables teachers to examine, dismantle, analyse, deconstruct and reconstruct pedagogical practices. Teachers are empowered to ask how meaning is produced, and how power is constructed and reinforced in the lecture hall. We need to urge teachers to understand curriculum as an expression of struggle and to acknowledge that it constitutes a primary agent for introducing, preparing and legitimizing forms of social life. The notion of cultural politics must be considered by both legitimating and challenging the cultural experiences that make up the historical and social particulars that constitute the cultural forms and boundaries that give meaning to the lives of students.

Critical educational studies is therefore linked to notions of self- and social empowerment since students learn how to read the world and their lives critically and relatedly thus leading to a deeper understanding of how knowledge gets produced, sustained and legitimated (Giroux 1986:132). It challenges both the established curriculum and the cultural selection that it embodies and the patterns of advantage and privilege which that selection gives rise to and perpetuates. It encourages students to question the content of their education and the ideology of the institution through the 'teaching' of and empowerment of a counter-hegemony.

The implementation of a critical educational approach will shift the focus from listening and reading to reading and creation. Students have for too long been taught to read and understand. This privileging of reading over writing limits the possibility that students will engage in '*praxis*' - the ideal consummation of both *verbalism* (theorising without action) and *activism* (action without reflection or theory). Reading for the creation of texts has been ignored, perhaps because of its political implications. By focusing on passive learning instead of critical creativity, the South African establishment's need for literate but passive citizens has been served.

In developing a critical educational approach, teachers should consider both content and methods. Shor (1987:186) maintains that relevant content presented in a non liberatory way reduces critical insights to empty words that cannot challenge students' taken-for-granted reality and cannot inspire commitment to radical change. Humanistic methods without critical content cannot help students become subjects capable of using critical knowledge to transform their world. Freire (1971a:28) suggests that content for critical consciousness must be developed by searching with the students for the ideas and experiences which give meaning to their lives and by exploring the nature and influence of literary, social and political conflicts. The dominant discourse could then be challenged and the competing discourses of contemporary philosophers would be allowed to confront the established power-knowledge hegemony leading eventually to a cultural revolution and change in education.

### Meaning construction

The experiences of students should be given pre-eminence in an emancipatory curriculum, therefore critical educators must learn how to understand, affirm and analyse such meaning. Freire emphasises that all knowing begins with experience, in his terminology 'knowledge made from experience'. Critical educational studies would include the development of forms of knowledge and social practices that validate the experiences that students bring to the classroom. Such experiences should form the basis of the teaching programme thus ensuring that students have an active voice in the content taught instead of the traditional approach of silencing them by ignoring their cultural capital. Critical teaching creates a process of learning and knowing that invariably involves theorising about the experiences shared in the dialogue process. A reconstruction of the South African science curriculum would therefore challenge the language forms, style of presentation, dispositions, styles of reasoning and cultural expressions that form part of and give meaning to the students' experiences.

Freire views the students' experiences as central to the construction of knowledge since they do not arrive at the classroom empty, 'they bring with them opinions about the world, and about life'. Education starts from the experiences of students, and either reinforces or challenges the existing social forces that keep them passive. Students' experiences or 'hidden voices' are essential to uncover, as they have the power to block learning. The blocks can be emotional (e.g. low self esteem), structural (e.g. lack of contact with English speakers), or socio-economic (e.g. prejudice). The emotional power behind these experiences can also inspire learning. By helping students articulate their concerns in the classroom, teachers help them understand the blocks and move beyond them.

An appropriate curriculum will therefore be based on and derive from the needs of the culture of the students to be educated. It is rather unfortunate that many science and maths teachers are unwilling to consider reform of the system, are least interested in changing the curriculum and the examination system and are strongly favourable to some of its more traditional and inappropriate aspects. The very structure of their thought has been conditioned by the contradictions of the concrete, existential situation by which they were shaped (Freire 1971b:22). The traditional pedagogy that characterises much science teaching depends heavily on knowledge of the English language, yet the majority of South African students have an African language as mother-tongue. The following example of context-reduced communication taken from a Primary Science Project (PSP) case study of science teaching in a KwaZulu Natal Grade 5 class succinctly illustrates my argument.

> *The teacher wrote the following facts on the board as a list of English sentences:Frogs are green. Frogs are amphibians. They live in water and on land. Frogs lay eggs. He drilled these sentences and then asked, "What colour are frogs?" An eager student replied, "Water!" The teacher couldn't help but be frustrated. The student couldn't help but read his frustration as her own failure.*
> (Diamondidis 1998:39)

Salient features that this case study represent are, firstly, the need to embed content firmly within context, after all, children in KwaZulu Natal know about frogs. Secondly, the need to question the teacher's use of English in engendering cognitive skills. The reason language minority students have often failed to develop high levels of academic skills is that their initial instruction has emphasised context-reduced communication, since instruction has been through English and unrelated to their prior out-of-school experiences. A more detailed analysis of language and science teaching falls outside the ambit of this paper.

Children do not come to school empty of science and technology. In multicultural schools we find children from vastly different backgrounds and experiences. The advantage of this situation is that the different cultural capital of the children, e.g. the knowledge of medicinal herbs, astrology, agriculture, animal husbandry, etc. is valuable existing knowledge that teachers can draw upon in the science class. Such approaches ensure that content is embedded in the context of the child's life world as opposed to a situation where the context is ignored.

Critical interpretation presupposes involvement and experience. Student involvement in the learning process is integral to teaching - as well the treatment of the content more as an experience than a lesson or object to be studied. Two stances can be taken by learners - an ***efferent*** stance that focuses a learner's attention on information to be retained after reading and an ***aesthetic*** stance that occurs when the learner's attention is on the lived-through experience of the content and thoughts, feelings, images, and associations which are evoked as the lesson proceeds. The latter fosters the development of a learners's understanding of the content's personal significance. An *efferent* approach, on the other hand, assumes that students' personal opinions are not valued and that there exists a correct answer which they are expected to reach. An *aesthetic* stance will ensure that students truly live the teaching-learning experience and are not encouraged to distance themselves from the content.

The *efferent* approach has been exacerbated by the undue stress on Formalism in the maths and science classes, a theory which encouraged an authoritarian academic environment and canonical cultural expressions. This paternalism made students spectators in the academic conversation rather than players and it reinforced the passivity, indifference and top-down authority of apartheid education. The task of the teacher was one of 'filling' students with 'hollow, alienated verbosity' while the student mechanically recorded, memorised and repeated the imposed content.

Freire counters this situation by insisting that there be a determined effort by the lecturer to relinquish the role of expert in the lecture hall and to provide the critical and reconstructive space for students to sort out their contradictions and conflicts, confirm themselves and gain understanding about the richness of other cultures and other voices. This paradigm increases awareness of the contradictions hidden or distorted by everyday understandings as well as creating a critical community in the lectures, empowering students to rethink their world and to interpret their experiences. Unfortunately, within the South African context, there was a tacit inculcation of the belief in the value of scientific craftsmanship and the hegemony of the natural sciences in the academe resulting in the lecturers, as custodians of knowledge, interpreting the content *for* the students. Any student's response to content is naturally conditioned to a certain extent by the student's own reading experience, cultural background and biases, the more impersonal factors of culture and society, and certain levels of language competence. The lecturer's attempt at constructing the meaning of a text would naturally be influenced by subjective bias as well. It is therefore logical that all interpretations of meaning and all meaning construction in the classroom, because of the subjective method of the exercise, will result in an indefiniteness of meaning since subjective bias and cultural conditioning denies objective truth.

Much African knowledge is marginalised from the science curriculum. What is oral and is directed at and participated in by the African community is the 'other' and does not fit into the 'established' tradition. The reconstruction process must now therefore be guarded against simply replacing 'established' content with local content. More appropriately, it should include the need to critically engage the experiences that students bring to the lectures. This means that such experiences in their varied cultural forms have to be interrogated critically so as to recover their strengths and weaknesses (Aronowitz and Giroux 1986:156). Students need to be provided with the skills and knowledge to critically appropriate the codes and vocabularies of different cultural experiences.

## Cognitive development

Critical thinking is a practical reflective activity that has reasonable belief or action as its goal - *It is reasonable reflective thinking that is focused on deciding what to believe or do.* The definition does not exclude creative thinking. Cognitive skills that help transform the classroom into a community of inquiry include reasoning skills, inquiry skills, concept-analysis skills and translation skills. Cognitive process instruction is more than a shift of emphasis towards basic skills; it implies a radical change in our current conception of learning and the fact that students can only learn when they are actively involved in piecing together their own ideas, when they get the total picture, when they have a will to doubt and when their interpretation is respected.

The origins of the cognitive approach are quite old; Galileo once said, 'You cannot teach a man anything; you can only help him to find it within himself'. If new knowledge is learned in a shallow way, it is difficult for the knowledge to be made the students' own, a part of their reality. Habermas (1984:220) also contends that genuine conceptual learning occurs only when learners make their own sense of knowledge:

> ...the curricula of schools are other people's knowledge, imposed on the student. Not surprisingly, some students do not bother to make personal sense of this knowledge but merely play the school 'game' of rote learning and reproducing the curriculum knowledge.

A cognitive approach emphasises the role of the student as active participant and not as Habermas warned, a passive recipient.

Giroux (1992:171), in outlining the cognitive approach, distinguishes between knowledge about, on the *digital dimension* of learning (univocality, precision, logic) experienced in school as opposed to knowledge of, or the *analogic dimension* (equivocation, ambiguity, description) experienced by students in the street. If knowledge is given, it is of a linear or relatively unproblematic nature, and therefore does not engage student experience within critical educational studies and is characteristic of *transmission education*.

The teaching of science using the traditional didactical approach of transmission education was described by Freire as *banking education* where the authoritarian teachers 'deposit' knowledge in the students' minds - a process that 'anaesthetises and inhibits creative power'. *Banking education* assumes that students' viewpoints and voices are of secondary importance to the authoritative knowledge passed on by the teacher (Freire 1971b:58).

The paternalism of this approach is essential to the maintenance of an oppressive political and social order as it ensures that students who complete the courses remain passive and unquestioning. However, banking education may be beneficial for the student in particular situations, for example, when motivated learners wish to obtain specific bodies of knowledge within a paradigm with which they are already familiar and knowledgeable. A negative result of banking education is what Freire refers to as *marginalisation* - by promoting myths about reality and maintaining the dominant ideology of the institution, the educators force the students to be marginalised; to be on the fringe of, or outside reality.

The use of local knowledges in the classroom is a possible approach in the use of Freire's (1971b:12) fundamentally different pedagogy with its dual thrust: *critical reflection* that must lead to *revolutionary action*. Freire leads us to further understand the dynamics of this intellectual process:

> In the learning process the only person who really learns is s/he who appropriates what is learned, who apprehends and thereby reinvents that learning; s/he who is able to apply the appropriate learning to concrete existential situations. On the other hand, the person who is filled by another with 'content' whose meaning s/he is not aware of, which contradicts his or her way of being in the world, cannot learn because s/he is not challenged (1973:101)

Science teaching using only critical awareness will continue to encourage the culture of silence - integral to the process is *praxis*/action. The ability to perceive contradictions and discontinuities along with the interrogation of content, leads to discourse awareness. Focusing on local knowledge will help students critique ideas and practices that are part of their environment and their experiences and a confrontation with the canon will question the ideology that underpins its constitution. But, this is reflection without action, and thought only has meaning when it is generated by action upon the world (Freire 1971b:64). The problems and conflicts discussed must therefore be relevant to the students' lives and they must be challenged to respond to issues that form part of their experiences. A cognitive model would encourage intense dialogue and advanced writing. When teachers and students are partners in dialogue, a different conception of the process of knowledge acquisition emerges:

> The cognitive dimensions of the literacy process must include the relationships of men with their world. These relationships are the source of the dialectic between the products men achieve in transforming the words and the conditioning which these products in turn exercise on men (Freire 1971b:12)

Short-term improvement in literacy skills can be achieved by motivating students and by reinforcing their written work. Only programmes that build upon cognitive processes can help individuals meet the long-term objective of using their literacy as a tool of personal growth and social transformation.

A cognitive approach ensures that we succeed in presenting science as a potentially emancipatory force in students' lives. The relation between analysis in the classroom and critical thought in general has to be illuminated so that they leave the institution with minds of their own and a critical awareness that might generate social change. When we develop in students some expertise in decoding structures of signification, we equip them intellectually to read our own practices, our institutions and the world as a text. When this happens, any authoritarian, hierarchical and exclusionary qualities that we reflect in our choice of content, courses and reading lists, our relations to students and our teaching strategies can be identified. Such a goal demands curriculum restructuring that conscientises students to see connections between the text and the world, increase their perceptions concerning the link between power and truth and expose them to the excluded images of otherness.

Conscientisation has to do with the development of a new mode of expression - a critical discourse. Students are guided through a dialogical exploration and interpretation of issues discussed. The process, similar to Dewey's (1940) problem solving approach, involves critical questioning, forming opinions, testing hypotheses, and making decisions. Students are encouraged to see reality clearly and critically, resulting in a positive teaching and learning environment, a sincere appreciation for the value of learning and a development of cognitive skills to solve practical problems.

South African education should embrace a cognitive approach since it is conducive to the development of autonomous, rational beings. The Ministry of Education's campaign to 'save the sciences', which heralds a new era in education - though contentious in some academic circles that feel that outcomes based education is doomed to fail, correctly shifts priorities in education from learning to thinking and requires a redefinition of the function of the classroom. Alternative curriculum strategies are necessary to counter the pedagogy of oppression and to ensure the intervention of critical educational studies.

## Conclusion

Psychoanalysis, Marxism and feminism have brought about a shift in pedagogical theory, a shift which suggests new models of teaching precisely by challenging the traditional assumptions of canonical knowledge and pedagogic authority as well as the classroom opposition of 'knowledge' and 'ignorance'. Traditional pedagogics conferred upon the teacher the status of expert, mentor, champion of the subject and master of the text who will transmit knowledge to the 'ignorant' student who desires to know. Critical educational studies encourage a confrontational attitude towards students, instead of paternalism, with a critical stance towards the content. When conflict is not ignored or suppressed, it forms a discursive site in which knowledge is produced. In order to move away from *banking education*, the teacher must acknowledge the conflict present in the classroom and consequently encourage debate and questioning of existing paradigms of knowledge. If knowledge is viewed as an entity that is static and fixed and absolute, no true teaching can take place because the knowledge is not open to dialogue and conversation and the role of the student is to merely master the knowledge.

## References

DIAMONDIDIS, E., (1998). A language sensitive science teacher training approach. *English teaching Forum* 32 (3), 12-19

FREIRE, P., (1971a). *Cultural action for freedom.* London: Penguin.

FREIRE, P., (1971b). *Pedagogy of the oppressed.* New York: Continuum.

FREIRE, P., (1973). *Education for critical consciousness.* New York: Seabury.

FREIRE, P. & HORTON, M. (1991). *We make the road by walking: Conversations on education and social change.* Philadelphia: Temple University Press.

GIROUX, H.A., (1981). *Ideology, culture and the process of schooling.* Philadelphia: Temple University Press.

GIROUX, H.A., (1986). Teacher education and the politics of engagement: The case for democratic schooling. *Harvard Educational Review* 56 (3), 213-38.

GIROUX, H.A. (1991). *Postmodernism, Feminism and Cultural Politics.* Albany: State University of New York Press.

HABERMAS, J., (1984). *The theory of communicative action.* Volume 1. London: Heinemann.

MANGENA, M., (2001), Saving the sciences. *The Teacher*, 5 (8), 4.

McLAREN, P., (1989). *Life in Schools. An introduction to critical pedagogy in the foundations of education.* London: Longman.

SHOR, I., (1987). *Freire for the Classroom: A Sourcebook for liberatory teaching.* New Hampshire: Heinemann.

**Key Words:** Critical educational studies, science teaching, meaning construction, cognition.

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# TEACHING ETHICAL ISSUES IN SCIENCE

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## Introduction

It is now mandatory for science teachers in England to teach ethical issues arising from dilemmas in science, (DfEE/QCA 1999) although the national curriculum of England takes as unproblematic the challenges that teachers may face in exploring contemporary controversies in science. Biomedical research, for example, is developing with great rapidity and the social and ethical problems concomitant with these changes are, to some extent, unpredictable. So, what problems do teachers face when addressing contemporary issues in science? And what do young people think about these issues?

Of the many controversial issues in science, advances in the genetic and reproductive technologies have a personal relevance for students. Understanding the implications of a genetic screening programme, for example, and the possibility of having an inherited genetic condition, concerns not only individuals but also their families and the wider society. Decision-making is likely to involve the private morality of the concerned individuals, their specific socio-economic contexts, their personal and social relationships and their educational background. Debates about cloning and genetically modified food indicate that political decisions are sensitive to public opinion. For example, the Human Genetics Commission, a non-executive advisory body to the UK government has circulated a questionnaire to the public on their attitudes towards developments in genetics[1]. The dissemination of information resulting from genetic testing has important civil rights implications. Formulating public policy and creating the conditions for democratic accountability on these issues presuppose a citizenry that has some grasp of the underlying science and an awareness of the values base. Young people entering medical vocations, the social services and teaching will need an appropriate background that enables them to deal with the many ethical, social and legal questions that will arise. The school education of an emerging lay and professional citizenry is crucial in providing a forum for rehearsal of these issues (Nuffield Council of Bioethics 1993).

A team at the Institute of Education, University of London carried out a large scale survey for The Wellcome Trust on the teaching of social and ethical aspects of developments in biomedical science (Levinson and Turner 2001). Questionnaires were sent to teachers and headteachers in 1000 schools in England and Wales followed by 111 interviews with individual teachers and groups of teachers across the curriculum. Findings from the survey indicate that science teachers tend to have an epistemological view of science as value-free, that they have little experience of managing ethical discussions in the classroom and that all teachers have a limited knowledge of what young people think about these issues..

An exploratory pilot study has focused on developing empirical tools to study the teaching of ethical issues in the new genetics. While ethical ideas and perspectives can be taught in a transmissive way, any understanding of them relies on belief, experience and emotions. Indeed the immediacy of research in the new genetics is the implications for individuals, families and communities. Interchange of ideas in the classroom in science, and certainly ethical issues in science, should involve opportunities for talk, discussion and argument (Newton, Driver et al. 1999). This preliminary research study focuses on two aspects of teaching and learning controversial issues in science: first, developing a probe to characterise the range of ethical arguments that students use when thinking about dilemmas in the new genetics, and, second, formulating a description of the strategies used in dialogue between student and teacher. The research therefore draws on ideas of discourse analysis that focus on dialogue, ((Edwards and Mercer 1987), (Lemke 1989), and current ethical thinking in aspects of genetics (Singer 1979) (Glover 2001).

[1] HGC Business: Consultations. See http://www.hgc.gov.uk

## The context

The medium that was chosen for the study is a one year post-16 course, *Science for Public Understanding(SPU)*. As the name of the examination course suggests, one of the important aims is to cover a range of issues which members of the public will need to understand if they are to participate in scientific and technological decision-making. It thus stands distinct from other syllabuses that have a more overt science content, and the course attracts non-science as well as science students. The module selected for the research is based on developments and ethical dilemmas in genetics covering inherited diseases, antenatal screening and pre-implantation genetic diagnosis. Four two-hour sessions were observed by the researcher. A fifth session not attended by the researcher, brought together strands of the module and a previous module for examination purposes. In the first session the teacher addressed the underlying science concepts – genes, chromosomes, alleles, dominance, recessive, genetic conditions, fertilisation, (including *in vitro fertilisation*), zygote. The second session broadened out the range of genetic conditions and the need for screening. Discussion of ethical dilemmas – the focus of this study – occupied the third session and the fourth session addressed the topic of designer babies through the video *The Gift*.[2] A wide range of strategies were used: videos, direct teaching, group discussions, true and false statements, question and answer sessions.

There are twenty four students on the course, although two did not attend any part of the module, and numbers attending the sessions varied from 22 to 12. For three of the four sessions, however, twenty or more students attended. There are ten young men in the group and fourteen young women, and in each session there were always slightly more women than men.

The teaching sessions take place in a further education (FE) college in London. A further education college is usually larger than a secondary school and runs many more courses, including a mix of vocational and academic courses. Mature adults attend courses at FE colleges and often work in classes with students in the 16-19 age group. Most of the students in this group are in the 16-19 age group, although there is a Somali refugee in her early twenties who, the teacher told me, had a disabled two-year old child. The class is ethnically diverse, consisting of refugees from Afghanistan and Somalia, students from the Asian sub-continent, Afro-Caribbean students as well as white UK-born students. The class reflects the ethnic diversity of the college, and those of many schools and colleges in metropolitan areas of the UK.

## The Research Study

The course tutor is an experienced teacher, a chemistry specialist, who has taught SPU since the course was being developed in 1997. Researcher and teacher agreed dates for the researcher to observe the teaching of the module. In an initial interview the teacher discussed the components of the course and the educational background of the students. Most students had some qualification in science and about half were doing academic or vocational post-16 courses in science. Letters were sent to all the students on the course outlining the aims of the research project and asking for their co-operation, offering them the opportunity not to take part in the study. No students opted out. Due to the nature of the timetabling in the college it was not possible to interview the students.

The teaching room is small, unattractive and noisy and the researcher sat in a corner, able to observe students, without being obtrusive. Audio-tapes of the teacher's talk during the lesson were taken and transcribed. Two groups of students were also recorded during group discussions and their conversations and dialogue with the teacher were also transcribed. Classroom talk was logged on a 30 second timeline and regular timed observations taken of teacher strategies, position in the classroom, gestures, activities of two randomly selected students, resources, lesson content and researcher's thoughts. Copies were taken of all paper resources used.

Semi-structured interviews took place with the teacher at the end of each session. These covered:

2 Information about this video and the company that produced it can be found at: http://www.ytouring.org.uk/

- the teacher's description of the session and perceptions of what was learned;
- responses to 'significant moments' in the lesson raised by both researcher and teacher;
- impressions of what students had learned;
- the teacher's understanding of what students knew, understood and felt before and during the session;
- challenges perceived by the teacher;
- responsibilities of the teacher in discussing particular ethical dilemmas.

In the first session of the module, before formal teaching began, each student was given a copy of the front page of the *Daily Mail*, a popular British tabloid newspaper. The front page began with small headlines '24 hours after the U.S. designer baby storm, a British couple demand a test-tube daughter' followed by the banner headline 'NOW, THE RIGHT TO CHOOSE A BABY'S SEX'.[3] The story referred to a British couple wanting to 'choose' a girl after their three year old daughter had died in a fire. A link was made to the case of a six year old girl in the United States suffering from Fanconi anaemia, whose baby brother was 'selected' to provide blood for a transfusion. The front page contained a picture of the little girl who died in the fire as well as a report of the story. Students were not required to give their names but a number was given to them by the researcher which they were required to record on the task sheets and to use again when repeating the task at the end of the module. The group was asked to answer three questions in relation to the headline and the article:

1. How do you think a 'designer baby' is made?
2. What do you think a test-tube baby is?
3. Some people think parents should have the right to choose things like the sex or eye colour of their baby. What are your thoughts?

### Analysis of diagnostic tasks.

A total of 29 students from both the 'test' and 'control' groups responded to questions set about the newspaper article. Responses to the three questions were coded for knowledge of 'designer babies' and 'test-tube babies' contained in the headlines of the article, and in constructing an ethical argument for the third question. The codes were separately checked by the teacher and the few differences that emerged were discussed and agreement reached.

#### Designer babies

A designer baby is a perjorative term used to describe babies born as a result of the technique of Pre-implantation Genetic Diagnosis, PGD. Drugs are administered to a woman to stimulate ovulation. The eggs are then removed and fertilised *in vitro*. When the resultant embryos have divided a few times a cell is removed and diagnosed for a particular disabling condition, such as Fanconi anaemia or muscular dystrophy, using a 'DNA chip'. Two or three embryos without the condition are selected and introduced into the mother's womb through a long hollow tube, to increase the chances of successful implantation. The salient technical points about this technique are *in vitro* fertilisation, genetic diagnosis resulting in selection and implantation.

#### Student responses to the diagnostic task

*HOW DO YOU THINK A 'DESIGNER BABY' IS MADE?*

None of the responses mentioned the *selection* of embryos with particular genetic characteristics. The responses were categorised as follows:

- Genetic code read on gamete before fusing
- Removal/addition of genes
- Genes made dominant or recessive
- Replacing an undesirable allele
- Parents choose child's genome

All the above categories included responses by more than two students. Other responses included 'denying embryo hormones' and 'artificial insemination of an ovary to get specific results'.

[3] *Daily Mail*, October 5th 2000

While it is possible to change the genetic constitution of embryos, the newspaper article concentrated on

a. the use of pre-implantation diagnosis for selecting an embryo to provide healthy cells for a sick sibling; and
b. the potential use of PGD for sex selection.

There was no evidence in any of the responses to suggest that students had used information from the text; rather they had answered the question based on conceptions they had held before reading the article. The thrust of the answers implies something being changed in the embryo's genetic make-up rather than the selection of an embryo with particular genetic attributes.

*WHAT DO YOU THINK A TEST-TUBE BABY IS?*
A test-tube baby results from an egg fertilised in vitro. Twelve of the students responses were very close to this description. Others mentioned a baby 'incubated in a tube' and seven students responded that a test-tube baby was grown or born outside of the womb. Some responses included the term 'baby made by a scientist'. Nearly all students thought that a 'test-tube' figured as the container for the fertilisation process. Terms used about test-tube babies included 'non-human' or 'unnatural'.

Some people think parents should have the right to choose things like the sex or eye colour of their baby. What are your thoughts?

Analysis of these responses was based on the ability to formulate an argument and the types of ethical argument used.

*FORMULATING AN ARGUMENT*
The definition of an argument is based on a simple logical structure. The minimal ingredients of an argument are:

- at least one statement that is reasoned for (the conclusion)
- at least one statement that is alleged to support it
- some signal or suggestion that the argument is underway (the logical indicator)
  (Beardsley 1975)

The texts of student responses were subdivided into statements and the responses configured into a flow diagram. Examples are given in figures 1 to 3. .

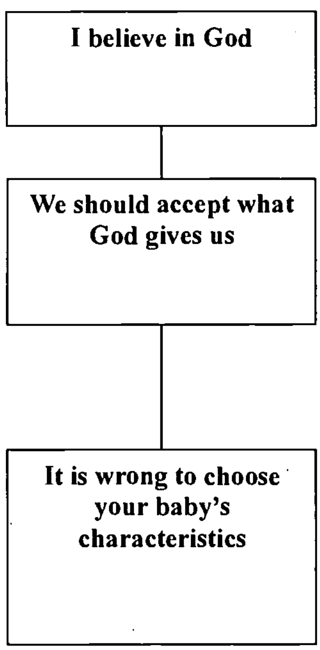


**Figure 1:** One line of sequenced statements

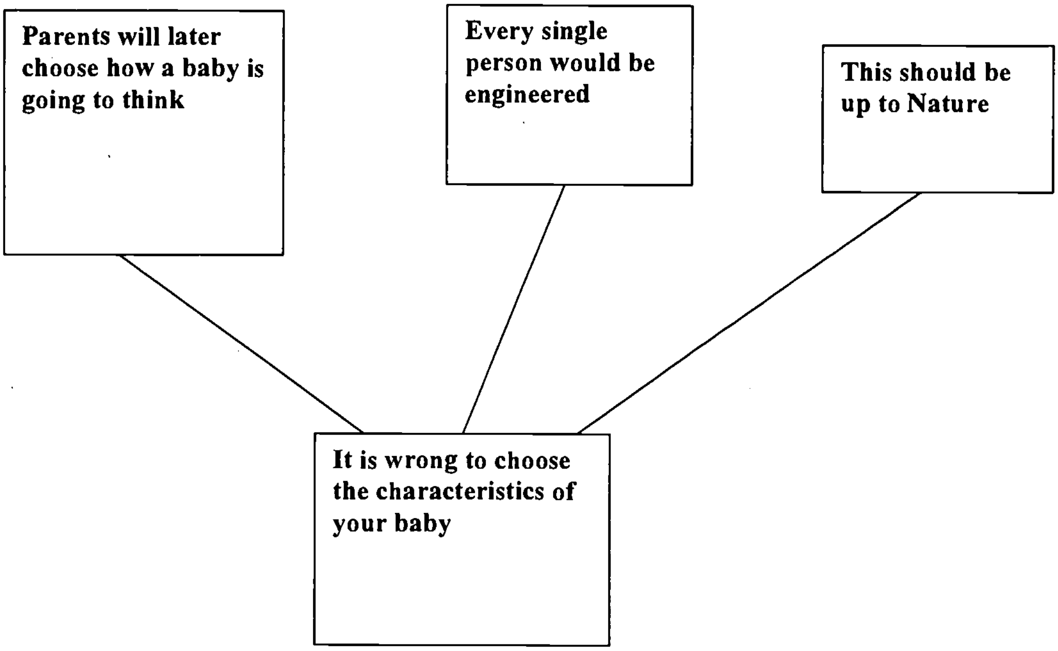


**Figure 2.** Multiple lines (Can be two or more statement sequences in each line)

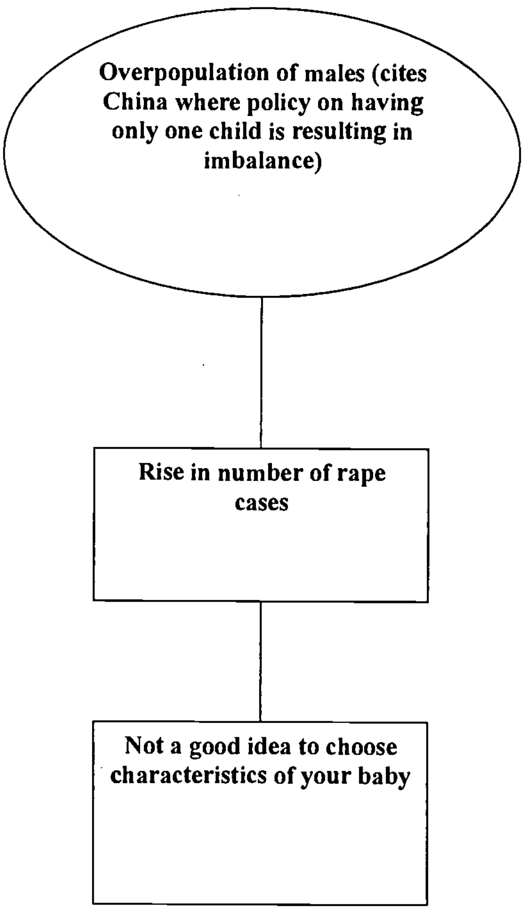


**Figure 3:** Sequence of statements including evidence

Three students did not produce an argument. Two of these contained assertions only, e.g. 'it is wrong', and one was incoherent. Arguments were configured in the following categories:

- two statements containing the minimal ingredients, e.g. 'It's wrong because parents don't have the right to decide';
- a line of supporting statements resulting in a conclusion, e.g. 'this should not be allowed because history has shown that messing with Nature invites the wrath of God' (another example is given in figure 1);
- more than one line of supporting statements resulting in a conclusion, e.g. 'It is wrong, inhuman. Imagine if everyone wanted a child of one sex there would be an imbalance of males to females.' (another example is given in figure 2)
- interconnected lines of supporting statements resulting in a conclusion e.g. 'It's wrong. A baby is not a fashion accessory. These decisions should not be based on opinion or subjective choice'.;
- statements based on refutable evidence resulting in a conclusion (figure 3)

Only two students based their arguments on evidence that was refutable. Both were based on reports that birth control policy in China has resulted in a sex imbalance, one of the students suggesting that this has led to a rise in the incidence of rape cases. Characteristics of societies with dramatic sex imbalances are marriage at an early age for women, emphasis on female chastity and women regarded as inferior in terms of power. (Guttentag and Secord 1983) These characteristics do not include rape, and appear to be characteristic of societies where there is no apparent sex imbalance, but the point is that the arguments proposed by the students can be tested, possibly with recourse to the literature. The rest of the students had often used arguments based on metaphysical beliefs but without empirical evidence that could be refuted. The arguments can be divided into three main categories, with examples, as follows:

| Type of statement | Examples of statements |
|---|---|
| **Arguing towards consequences** | |
| Unpredictability | Who knows what the long term effects would be, physically, mentally, emotionally |
| Slippery slope | In the end parents would be choosing what babies should think |
| Measurable consequences, e.g sex imbalance | It would lead to many more boys than girls, like in China |
| **Arguing through a values position** | |
| Social justice/image of society | This technology would only be for the rich |
| Nature/God | I believe in God and we should be grateful for what God gives us/ and it goes against Nature |
| Cosmetic | Having a baby isn't like choosing whether to have chocolate sauce on a vanilla ice cream |
| Love for baby | We should love the baby for what it is |
| **Arguing from rights** | |
| Parents' rights | It shouldn't just be up to the parents to decide |
| Rights of the embryo (potential child) | Wasting the life of the child that might have been/no one asked the embryo what it wanted |

## Discussion

I have attempted to create a typology of pupils' ethical perspectives and therefore how these might be anticipated and addressed in the classroom. It should also be noted that where students made interconnected statements they frequently used more than one type of ethical statement. Arguing towards consequences was popular among students' written responses. These arguments resonate with Warnock's claim that there must be 'some limits beyond which people must not be allowed to go' (Warnock 1985).Discovering these limits, however, and deciding their ethical status are further problems. Risk assessment would be deemed integral to determining these limits but risk was not mentioned by the students. As Wynne has pointed out there is less popular resistance to new technologies when the outcomes are both predictable and familiar, even though the risks may be higher than those with less predictable and familiar outcomes (Wynne 2001). Public perceptions may thus have a role in ethical decision-making.

Students often used the 'slippery slope' argument without avoiding 'black-or-white' fallacies. Development of a new technology might make the possibility of controlling minds more real, for example, but it does not follow that the predicted consequence will be enacted. Arguing toward consequences is essentially a utilitarian argument involving the equality of interests (Singer 1979). Benefits have to be weighed against possible harm done, but students seem to consider the harm without assessing the benefits although this may be the result of a research fault in the way the question was presented.

Metaphysical assertions are common, referring to belief in God or the danger of disturbing Nature where God and Nature were broadly treated as equivalent. No students justified this deontological position. For example, interference with Nature in the development of medicines for curing diseases could be invoked as a permissible intervention to underpin the grounds on which genetic selection might or might not be allowed. But belief in a Deity or Nature was used more as a mantra than as a justification.

## Teacher-student dialogue

Learning takes place in the context of the classroom and is mediated by both the teacher's and students' implicit understanding of the ground rules of educational discourse (Edwards and Mercer 1987). Beyond the ostensible confines of talk are the beliefs and shared understandings that both teacher and students bring to the classroom. Edwards and Mercer have produced a list of discursive devices that typify classroom discourse and the aim of this preliminary interpretive study is to capture and to problematise the nature of the interactions between teacher and student.

In session 3 the teacher concentrated on teaching aspects of ethical dilemmas which contextualised the science previously taught. The analysis is divided into a. The teacher's comments at the beginning of the module; and b. A discussion of a classroom interaction in session 3. Any names mentioned have been changed.

## Analysis and findings

*PRE-MODULE INTERVIEW*

The teacher outlined her hopes and challenges for the topic. It should be 'interesting' and 'enjoyable' and within the SPU course it is the subject 'that gives most scope for debate, where there are really no right answers.' Her objectives were that the students would have the 'confidence to weigh up these issues', to 'improve their discussion skills' and to be 'aware of other opinions so they can freely make up their own minds.'

To achieve these objectives the teacher's strategy was to ensure the students were 'fairly clear' about the science because in issues where there is a 'fuzzy morality you have to grasp quite a bit more science to actually understand what's happening'. Given time constraints in covering the content of the module, the teacher acknowledged there was a potential tension between teaching the substantive science concepts and the time needed for open and reflective discussion of the moral and ethical issues that emerge from ethical dilemmas.

Other problems she felt she would face were that it 'would be easy to go off on a tangent and to be easily sidetracked.' The students were thought to be 'not very good at discussions'.

*TEACHER-STUDENT INTERCHANGES*

Session 3 turned out to be the most interactive session. It was characterised by long tracts of teacher talk interspersed with interventions from students, and from one student in particular. During the first hour of the session the teacher asked one closed question but there were a series of questions, clarifications and counter-arguments from students. One of these exchanges is discussed.

*TABLE 1*

| Context | Exchange | Code | Researcher thoughts | Teacher reflections from interview |
|---|---|---|---|---|
| The teacher has discussed a couple where the mother is considering having an amniocentesis to test for Down's Syndrome and is mapping a scheme on the whiteboard to identify the consequences of taking different decisions. Directly before this interchange the student asks how an amniocentesis is carried out and how the test can precipitate a miscarriage. | S: So why doesn't it happen all the time then?<br>T: Because you don't poke around inside the womb all the time.<br>S: What I mean is it's one in one hundred (chance of miscarriage). Everytime they do that test, it's one in a hundred.<br>T: Yes. That's right. Well it probably depends . .some pregnancies are more . some people seem to hold their pregnancies better than others, may be it depends on the skill of the surgeon who's doing the procedure, I honestly don't know. Most biological things are like that, aren't they, there's a random finite chance of one thing happening or the other, it's not absolute. Most biological things are like that.<br>S: Yes, but not with the same severity.<br>T: You know if there's flu going around in this room will half of us catch it and the other half won't?<br>S: Yes but if we catch it we're not going to die, are we?<br>T: No. But that's not the issue, we might do.<br>S: Of course it is. Obviously it's more important if someone's going to die than someone's going to catch a cold, do you know what I mean?<br>T: Yes it is. But the question of why is not one we can answer, it's biological randomness, things are all different, and the reason we're all different is partly genetic, of course. Right. So if she does have the test . . . | Spontaneous contribution from student. | A sense of growing irritation between teacher and student. His contribution interrupts her purpose of listing the possible consequences on the board. | ' there's an element of showoffness"you do need to move the lesson forward a bit."It is difficult if someone takes a fundamental Islamic position as he does. I felt it was a discussion the others wouldn't have responded to at that point. |

The student queries the consequentialist position presented by the teacher. Having an amniocentesis involves risk of a miscarriage but teacher and student interpret the concept of risk in different ways. To the student any risk is unacceptable if it endangers the life of the foetus; in the teacher's presentation the risk of miscarriage is but one factor to take into account when making a decision. Understanding the concept of risk is not a problem for the student, it is the moral framework within which he treats the nature of risk that creates the difference between his argument and the teacher's. The student's ethics are predicated on a religious basis (in this case stemming from his Islamic beliefs) so he makes a very clear distinction between 'natural' miscarriages as being due to the will of God and miscarriages resulting from human intervention as wrong. In a later group discussion on the consequences of testing for Down's Syndrome the student outlines his position at the beginning of the activity: 'From my Islamic beliefs . . . we're told that God gives us tests in different ways, yeah? If we see any little problem that we're running away from then we're not standing up to that test, even if we don't understand things now.' Differences between teacher and student in this interchange reach an impasse with the teacher affirming 'that's not the issue' and the student countering 'Of course it is'. The teacher shortly continues her narrative with a rhetorical flourish 'Right'.

Edwards and Mercer have characterised the basic I-R-F structure in classroom teaching as a commonality of all patterns of classroom discourse; there is an Initiation by the teacher, a Response by the student and Feedback by the teacher. The IRF framework can be extended, as this section of classroom exchange illustrates, to student assertion with a follow up by the teacher (Martins, Mortimer et al. 2001). Misunderstanding generated through the student's intervention appears to be more than a breakdown in shared understanding of the implicit rules of classroom discourse. Negotiating beliefs in ethical perspectives constitutes a more formidable challenge to the teacher, as these are balanced against the content knowledge to be taught and the inclusion of all the class in the discussion. The intervention is problematically dismissed as 'showoffness' and the difficulties in discussing a fundamentalist position.

## Discussion

While this paper cannot generalise from an exploratory study it is clear that teaching social and ethical issues in science contexts raises difficult problems for the teacher in managing discussion and in anticipating the kinds of questions raised by students. An analysis of the patterns of the types of ethical arguments that students use will at least help the teacher to anticipate students' concerns and prepare arguments that will challenge and clarify their thinking. Further research will need to explore whether students use similar ethical arguments in other contexts. It also reveals that the level of content knowledge needed to discuss these issues appears to be low but this may depend on the context of the discussion, the type of ethical question asked and whether the discussion is targeted at matters of policy or areas of private morality.

Analytic frameworks such as Edwards and Mercer and Toulmin (Toulmin 1964) do not appear to be suitable techniques to analyse dialogue in relation to ethical dilemmas between teacher and student. Several themes have emerged from analysis of the lesson transcripts involving classroom exchange and teacher interviews, 'control of discussion', 'teacher-student difference in belief systems', 'distinct classroom discourse between science and ethics'. The challenges identified by the teacher in 'control of discussion' are consistent with those found in the *Valuable Lessons* report.

'I remember that there was something about genetics that came up, looking at animal testing. At the end of the video a couple of kids picked up on it and there was a debate and I wasn't really involved. One child spoke vehemently against testing for cosmetics. And these sort of issues are raised in an uncontrolled way and that's part of the problem and can catch people unawares.' (Science Teacher, School A) (Levinson and Turner 2001)

It is a different proposition to manage I-R-F patterns of classroom talk of substantive science concepts compared with the ethical issues raised by students. Scott, for example, has reviewed studies of classroom discourse in science (Scott 1998), but these studies rarely transcend science concepts and procedures. As we have seen, broaching ethical issues can have an effect on the teacher's authority, which changes the power relationships and subsequently the nature of the classroom discourse. Edwards and Mercer's categories are drawn from studies with younger children. There needs to be a broader description of the cognitive and affective domains that a teacher has to contend with in a discussion of ethical issues in a science context. These domains have been shown to include:

- substantive science concepts: e.g. 'gene', 'carrier', 'chromosome';
- nature of science: e.g. 'reductionist', 'susceptible to values', 'uncertain/certain knowledge'
- technological concepts, (know-how): e.g. procedures of an amniocentesis
- procedural concepts: e.g. 'probability', 'risk', 'screening';
- ethical concepts: 'religious beliefs' (teleological); 'acting according to strict moral principles' (deontological); 'appraising and balancing consequences' (consequentialist/utilitarian);
- feelings and emotions, sensibilities: how you and a partner might feel about being a carrier; 'killing a baby', relationships within the family;
- contextual factors: students' and teachers' beliefs and attitudes shaped by their own personal experiences.

Further research will explore how these domains manifest themselves in other types of argument and whether there is scope to provide a more general framework.

It is demanding a lot from science teachers to address the ethical aspects of contemporary science issues: few teachers, whatever their specialism, can handle this area with much confidence or experience. This is not due to any inadequacy on the part of the teachers but to the complexity of the issues. These new technologies are loaded with imponderables: assessing risk, the complex nature of the scientific process (how much can teachers know whether experiments have been carried out with proper controls in place; the different assessments of the developing technology); changes in both the nature of the ethical and legal processes as the technology develops. These are difficult tasks for government appointed committees staffed by experts, let alone teachers who have pastoral, administrative and academic duties, and a varied curriculum over which they cannot possibly have full up-to-date knowledge all the time. As we have seen the teacher has to work across domains and deal with different forms of enquiry. Translating the aims of incorporating ethical issues in science to the micro-processes of teaching in the classroom is deeply problematic.

## References

Beardsley, M. (1975). Thinking Straight. New Jersey, Prentice-Hall Inc.

Edwards, D. and N. Mercer (1987). Common Knowledge. London and New York, Routledge.

Glover, J. (2001). Future People, Disability and Screening. Bioethics. J. Harris. Oxford, Oxford University Press: 429-444.

Guttentag, M. and P. Secord (1983). Too many women? The sex ratio question. Beverley Hills, Sage Publications.

Lemke, J. (1989). Using language in the classroom. Oxford, Oxford University Press.

Levinson, R. and S. Turner (2001). Valuable lessons. London, The Wellcome Trust.

Martins, I., E. Mortimer, et al. (2001). Rhetoric and Science Education. Research in Science Education - Past, Present and Future. H. Behrendt, H. Dahncke, R. Duitet al, Kluwer Academic Publishers.

Newton, P., R. Driver, et al. (1999). "The place of argumentation in the pedagogy of school science." International Journal of Science Education 21(5): 553-576.

Singer, P. (1979). Practical Ethics. Cambridge, Cambridge University Press.

Toulmin, S. (1964). The Uses of Argument. Cambridge, Cambridge University Press.

Warnock, M. (1985). A question of life. Oxford, Blackwell.

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# KORMILDA SCIENCE PROJECT
# A SECONDARY EARTH SCIENCE COURSE WITH AN INDIGENOUS PERSPECTIVE

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**Abstract**

The Kormilda Science Project provides a semester length unit of work of core curriculum science for years nine and ten. The main aims are, concurrently, to impart core curriculum scientific skills and knowledge whilst providing an improved understanding of Australian Aboriginal culture. The Project's central thrust is the delivery of core secondary-level science content, integrated within an Aboriginal cultural and community context. The indigenous context has been drawn from three diverse Aboriginal countries. The science content has been selected to comply with both the Australian National Science Curriculum guidelines and the state of Victoria's Curriculum Standards Framework 2 (CSFII). The aspects of Aboriginality involve material of a contemporary nature and relate to examples of oral history that provide a traditional creation account pertaining to natural landscape features; traditional art-forms and their interpretation, and traditional engineering practices relating to land and water features. An essential key component of the Project has been the ongoing active collaboration with the respective elders and traditional owners from each of the three Aboriginal countries involved.

**The Project's Inception**

The Kormilda Science Project evolved from a year-long science teaching position at Kormilda College (Darwin, Northern Territory), in 1992. My allotment included a year nine class composed of Aboriginal students who were drawn mainly from traditional communities located across the Northern Territory. For the majority of these children English was their second language.

**Precedents For The Project**

During the initial development phase, 1992 – 1993, precedents for similar for cross-cultural science curriculum were actively sought from the literature. There was very little available, particularly so for the secondary science curriculum. Hence in a very real sense the Kormilda Science Project has pioneered this field. In more recent times the underlying concept of the Project found support in innovative educational theories and processes such as collateral learning (Jegede 1995) and the concept of cultural boarder crossing (Aikenhead 1996). Such theories provide a measure of reassurance that the Kormilda Science Project (KSP) may well assist in addressing the educational needs of Australia's Aboriginal youth.

**The Project's Broad Aim**

The Project's broad aim was the development to publishing level, of a stand-alone, semester-length unit of earth science appropriate for years nine or ten. The innovative and central strategy of the KSP is that the science content is immersed within an Aboriginal community cultural context. The Aboriginal aspects of the KSP involve cultural material of contemporary nature as it pertains to Aboriginal oral history representative of traditional creation accounts. These accounts are presented for the students as expressed in both the local language and their English translation, and also in the local traditional art style together with their interpretation.

**Specific Intents And Aims**

The intention behind the KSP was to produce a resource package that:

- Provides for a cross-age, cross-cultural science unit that meets the curriculum requirements as specified within the "Earth and Space" strand of both the Australian National Curriculum Profile and the state of Victoria's Curriculum and Standards Framework II.

- Serves as a readily accessible indigenous en-cultured science resource for secondary and post-primary schools providing a curriculum that complies with the appropriate national or state guidelines.
- Encourages group work within a cross-age and mixed ability educational setting.
- Is cross-curricula, to the extent that significant amounts of the content, skills and processes are readily identified with the social sciences, such as Victoria's key learning area (KLA) "Studies of Society and Environment" strands "Place and Space", "Culture", "Resources" and "Natural and Social Systems".
- Attempts to provide students with a holistic perspective on Aboriginal culture community.

There are two specific aims are to:

1. equip students with the scientific skills and knowledge as they apply to the western world view.
2. encourage students to adopt two ways of viewing Australia's landscape and its creation. One through the influence of Aboriginal culture that provides a subtle and uniquely Australian perspective. And the second, while no less valuable, that is distinctly qualitative, analytical and universal in nature.

**Kormilda Science Project - Australia map**

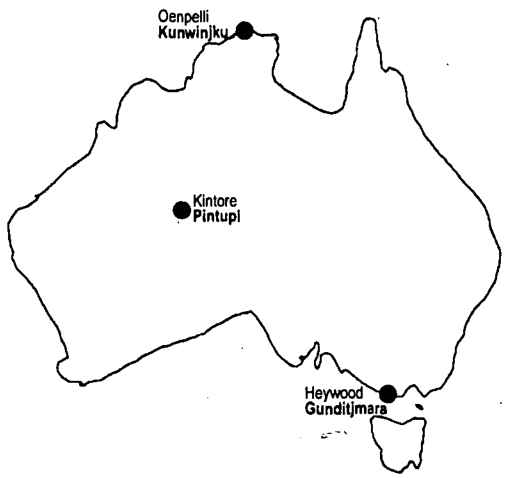



**Fig.1**: The Aboriginal communities involved with the KSP.

### The Support Team – Who And What Were Involved?

To facilitate the research and development behind the KSP net-works of support people drawn from both Aboriginal and the wider community, had to be established in both the north and south of the Northern Territory, and in Victoria. A vital, key factor behind the success of the KSP was the high level of on-going and effective collaboration with the respective traditional owners and elders from each of Kunbarllanjnja (Oenpelli), N.T., Walungurru (Kintore), N.T, and Heywood, Victoria. It was only through the exacting process of cooperation and the shared understanding of co-ownership of the KSP with the Aboriginal communities that the necessary depth, accuracy, sensitivity and accountability of the Project materials was achieved. Figure 1 indicates the location of each community together with their respective tribal name. The distance between Heywood in southern Victoria and Oenpelli in the "Top End" is more than 3000 kilometres, making the field work a logistical and financial nightmare.

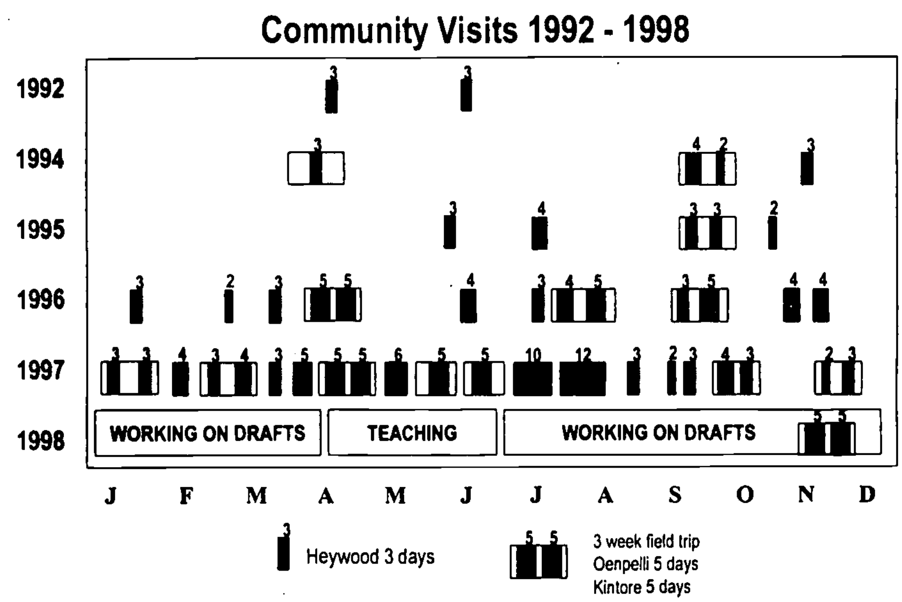
Aside from the three communities, there are a further forty people who have donated their time and expertise in a particular scientific, technological or cultural field, to the KSP. This group have been drawn from a variety of fields, groups and authorities representing government, church, university and private consultancy groups. All of these individuals, many of whom lead extremely busy lives, have without exception been very generous and gracious with their time and expertise towards the completion of various components of the Project. Some of the groups and agencies represented from the Northern Territory include the Parks and Wildlife Service, The

Department of Minerals and Energy, The Northern Territory University, Church Mission Society, Education Department and the Fink River Mission. From Victoria were the Universities of Melbourne, Monash and Deakin, Department of Aboriginal Affairs (Heritage Branch), Department of Natural Resources and Environment, Geological Survey of Victoria, Melbourne Museum and Library, Winda-Mara Aboriginal Corporation and the Department of Education. Of vital importance has been the generous financial and technical support provided by Rio Tinto.

An extremely important level of support during the final stages of development was provided by each of the eight secondary colleges who conducted trials of separate sections of the final draft. The schools were Kormilda College, Darwin; Saint Phillips, Alice Springs; and from Victoria, Emmanuel College, Warrnambool; Billanook College, Lilydale; Bairnsdale Secondary; Echuca Secondary; Heywood Secondary and Northlands Secondary. Two workshops, involving science teachers who were likely to be involved with conducting trials of the materials, were conducted to provide feedback on early drafts.

**The Stages Of Development**

The Project has evolved over a seven-year period. The actual time spent on field research in the communities is indicated in figure 2:




The Project has evolved through several key developmental stages –

A. Initial Contact with the Aboriginal Communities:
   a. Kunbarllanjnja – April 1992
   b. Walungurru – September 1994
   c. Heywood – November 1994
B. Preliminary field work in communities to establish working relationships with the key elders, building rapport, establishing networks in wider communities, connecting with the cultural environment. 1994 - 1995
C. Conducting the field work, researching, collecting and documenting the data. 1995 - 1998
D. Production of the first level of drafts, followed by a review process involving the elders and traditional owners in each community, and the various consultants and experts from the wider community. The feedback determined the future direction of the drafts, and improved focusing of the content. 1996 - 1997
E. Production of the second stage of the drafts with further feedback sought from the communities and western consultants. Review workshops were held with science teachers who had some level of experience with Aboriginal students, to further fine tune materials. Darwin: June 1997; Portland: September 1997 Production of Third Draft: December 1997 – 1998
F. Limited trials conducted in three secondary colleges term 4 (October – November) 1998.

G. Fourth Stage of Draft which incorporated advice and information received from consultant and peer reviews, and the feedback from trials in schools. November 1998 – February 1999.
H. Conducted extensive trials of materials in several secondary colleges from both Victoria and the Northern Territory. Schools were representative of state, Catholic and Private school systems.
I. Commenced preparation of a teachers' guide in response to repeated requests based in part from feedback from the trials. November 1999
Final draft completed – commence searching for a publisher. 2000 .

**The Science Content And Cross-Faculty Nature Of The Project**
The science content essentially focuses on the requirements of the CSFII substrand, "The Changing Earth", at level six. This corresponds to years nine and ten in Australian schools, with a majority of students between the ages of 14 and 16 years. The science content will help to provide students with the prerequisite skills and knowledge sufficient to pursue science studies at higher secondary and hopefully tertiary levels. Typical earth science topics such as landforms, rocktypes and minerals, weathering and erosional processes, soil types and their properties. To help develop a more comprehensive western world view of the three Aboriginal countries, relevant topics in chemistry, physics and biology are included. Hence from a western science point of view, the science content runs decidely across all fields.

Further, and in keeping with the holistic nature of traditional Aboriginal educational practises, the KSP materials are purposely cross-curricula, to the extent that significant proportions of the content and processes are readily identified with the social sciences i.e. geography, social studies and history. It is perhaps worth our while to consider parameters, other than key learning areas and curriculum profiles, with which to measure the intrinsic value of cross-cultural curriculum project materials such as the KSP. The kunwinjku people from Kunbarllanjnja recognised the reconciliatory value of the materials. Several of the elders described the Project in terms of "bridging black and white" and "bringing us all under one umbrella."

**Publishing – A Problematic Issue**
Ninnes (1999) provides a very comprehensive and compelling overview of the need to rethink science education, Among other aspects he provides a comparative analysis of the extent to which Australian and Canadian science textbooks represent indigenous knowledges and identities, and specifically the need to address various problems associated with the way in which indigenous culture and knowledge is represented in standard science texts. These problems remain unresolved. Perhaps the Kormilda Science Project will help address some of these issues.

To-date, December of 2001, there has been no interest expressed by any one of the eight major educational publishers approached in Australia. The general response has been one of interest but their opinion is that because the KSP does not directly address the core curriculum it is not seen as being commercially viable. It appears the Kormilda Science Project may be too far ahead of the times.

Efforts are now underway to secure funding to publish the Project.

**An Example Of The Content Development Drawn From The Kunbarllanjnja Community**
During a five year period, 1994 – 1998, field work and the associated consultative processes continued in and around the Kunbarllanjnja community. The local Kunwinjku people have, as part of their traditional world-view, what is known as the Duruk Djang, or Two Dog Dreaming. This oral history account describes the passage and ensuring adventures of two dogs, Omwal and Adjumalarl (sister and brother). As these two dogs travel across the local floodplains and escarpment country, they create several landforms. The student materials presents thia account in two versions: one in the local Kunwinjku language and the second in English. The intention here is to better enable the students to appreciate primary source of this unique piece of oral history. The passage also highlights the high degree of repetition and other strategies used in the oral tradition to help the listener remember the details. Also provided are the more subtle social values inherent in the account. Students are able to appreciate that Dreaming accounts are multi layered in meaning.

To complement this traditional version of the creation of local natural features, students are also given the western science interpretation of the same natural features, including waterfalls, springs, waterholes and rock formations. Other supporting aspects of science included in this section are crustal faulting, soil types, plant communities, sedimentary rock types and their formation, differential erosion and the chemistry of ochres.

The section on soils is developed around the five different soil types, and their accompanying plant communities, found along the creation path taken by Omwal and Adjumalarl. The section on ochres and their chemistry is developed in the context of the magnificent collection of x-ray style rock art, located on the hill, Injalak, close by the town of Oenpelli.

A similar approach is used with the other two countries and cultures involved in the Project – the Gunditjmara people around Lake Condah in the Western Districts of Victoria, and the Pintupi people centred around Walungurru in Central Australai. These two areas were identified and chosen because of their very different geological (western) origins of the landscape, a volcanic igneous and plutonic igneous respectively.

## References

Jegede, O. (1995 Collateral learning and the eco-cultural paradigm in science and mathematics education in Africa. Studies in Science Education, 25, 97 – 137

Aikenhead, G.S. (1996) Science Education: Border crossings into the subculture of science. Studies in Science Education, 27, 1 – 52

Ninnes, P. (1999) Representations of Indigenous Knowledges in science textbooks in Canada and Australia, Paper presented at the Annual Conference of the Comparative and International Education Society, Toronto, Canada, 14 – 18 April 1999.

**Key-words:** indigenous context, cross cultural science curriculum, collateral learning, cultural boarder crossings, community involvement, cross-curricula development, reconciliation.

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# CHALLENGES IN THE DEVELOPMENT OF NA INVESTIGATION-ACTION PROGRAM IN THE INITIAL FORMATION OF PHYSICS TEACHERS

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## Abstract

Our aim is to reflect on an educational investigation-action program for the initial formation of Physics educators, centered on the possibilities of creating *networks of critical communities*, committed to the classroom. We discuss, particularly, a project that has been developed in the Physics teacher formation course of the State University of Ponta Grossa/PR- Brazil, in the discipline of methodology and Practice of Teaching. For the development of this educational investigation-action we have used Freirean categories, in order to think the school culture over, not only directed towards cultural transmission, but specially towards its production. In initial teacher formation, beyond leading them to incorporate this investigation project in practice, the greatest challenge is its constructive consolidation in the exercise of teaching and of citizenship. We aim at emphasizing the collaborative construction of the practices and the knowledge they guide. For this reason we have adopted a concept of Physics teacher formation based on the investigation of their own educational practices, as a research program. There are difficulties in the elaboration of projects. Some challenges to be faced. If the project is part of the teacher's formation, we must face and overcome the obstacles. This is also a way of sharing and creating conditions for dialogue, without concealing our limitations.

## Introduction and Context

Many are aware of the situation in which Natural Science Education[1] is found, concerning its frail processes and results, the appropriation of scientific knowledge and construction of active citizenship, by all those involved in the learning process, on all levels of schooling. A plausible hypothesis for the extension of this problem in Brazil, as well as many other countries with a distinct culture and history, is the initial teacher formation, and this is reflected on the kind of *educational activities* proposed in the classroom. Another hypothesis may be the chaos in which the educational system as a whole is found, where the traditional lives side-by-side with innovative proposals, originated even in official agencies such as the Curriculum Parameters and Guidelines (PDC).

Based on these appointments, we present a work, which has been conducted since 1993, and developed systematically from 1997 on, with an investigation-action group elaborating, implementing and assessing educational programs, in the sphere of methodology and practice of natural science teaching (Physics). The thematic concern is the transformation of the educational practice within a dialogical problematization perspective. We intend to actuate on the formal school scenery in a collaborative manner, implementing the investigation-action, to point out possible orientation in teacher formation policies.

One must extend the *reflexive process* (Mion, 1996), towards *networks of critical communities* of educational active investigators, in initial teacher formation. This implies, also, in continued formation, within the framework of a scientific investigation program. One must conceive the *reflexive process* as a means to make the formation of the active investigator possible, empowering him/her before the knowledge that is exchanged and produced in school education. As teachers in all levels of teaching we have reasons to state that the changes only occur with active participation of the teachers, willing to reconstruct their own practice. This conception of work implies in the education worker **being more** (Freire, 1987).

This is an investigation-action program, in which there is a collective project to guide the subject and personal projects, constructed collaboratively by the participants, in order to elaborate, develop and assess their educational proposals in Physics. The development of the project occurs in Methodology and Practice of

Teaching classes along the 4th and 5th years of the course. In the 4th year the students research the theoretical and practical background for their classes, and in the 5th year they elaborate their personal projects, implementing and assessing them, and thus constructing their own Physics educational proposal.

The project seeks, furthermore, to materialize the connection between teaching, research and extended activities. In teaching, it involves the initial formation of teachers in the physics teacher preparation courses, as part of their professional training. In research, it allows them to carry out the project of Teaching Methodology and Practice as an investigation-action program, on one hand, and on the other, it allows every one of them to elaborate, implement and assess their own scientific initiation program, constructing at the same time a proposal for the development of an educational experience in Physics- the internship. It is important to emphasize that these actions are supported by more than investigation, it is '.the thinking of the practice, and thinking the practice is the best way to think right.' (Freire, 1982:10). The extended activities are characterized by the implementation of these projects in elementary and secondary schools in the region. The Physics students, who develop and assess their own Physics teaching proposal, then take the constructed proposal to the classroom.

## Our Theoretical and Practical Guidelines

The greatest subside to this proposal, and which structures the investigation program, is contained in the functions of the Critical Social Theory (Habermas, 1987): 1) its theoretical elements; 2) organization of the illustration process by means of project development; 3) organization of action. By adopting as an educational conception the dialogical problematization perspective (Freire, 1987 and 1997), and, as a research concept, the critical-active educational investigation-action, we addressed the core of the proposal: *the method of conscientization* in Freire, and the exponential self-reflective cycle spiral (Levin, 1978), re-elaborated in educational investigation-action, of an emancipating matrix (Carr and Kemmis, 1988).

From then on we have added the concept of scientific literacy, looking for its interpretation and its adequacy to our purposes (Bazin, 1977; DeBastos, 1990 and 1995; Fourez et al., 1977 and Bloomfield, 1997). These authors center on the incorporation of scientific and technological knowledge in the cultural universe of those involved, even if there are differences in the way each one approaches the problem.

The educational proposals in Physics are structured around an epistemological and methodological axis in which technical objects are investigated and transformed into generative equipment. In other words, they obtain an educational and didactic dimension. In order to achieve this, it is necessary to recreate the concept of Freirean generative themes into generative equipment, a work started by Bazin (1977), followed by DeBastos (1990 and 1995), and recently with fertile theoretical and practical approximations, by Bloomfield (1997). Considering the strong restrictions in formal teaching, this is a complex and difficult work.

For the organization of our activities, we used the Pedagogical Moments (Angotti and Delizoicov, 1992a and 1992b), which is a result of a construction focused on natural science teaching, and based on codification, decodification and recodification. Dynamically and evolutionarily speaking, such moments are categorized in: *initial problematization, knowledge organization and application of this knowledge*. Although the third moment, centered on application, may seem to contradict a dialogical problematization perspective, we would like to stress that this application is neither mechanical nor direct; but rather, a return to the problematized questions aided by the light of incorporated theory, in search of a change in the educatees' cosmovision.

Another relevant aspect is the use of an epistemological category known as the *unifying concepts* of the meaningful thematic, in order to avoid excess fragmentation in thematic reduction and in the approach. The cultural gains obtained from the knowledge of science and technology need to be socialized among all the students and this will not occur without the acquisition of *unifying concepts*, the universals (Angotti, 1991 and 1993). This also leads to an emphasis on the relational aspect, on the articulating ability of the concepts, associating constructively to others, seeking the structuring and the ordering of knowledge. What we want, in practice, is to move forward regarding the complexity of Natural Science teaching, attempting to articulate scientific knowledge, technological processes and products and the most evident social relations among them.

The unifying concepts, necessarily supra-disciplinary, are: 1)transformation: of the living and non-living matter, in space and time. 2) Regularity: grouping transformation according to rules, similarities, open or closed loops, repetition or conservation in space and time.3)Energy: concept that encompasses the previous one, but attains a higher level of abstraction and permitting its expression in mathematical language; it is also associated with positive or null variation of entropy in closed systems. 4)Scales: frame studied events in their most distinct dimensions; ergonometric, macro or microscopic, of normal, instant or remote duration, and using the three previous concepts, the use of 'energy ranges', or energetic scales.

In the problematization perspective of Physics knowledge, its limits are discussed also. When unveiling the object, the concepts involved are reorganized by means of *concept maps*, requested for the analysis of recorded data, in collective or individual reflection, as well as for eventual re-planning. In this process the educates undergo a re-elaboration, development and assessment of proposals, reflecting their practices on *critical reflective processes*.

The *reflective process* (Mion 1996) privileges two moments: the individual and the collective ones. On the individual level by self-reflection, and on the collective one, among teachers that elaborate an action plan, and also among the students they teach. The dialogue, among teachers and students, is the connection that validates the investigation process.

We understand that contemplating reflective processes enables us to construct and experience reflective processes around our own educational practices in the school's daily work. The path lies in the spiral of planning, action, observation and reflection for re-planning, thus constructing a 'new' knowledge, better informed and committed to the changes in our reality- educational knowledge, which may become critical knowledge.

According to Angulo (1990:41), 'the development of educational action is attached to the development of the teacher's self understanding', which may reflect on his/her students and on the reality they experience.

The rationality employed here – critical active educational investigation-action- is in tune with communicative action (Habermas, apud Carr and Kemmis, 1988) and with dialogistic (Freire 1987). There are approximations between Habermas' critical educational science and the conscientization process described by Freire (1987), and we find common elements between the concepts of 'educator-educatee' and 'critical active researcher' (DeBastos 1995).

We may understand, then, that the *role of the teacher is to transform an experience lived into an experience understood, thus reaching critical knowledge*. The action itself is the starting point, and once it is understood, we achieve what I call *Freirean study*, where 'studying is, mainly, to think the practice over' (Freire, 1982:11). Once this practice is understood, knowledge will be produced, which will subsidize the indication of a re-planning that may reconstruct this practice and may allow 'different doings' in the following activities.

This subside is the new collaborative knowledge produced in the reflective process, and may be understood as a rational reconstruction. Once the bi-monthly period ends, with at least 8 weeks of work within the schools and in Physics class management- the students start to 'study the practices', with a systematization of the reflective processes, which enables them to achieve a higher leap I knowledge production.

The status of *rational reconstruction* can be attained at the moment the work developed is interpreted and critically analyzed. Looking at the inner history of what happened, I am capable of looking at it from the inside, since I experienced it, thus strengthening the whole process, not as micro-reconstructions done at the end of each cycle, but as another ring in the self-reflective spiral.

So I find myself in a group with many subjects, including me, and each one analyses one's practice. But there are collective moments, when we do Freirean studies within the community of learning. The characteristic of the program has a shared thematic concern, which is the educational practice in Physics. In Lakatos (1979:161), the elements of a series of theories are connected by a *remarkable continuity*, which welds them to research programs. And, according to him, this continuity performs a vital role in the history of science.

In our case, this program is composed of many projects. All the questions of the personal projects, their worries, thematic concerns, derive from the main thematic concern. There must be a connection beyond the dialogue among those involved, which represents the problematization of the educational practices proper.

How can one analyze that? Looking back on History, one looks at the program. We look objectively at the records, and also at what was planned. The objectivity of this rational reconstruction is reached by means of the records and their distance from us. The subjectiveness is our interpretation; looking at what happened and interpreting it. According to Lakatos (1979) each one has an individual 'philosophy'. This means that we have our guiding theories and the idiosyncrasies that guide this interpretation.

The scientific method is of fundamental importance in the conduction of the research. This qualifies the investigation-action as *the* conception of research to address educational practices in the formation of active investigators, and the work with people to form teachers.

It is precisely this scientifically methodological way of objectively and subjectively analyzing that allows the production of new knowledge. The subject is inside, the author and actor of the proposal, teacher and investigator, in the same person. Although these two are not the same thing. When we refer to the program, we refer to the organization of illustration processes, since there is an established scientific method in the moments of planning, action, observation and reflection. In the observation records are collected, and these allow us to do a rational reconstruction, even in a small scale.

In methodology and Practice of Teaching, the *supervising teacher* does not need to watch the intern's classes, but there must be a way to portrait accurately the reality. These are the records. They can be written and are practical and illustrative. There is also mechanical recording, such as audio or videocassette.

The following table is an example of the schedule developed since 1998.

| Action | Description of action | Period |
|---|---|---|
| Present and Analyze | Present and analyze program of the discipline | 1st week of March |
| Elaborate/deliberate/ chose | Construction of the schedule, choice of school and group for internship | March 1999 |
| Construct | Construct pre-projects | March '98 |
| Present | Seminars to present internship projects | Last week of march |
| Reading | Indication of reading | Last week of march |
| Guidance | Guidance for the first field works | April |
| Visitation | Visit the school to make preliminary observation/contextualization | April and May |
| Studying | Read and study a concept of research; educational investigation-action | Last week of April |
| Watch and record | Watch Physics classes in the group chosen, recording contents addressed, syllabus emphasis, methodology, textbook adopted, dialogistic, problematization | May and June |
| Discussion and analysis | Seminars to discuss and analyze what is observed among colleagues and the supervisor | May and June |
| Organize and construct | Organization of the information collected | March thru June |
| Planning | Planning classes for the next semester | July |
| Act and record | Class management in the chosen group, action, followed by recording and observation | July thru October |
| Reflect | Reflection over the recordings, with colleagues and the supervising teacher | July thru October |

| | | |
|---|---|---|
| Re-planning | Re-planning of 2nd week classes, following the spiral above throughout the third bi-monthly period (July, August, September) | July thru September |
| Systematization | Systematization of the reflective process, returning to the school to talk to the students about the classes. | September thru November |
| Elaboration | Elaboration of the internship report | November |
| Writing | Writing the scientific text | November |
| Presentation | Seminars for presenting research reports | Nov/ Dec |

## Challenges in the Construction of the internship practice, based on an educational investigation-action

We have noticed some difficulty when students elaborate their projects, such as the resistance against making records, as well as the lack of perception that the research is a cognitive instrument for professional formation. In our understanding, this is due to distorted conceptions of teaching, research and knowledge production.

The university also sets some bureaucratic barriers that limit the responsibility of the intern for the group. And there is also another challenge: the resistance some teachers offer when they are hired by one school and need to chose another group they do not teach for their internship.

The relationship between student and teacher is another challenge. We have noticed different understandings of what dialogue is, maybe due to the conceptions incorporated in our practices. To establish a dialogue it is necessary to depart from common questions among all of those involved. This may happen in situations of the student's reality. But we have two distinct and at the same time connected situations. The object we have in common, and which we have what to dialogue about, is the educational practice. On the other hand, in Physics teaching, we have a possibility of reaching a dialogue around concepts and practices, that is, through the problematization of concepts and their study in Physics, based on the production and workings of technical artifacts (the fridge, the CD player, and so on), in educational activities aiming at turning them into generative equipment.

Another challenge is, therefore, to lead the teachers into incorporating the need to investigate, redirecting the practice towards the construction of active citizenship. Constructing, in practice, our ideas, from the investigation of our actions, means to plan the changes desired and not merely believe that practice will bring this experience.

The problem that persists in some of our students is a distorted understanding of the internship, seen as a period of 'teaching classes' only, as if it were the most important in the educational act. That is, they take long to understand that this step is the moment of transforming experiences lived into experiences understood. Some students do not seem to understand this intention as a 'method of conscientization'. They have a commonsense understanding in which being dialectic means avoiding conflicts and directness. The 'right of each one to say one's own words' (Freire 1987) may be carried out by means of the proposal, and this in turn leads to active citizenship.

One must see the contradictions in practice. One of the intentions of this proposal is to lead the students to notice that they have the capacity for self-change, that is, act differently when it comes to one's own educational practices. People must in the first instance understand what they are doing, even if they decide not to act different later.

## Conclusion

We would like to conclude with two relevant aspects:

The fact that the students started to look for *strictu-sensu* courses on education is the first positive sign we noticed. For a Physics Teacher Formation course, this means a contribution to the rescue of the student's self-esteem. Until then, none of the students who graduated had entered a Post-Graduation course in Education. The Physicist was the only one who could be entitled a researcher for them. We think the merit belongs to this work, whose intention is to change the conception of teacher formation.

As a second improvement, it can be remarked that the students who graduate return to the university and engage collaboratively in the project, seeking to continue their formation. One could infer that this is the result of their understanding of the importance of a research project. It is the link they needed to establish new interlocutions, and as a consequence, the institutionalization of their personal projects in Post Graduation Programs in Education. This, in our view, is another clue to the institutionalization of the teacher initial formation as a research program.

## References


ANDERSON, S. e BAZIN, M. **Ciência e (in)dependência.** Livros Horizonte, Lisboa, 1977 (2 volumes).

ANGOTTI, José André Peres. **Conceitos Unificadores e Ensino de Física.** Revista Brasileira de Ensino de Física. Vol. 15, ns (1 a 4), 1993.

ANGOTTI, José André Peres. **Fragmentos e Totalidades no Ensino de Ciências.** Tese de Doutoramento, FEUSP, 1991.

ANGOTTI, J.A.P. e DELIZOICOV, D.N. **Metodologia do Ensino de Ciências.** Cortez, São Paulo, 1992a.

ANGOTTI, J.A.P. e DELIZOICOV, D.N. **Física.** Cortez. São Paulo, 1992b.

ÂNGULO, J. F. (1990). "**Investigación-acción y Curriculum**: una nueva perspectiva en la investigación educativa". Investigación en la Escuela, n. 11, p. 39-49.

_______. **Hacia una nueva racionalidade educativa**: la enseñanza como práctica. Investigación en la Escuela, n. 7, p. 23-36.

ATAS das IV, V, VI e VII Escolas de Verão de Investigação-Ação Educacional. Santa Maria/RS-Brasil 1998, 1999 e 2000; Ponta Grossa/PR-Brasil em 2001.

BAZIN, Maurice. **Ciência na Cultura? Uma Práxis de Educação em Ciências e Matemática: Oficina Participativa.** 1999. (mauriceb@exploratorium.edu).

BLOOMFIELD, Louis A. **HOW THINGS WORK: The Physics of Everyday Life.** J,Wiley, USA. 1997.

CARR, W. e KEMMIS, S. **Teoria crítica de la enseñanza**: investigación-acción en la Formación del Profesorado. Martinez Roca, Barcelona, 1988.

CARR W. **Cambio educativo y desarrollo profesional**. Investigación en la Escuela, n. 11, p. 3-11, 1990.

_______. **What is an Educational Practice?** Journal of Philosophy of Education, v. 21, n. 2 : 163-175, 1987.

CHALMERS, A. F. **O que é ciência afinal?** São Paulo, Brasiliense, 1993.

DE BASTOS, F. P. **Alfabetização Técnica na disciplina de Física**: uma experiência educacional dialógica. Dissertação de Mestrado, UFSC/CED, 1990.

_______. **Pesquisa-ação emancipatória e prática educacional dialógica em ciências naturais**. Tese de Doutorado, FEUSP, 1995.

FOUREZ, Gérard et al. **Alfabetización Científica y Tecnológica: acerca de las finalidades de la enseñanza de las ciencias**. Ediciones Colihue S.R.L. Buenos Aires, Argentina 1997.

FREIRE, P. **Pedagogia do Oprimido**. Rio de Janeiro: Paz e Terra, 1987.

_______. **Pedagogia da Autonomia**. Rio de janeiro: Paz e Terra, 1997.

_______. **Educação como prática da liberdade.** Rio de Janeiro : Paz e Terra, 1989.

_______. **Ação cultural para a liberdade.** 8. ed. Rio de janeiro : Paz e Terra, 1982.

HABERMAS, Jürgen. **Conhecimento e Interesse.** Rio de Janeiro, Guanabara,1987.

HABERMAS, Jürgen. ***Teoria y práxis.*** *Madrid.* Tecnos, 1987.

KEMMIS, S. **La formación del profesor y la creación y extensión de comunidades críticas de profesores**. Investigación en la Escuela N.

KEMMIS, S. e MCTAGGART, R. **Como planificar la Investigación-acción**. Laertes, Barcelona, 1988.

LAKATOS, Imre. **História da Ciência e suas Reconstruções Racionais**. *E*dições 70. Lisboa/Portugal.

LAKATOS, Imre. **Falsificação e Metodologia dos Programas de Investigação Científica**. Edições 70. Lisboa. Portugal.

LAKATOS, I. O falseamento e a metodologia dos programas de pesquisa científica. In: LAKATOS, I e MUSGRAVE, A. (orgs.). **A crítica e o desenvolvimento do conhecimento**. São Paulo: Cultrix, 1979.

LAKATOS, I. e MUSGRAVE, A. (orgs.). **A Crítica e o Desenvolvimento do Conhecimento.** São Paulo, EDUSP/Cultrix, 1976.

MENEZES, L. C. **Formar o Professor Junto com a Escola.** In: ANAIS do VIII ENDIPE. vol. 2. Fpolis-SC. 1996.

MENEZES, L. C. **Vale a pena ser Físico?** São Paulo:Moderna, 1988.

MION, Rejane A . **Processo Reflexivo e Pesquisa-ação** : apontamentos sobre uma prática educacional dialógica em Física. Dissertação de Mestrado. PPGE/UFSM-RS, 1996.

MION, Rejane A. e DE BASTOS, Fábio Purificação. **A Investigação-Ação na Formação do Educador.** In: ATAS da IV Escola de Verão de Investigação-Ação Educacional. Santa Maria-RS. 1998.

MION, Rejane A. et al. *Mudando o Trabalho Educativo de Formar Professores de Física.* **PERSPECTIVA**: Revista do Centro de Ciências da Educação. Florianópolis, v18,n.33, p.93-114, jan./jun.2000.

MION, Rejane A. et al. Educação em Física: discutindo ciência, tecnologia e sociedade. ***Revista Ciência & Educação.*** Bauru-SP. Vol.7, n 2, Dezembro, 2001.

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# 062 CREATING A TYPOLOGY FOR UNDERSTANDING EXPERIENTIAL LEARNING FOR SCIENCE AND TECHNOLOGY TEACHERS

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**Abstract**

Experienced teachers are fully aware that motivation to learn and retention increases when instructional content is related to the specific contexts of learner's lives and interests. Based on this belief science and/or technology teachers, for example, strive to understand how young people might more easily grasp concepts like momentum, or electricity. What experiences, they ask, do most young people have in their everyday lives that can be tied to the science and technology curriculum? Other subject teachers have similar interests and structure their classroom learning activities to reflect what their instincts and experience tells them. Standardized school curriculum, meanwhile, is predisposed to conceptualizing, prioritizing, and structuring content based on what society and government thinks is best.

What can we learn from teachers, learning theories, and from our knowledge of schooling, as currently construed in the educational sciences literature? What is an accurate and fair depiction of what teachers go through as they mature in their work? By looking at the role of experience in learning and by describing alternative conceptions of knowledge, a larger 'picture' emerges. That picture is a typology of experiential learning designed to help inform teachers work in school settings.

## Introduction

Psychologists have shown that knowledge can be acquired independent of practical action, by observing and imitating others and by extracting knowledge from experiences coded in text (Buchmann & Schwille, 1983). Critics of this view argue that too much of learning, in schools especially, consists of the vicarious substitution of someone else's experience and knowledge. Yet attention in the literature to critical thinking, constructivist learning, disembodied knowledge, and situated cognition, all notions grounded in experience, seem to favour the view that real learning begins with the experiences of the learner and that behaviourial, cognitive, and social theories of learning should be abandoned for some principle or theory with more explanatory power.

This paper will explore, through a student teacher learning journal exercise, the beliefs beginning teachers hold about how people learn. A review of journal entries from teacher candidates at the Faculty of Education, The University of Western Ontario, suggests there exists a tension between what teachers believe about how people learn and what the university teacher education curriculum espouses. These recently written journal entries will be presented and analyzed using narrative (Connelly and Clandinin, 1990) and life history methodologies (Jones, 1983). What can be learned about the role of experience in learning? What are the implications of an alternative view - a view that values experience as well as school knowledge?

## Laying the Groundwork for Experiential Learning

An effective way to analyze 'experiential learning' is to use a method of analysis used in philosophy. Philosophers would compare and contrast a concept being investigated with something it is not. The one contrasting concept which does hold potential for comparison with experiential learning is learning through study. What does it mean to experience something as opposed to study it? According to the dictionary, to study is to learn or gain knowledge by means of books, observation, or experiment. To experience is to live through something, to act, to do, to suffer the consequences of, to respect, to feel, to internalize something.

It would seem the act of studying could be an aspect of experiencing. Experiencing may involve studying but it is unlikely that studying, by itself, would meet all the criterial for being called experiential learning. Yet studying has a speculative aspect to it which transcends experience in some way. The process speaks to a way of learning or thinking that is unique. It need not be utilitarian to be useful. The purposes for which study is intended determine its utility. Often this is a very personal process. The object of one's study may have no universal appeal at all, but it is still useful to that individual. Study, then, is often contemplative in nature. To experience something, by comparison, is to 'get involved'. Consider the following journal entry from one Julie, a science student teacher.

> *The initial three days of my practicum served as the lucrative basis for the remainder of my 'in-class' experience. It was during these days that I was able to form my very own pedagogical approach based on the methods inherited from my associate teacher (including methods I chose to alter). Because my associate granted me the freedom 'to run' with her class, so to speak, my entire adventure thereafter is one I hold in high esteem. It was this very freedom I valued most. I was encouraged to direct my teaching methodologies in a manner similar to those most appreciated by typical adult learners. My pedagogical stance was oriented towards a more 'life-centred approach. Just as adult learners possess a deep-rooted urge for self-direction so too did the individuals I taught. The instant I put theory into practice I encountered another valuable obstacle. I soon realized that all the academic knowledge I possessed was a futile variable if I could not synthesize and convey it in a relevant, life-centred manner to the group of learners I was facilitating. It quickly became apparent that how an individual fares in the process of learning proved to be most essential in my experiential learning.*

Having speculated about the essential features/characteristics of 'experiential learning', and about teachers who practice or don't practice it, the theoretical groundwork for a typology needs to be laid. The following observations and typology are based on the input of teacher candidates at The University of Western Ontario. To create the typology a class of fifty teacher candidates from the Faculty of Education, The University of Western Ontario were asked to document how the teacher practicum [during four weeks in the schools] constituted experiential learning. Many of these teachers were from the field of technological education where work experience is a requirement for admission to the profession rather than a bachelors degree, or from science education. All students were mature adult learners who had career and life experience to draw upon.

Questions which helped formulate the resulting typology included the following. How is practice teaching experiential? "Practice teaching", stated one student teacher, "has been valuable in my learning and development as a teacher because it puts things into perspective. Discussing classroom management techniques and student behaviour at the Faculty seemed dry and useless until I was able to see and do these things first hand in a secondary school setting. Through the application of this knowledge, I felt like I was really learning". Most students were quick to differentiate between the time they spent at the Faculty taking theory courses versus the time they spent engaging whole classes of students in learning activities. All students agreed that being a spectator or observer was an experience but a less significant one than being in a leadership role. Most agreed that to act in the role of teacher was a multi-dimensional experience. It included emotional, intellectual, and physiological elements that were readily identifiable. Learning at the Faculty, by contrast, was considered a passive exercise in which accountability and performance were governed by institutional norms as well as individual effort.

One participant 'George' [a pseudonym] raised the issue of the schools themselves. After years of underachievement in schools this middle aged technology teacher candidate found meaning in a career of 'organ building'. His reflections about his learning exprieriences are compelling.

*My real learning endeavor was initiation into the world of organ-building. Here at last I was able to use my abilities and eclectic knowledge base to truly extend my abilities and experience [in the building of church organs]. This gave me the opportunity to research material which for me was exciting and new. Learning and developing new methods of accomplishing tasks and making them time and cost efficient became for me the beginnings of a new way of looking at the learning process, and made me acutely aware that most skills are in some way transferable from one discipline to another. This too was a time of great personal accomplishment and realization that I had wasted so much time in school by not making the most of what was offered. Indeed, when I finally re-entered University in pursuit of a BA I was highly motivated and successful"*

The learning environment was identified as an integral aspect of learning, especially how the environment establishes a safe place for emotional diversity. Some students, it was felt, had a strong sense of self, others had a fragile self-esteem. But how were levels or types of experience to be identified in this context, we pondered. Surely, the nature and quality of the experience for the participants in the practice teaching itself was distinctive but general at the same time. How is a typology to be constructed?

The discussions around which consensus was achieved grew more meaningful as the categories of a chart were devised. The result was three classifications of experience: affective, sensory, and cerebral. To distinguish the elements of an experience four categories were developed. They included a) the type of activity, b) the type of involvement, c) the type of personal development associated with the experience, and d) sense of self. (See chart - A Typology for Analyzing an Experience). The last category, sense of self, attempts to identify what Harre and Gillett (1994) describe as having a sense of physical location. These psychologists conclude that discursive learning in schools is actually destructive for many students. It can diminish self-esteem. On the other hand, balancing book studies with practical projects builds self-confidence and emotional maturity. It was thought that these four elements of the typology, as a start, were relatively comprehensive in further delineating what constitutes an 'experience.' [The classifications are not meant to celebrate or diminish any one experience over another. They are meant to distinguish and classify experiences.]

**A TYPOLOGY FOR ANALYZING AN EXPERIENCE**

| Classification of Experience | Nature of Activity | Type of Involvement | Type of Personal Development | Sense of Self |
|---|---|---|---|---|
| affective | social, intuitive | listening, speaking, feeling | emotional | secure/insecure |
| sensory | building competence, practical | acknowledging, doing | perceptual | competent/ incompetent |
| cerebral | accumulation of information, reflection | expressing, imagining, observing, contemplating | conceptual | realism/idealism |

The development of the typology was the result of several attempts to be comprehensive and meaningful in finding terms which everyone could agree upon. Once we had a set of headings that made sense, it was possible to focus on the range of experiences associated with different activities, in this case, based on a four-week practice teaching opportunity.

It was difficult to reach complete consensus on how each member or group of people associated with the practicum classified experiences in the typology. Practicums, after all, are temporary, communicative, and new, rather than permanent and repeatable. Some agreement was achieved, however, suggesting that the typology, at a minimum, is helpful in explicating the elements of 'experiencing' something, in this case classroom teaching. Most agreed, for example, that learning how to be a teacher includes a balance of effective, sensory, and cerebral components.

Reflecting on the usefulness of the chart is an on-going process. Each year students are introduced to the chart and asked to validate it based on their practicum experience. One conclusion we have been able to make is that the intensity and quality, i.e., the magnitude or significance of an 'experience' is difficulty to gauge and is not accounted for in the typology. All conceded that to learn from an experience involved attention to discursive and non-discursive material.

Can these findings be confirmed through other types of field experiences and applied more widely? Time and further testing will help provide the answer to this question. This last year's cohort agreed that the only way to be definitive about whether or not something could be classified as an 'experience' was to determine if each of the three elements, affective, sensory, cerebral, were present. In other words, if there was an absence of any one element, identifying or labelling the experience as meaningful would be problematic. The more elements missing, the less authentic the experience.

**Applying the typology**

The typology represents a beginning only in terms of analyzing what it means to 'experience' something rather than 'study it.' The typology does provide an alternative conception of learning that the social, behavioural, and cognitive conceptions don't include. That conception encompasses active and passive processes, cerebral, emotional, and sensory stimuli. It might best be found in the notion of 'meaning-making' - drawing on discursive and non-discursive learning to create meaning.

If we accept that experiential learning is a significant departure from the learning theories which guide curriculum development in our institutions then the implications are dramatic. The very foundation upon which existing school subjects and adult oriented curriculum are built may be counterproductive in helping people learn. Some argue (Aikenhead, 1994) that school subjects are nothing but abstractions of reality. Recent criticism of the disciplines which form the core of university teaching also indicates a problem. Does our construction of curriculum generally, serve a useful purpose, contemporary or otherwise?

In this context the instutitionalization of learning through schools is worthy of critical examination. What are the latent functions and dysfunctions of schooling? What long term memories associated with schooling form the 'residue' for adults? Lindeman's (1926) classic words, are particularly germane: "Too much of learning consists of vicarious substitution of someone else's experience and knowledge" (p. 6). By looking at the role of experience in learning and by describing alternative conceptions of knowledge, a larger 'picture' emerges. That picture is a typology of experiential learning designed to help inform teachers' work in school settings.

Further research and reflection will determine if a strong sense of self leads to retention and meaning for students. It will also be necessary to consider how it is that experience equals or transcends knowledge, especially as it is packaged in schools. Will the scholarship associated with how people learn ever be reframed so that the educational sciences orientation which currently drives the curriculum development in schools can be examined critically? The premises we hold about human development in school settings need to be questioned and debated. Such a synthesis is an integral, albeit discrete, part of what it means to be educated.

## References

Aikenhead, G. (1994). The social contract of science: Implications for teaching science. In J. Solomon, and G. Aikenhead (Eds.). *STS Education: International perspectives on reform* (pp. 11-20). New York: Teachers College Press.

Buchmann, M. and Schwille, J. (1983, November). Education: The overcoming of experience, *American Journal of Education, 92,* 30-51.

Connelly, F.M. and Clandinin, D.J. ( 1990). Stories of experience and narrative inquiry. *Educational Researcher, 19(5),* 214.

Harre, R. and Gillett, G. (1994). *The discursive mind.* London: Sage Publications.

Jones, G.R. (1983). 'Life history methodology'. In Morgan, G. (Ed.) *Beyond method: Strategies for social research,* Beverly Hills: Sage Productions.

Lindeman, E. (1926). *The meaning of adult education.* Montreal: Harvest House

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# SHAPING TERTIARY SCIENCE AND TECHNOLOGY EDUCATION IN NEW ZEALAND: A RESPONSE TO THE FOURTH TEAC REPORT

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**Abstract**

Since April 2000 the Tertiary Education Advisory Commission has considered how the tertiary education system can contribute to the development of a knowledge society and economy in New Zealand. The contribution of science and technology to this development is widely appreciated. Less appreciated, is the crisis in under-supply of scientists and technologists in both New Zealand and globally. TEAC with the release of its fourth report – Shaping the Funding Framework - has attempted, within an overall tertiary strategy, to address some of the reasons for this under-supply through a variety of measures such as: priority indicators for programmes; proposing caps on funding postgraduate programmes which do not meet a requisite research 'threshold'. While TEAC proposes a significant rethink on the mechanisms for distributing the tertiary education 'cake', it does not appear to have embraced the complexity of the tertiary science and technology education/research environment. This omission has serious implications for tertiary science and technology education. It may be that universities will be unable to ensure, with any degree of certainty, that science and technology graduates will leave a tertiary education system with the necessary competencies for full and effective participation in the 'knowledge society and economy'.

## Introduction

The New Zealand Government, apparently without cross party dissent, stated that:

> the enhancement of New Zealand's future quality of life will be increasingly reliant on scientific knowledge and technological know-how (Upton, 1996a).

More recently, the vision of a 'knowledge society and economy' has seen the appointment of the Science and Innovation Advisory Council – its core mission to identify how New Zealand could ride the knowledge wave. Earlier this year, the significant 'Catching the Knowledge Wave' Conference generated over 100 recommendations on how New Zealand can lift its economic and social performance and create a knowledge society.

This reflects a growing appreciation in New Zealand and shared by industrially advanced countries of the importance of the contribution of science and technology to society generally (Carnegie Commission, 1994). Indeed the President of the United States has made his conviction clear that 'science and technology can promote economic growth and international competitiveness' (ibid). The Science Policy Research Unit (SPRU) of the University of Sussex has identified that 'science and technology are now strategic resources to be deployed as effectively as possible' (Martin et al, 1999). There has been a consequent escalation in economic and industrial competition between countries. The SPRU authors also maintain that 'companies and countries must innovate if they are to thrive, with knowledge-based industry and services becoming more crucial' (ibid).

It is clear that the competitive pressures engendered by the international appreciation of the crucial role of science and technology skills are spreading rapidly into the educational world since tertiary institutions provide the training for the staff and the future leaders in the knowledge-based industries. Within New Zealand, the Royal Society of New Zealand clearly articulates this: 'Education and training: not just in terms of volume but also matching supply with demand for a skilled workforce of scientists, technologists, technicians and support staffs but also into developing areas of science and technology' (RSNZ, 2000).

Obviously, the role of tertiary science and technology education is crucial in realising this 'knowledge society'. The 'path to the [any] region's long term future will not be trod by the workforce of today....It will be trod by the young. Hence the quality of .education, both in terms of basic skills and in terms of technological literacy, will contribute greatly to determining whether that path leads to economic prosperity or decline' (NYAS, 1996). This view is supported by Dr Jim Watson, founder and chief executive of the successful New Zealand biotechnology company Genesis Research and Development, who states that 'the 'young' are the standard-bearers of our scientific revolution ...they must be encouraged to discover the paths of the future, not trained in the ways of the past (Watson, 2000)' Australia has identified the "urgency in the battle to attract the most able people to science and technology" (PMSEC, 1996).

In recognition of this and of the inextricability of science and technology education with research New Zealand increased its public investment in research intending the *annual* amount of $530 million committed in 1996 to reach $1330 million fifteen years later (Upton, 1996b). This necessary focus on research has caused speculation about the ability of the existing tertiary teaching organisations and structures to provide sufficient competitive, educated and skilled research talent in science and technology to service the sophisticated needs of research. The Royal Society of New Zealand (RSNZ, 2000a), for example, advocates a review of the student loan scheme which systematically favours those studying shorter courses which take them into service industries and disadvantages those doing masters or PhD courses essential for the training of scientists and technologists. These New Zealand needs face predicted international competition since the USA acknowledges that it is massively under-supplying its own requirements for scientists and technologists. (Figures of estimated shortages of Software Engineers alone are often stated as 300,000+.) The Chinese have stated that they will be short of 1 million engineers......

## Tertiary Education Advisory Commission

The Tertiary Education Advisory Commission (TEAC) was convened in April 2000. Its task was to propose how the tertiary education system can best develop a knowledge-based society and economy. The subsequent release of the four TEAC 'Shaping' reports (TEAC, 2000,2001abc) – covering Vision, System, Strategy and Funding Framework - during 2000-2001 signal a further 'rethink' of the provision of tertiary education in New Zealand. One of the key messages of this policy framework, as specified in these reports, is quite explicitly, the development of a knowledge society. The reports propose mechanisms to enable the Government to 'effectively steer the education system in a strategic manner' (presumably towards the realisation of a 'knowledge society'), principally through a new funding framework and adoption of centres of research excellence (CoRE).

An analysis of the current crisis facing science and technology in New Zealand is given and the ability of the TEAC 'Shaping' reports to effectively respond to this situation is presented in the following sections.

## Training Outputs In Science And Technology

In view of the crisis of under-supply of scientists and technologists outlined in the introduction, it is necessary to analyse the current and future outputs of science and technology practitioners by New Zealand's tertiary sector. Analysis of the production of graduates in New Zealand shows very clearly how tertiary outputs do not reflect the stated needs of the country for science and technology: in 1998 67.3% of New Zealand graduates qualified in the areas of Arts, Business or Social Sciences; 5.6% qualify in engineering and technology: 2.6% as physical scientists (NZVCC, 2001). Other figures from the extensive web site of the Ministry of Education (MoE, 2000) show the enrolment situation in the whole tertiary sector (includes both universities and polytechnics). The figures (1999) include certificates, diplomas and degrees:

| | |
|---|---|
| Engineering | 4% |
| Industrial Trades | 5% |
| Natural & Applied Sciences | 8% |
| Commerce/Business/Humanities/Social | 40% |

Further in degree and post-graduate enrolments (1998) there is a similar picture:

| | |
|---|---|
| Engineering | 6.9% |
| Physical Science | 11.8% |
| Commerce/Business/Humanities/Social/Law | 51.8% |

While there are a number of complex, interrelated reasons for this reduction in relative outputs of science and technology to business graduates, the situation is, for the most part, a result of the increasingly competitive environment of current tertiary education introduced through education policy in the previous decade (1990-1999). Competition is promoted through the funding model, Equivalent Full Time Student (EFTS) system, which funds tertiary education institutions on the basis of enrolled student numbers. The institutions have tended to compete in courses where entry costs are low. Business courses (other than accounting), for example, do not require professional accreditation (cf engineering), and infrastructure costs (eg equipment, laboratory space and library material) tend to be less than those required in science and technology. The resultant growth in business, commerce, information systems and management based degrees has been significant. In the period from 1996-2000, bachelor degrees increased from 27 to 38; master degrees from 24 to 35. Such growth is also a response to student demand, as the perceived individual positional benefits of business courses are high relative to the costs and time involved (Kingsbury, 2001). To ensure that each institution is responsive to this student demand and captures its share of the students and related funding potentially available, institutions have diverted funds from academic interests into expensive and extensive marketing campaigns and departments. Further, when the profile of the science and technology graduates is further analysed, there is continued under-representation of women and certain ethnic groups.

The rapidly increasing international demand for those with science and technology qualifications, combined with the weak New Zealand dollar, would seem to indicate that the tertiary sector is not configured appropriately to meet additional needs of the area. Additionally only 11% of the population have tertiary qualifications as compared to 49% in the United States of America. While the increase in participation rates in tertiary education has taken NZ from the bottom of the OECD to somewhere just below the middle, this figure (11%) suggests that the demand driven reforms of the last decade have failed to position New Zealand in a strong position from which a 'knowledge society and economy' can emerge.

**TEAC Recommendations: Solving the problems?**

Even before the TEAC reports were released the Government has signalled (since 1999) a shift away from the competitive model, and is seeking an agreed nationwide plan for tertiary education provision, and an environment in which providers collaborate rather than compete. TEAC has proposed that 'collaboration' becomes measurable criteria for access to funding. The message is that we must collaborate in order to compete for funding. While the universities have in the main, welcomed an end to market forces thinking and embraced a system based on incentives and partnership (albeit partnerships competing for access funding), there is concern at the imposition of 'collaboration' in such a pro-active manner. Cooperation is alive and well in and between institutions, arising from contact between academics (Kingsbury, 2000). So too, is academic competition, since academic excellence and reputation are not achieved in isolation, but require stimulus of opposing views, values and positions. There is concern that [academic] competition, which is critical for successful collaborative partnerships to be forged, will be minimised, raising issues of academic freedom and institutional autonomy.

These issues of autonomy and freedom appear to be replaced with principles of 'differentiation and specialisation', in that TEAC believes that reducing duplication and encouraging specialisation amongst providers and programmes will ensure more effective allocation of government resources and promote quality in areas of focus (Marshall, 2001). Their mechanisms for achieving this are functional classifications and profiles (which will enable an institution to be able to offer certain 'types' of courses and not others). Universities have expressed concern in these mechanisms as their activities are a mix of functional classifications (which will have implications for compliance/administration costs), and that some degree of duplication of disciplines between universities is desirable on the grounds of geographical and social equity and access. TEAC proposes that, based on available funding, the 'top' (ie postgraduate) and 'bottom' (ie foundation) courses receive most attention and funding priorities. This will have the effect of constraining undergraduate degree levels, and when added to the proposed higher merit-entry levels for undergraduate degrees, may further diminish enrolments in science and technology. Most 'knowledge' societies support both broad bases in education and selected specialist/research foci in their universities. The underpinning of the requisite generalist education for a knowledge society (ie humanities and science in undergraduate levels ensures the populace has awareness and skills to contribute to the knowledge economy) does not appear to be a focus of the reports to date. TEAC does have equity provisions for marginalised groups (on the basis of ethnicity, not socio-economic status) in tertiary education, but does not acknowledge (apart from funding mechanisms to ensure more foundation courses are available) that there is serious work to be done at both primary and secondary school levels. This is critical for all ethnic groups in science and technology, particularly for Maori and Pasifika students.

## Funding Of Tertiary Science And Technology Education

In a report to TEAC investigating trends and international comparisons in university funding states:

> Over the last two decades, real Ministry of Education funding per EFTS has fallen at an increasing rate, the number of EFTS per staff member has risen and the proportion of academic staff to total university staff has fallen. ..Although New Zealand's lower level of spending per EFTS (compared with the OECD average) is in part a reflection of the level of GDP per capita, the country does spend less than would be predicted from GDP levels. Of concern is the deficit of just over US$3000 per EFTS compared with Australia (Scott & Scott, 2000 p4,5).

The result for science and technology courses in New Zealand at tertiary level is that funding has fallen to levels that are causing abandonment of these courses especially in the smaller institutions ie in the Polytechnic sector. In relative terms it is necessary to cross-subsidise from non-practical courses to science and technology courses. Similarly, at the postgraduate level, although postgraduate EFTS are funded at higher rate than undergraduate, current subsidies fall short of costs in sciences and engineering where cross subsidises to postgraduate from undergraduate programmes has become a necessity.

it has been necessary for some cross-funding support of programme costs from other sources. Fiscal data for the year 2000 are shown in Table 1 (source: RSNZ, 2000b).

**Table 1:** Year 2000 funding for Tertiary Institutions in New Zealand

| | Non Deg | UGrad | PGrad | ResPGrad |
|---|---|---|---|---|
| | | NZ Dollars | | |
| **Arts/Business SR** | 5314 | 5484 | 7014 | 12614 |
| **Arts/Business NSR** | 4726 | 4896 | 6426 | 12026 |
| **Science/Engineering (Non Deg)** | | | | |
| **Computing SR** | 8099 | 8469 | 11799 | 22999 |
| **Science/Engineering (Non Deg)** | 7208 | 7578 | 10908 | 22108 |
| **Computing NSR** | | | | |
| **Engineering (Degree) SR** | 10090 | 10560 | 14490 | 28190 |
| **Engineering (Degree) NSR** | 8969 | 9439 | 13369 | 27069 |

| | | Ratios | | |
|---|---|---|---|---|
| Sc/Eng/Comp:Arts/Bus SR | 1.52 | 1.54 | 1.68 | 1.82 |
| Sc/Eng/Comp:Arts/Bus NSR | 1.53 | 1.55 | 1.70 | 1.84 |
| Eng(Deg):Arts/Bus SR | 1.89 | 1.93 | 2.07 | 2.23 |
| Eng(Deg):Arts/Bus NSR | 1.90 | 1.93 | 2.08 | 2.25 |

In addition to the grossly unfavourable ratios of funding utilised by the Ministry of Education to distribute Government grants for science and computing qualifications in New Zealand, attention must also be drawn to the similarly unfavourable ratios that apply to the teaching of engineering disciplines. In the United Kingdom the ratio of engineering funding to that of arts is between 2.4 and 3.6, depending on the speciality[10]. The New Zealand ratio is approximately 1.9. Again this must necessarily impose gross stress on the quality provision of education and training. This stress is evidenced in the tension existing between the requirement for more multi-skilled graduates, as articulated in policy by successive governments, and the effect of the diminishing resources of most science and technology faculties available for teaching related areas. Funding pressures can mean faculty staff are unable to invest time and resources in essential curriculum and pedagogical tools, such as defining new approaches, inventing new ways of teaching and integrating new elements (for example, distance learning modules) required to educate and train qualified multi-skilled professionals for the future.

It must also be recognised that the *absolute* costs in New Zealand are very significantly less than the costs in the UK. The average governmental cost for degree training in Science and Engineering training in the UK is 3465 pounds (1998-99) which converts to $NZ11180. *This is exclusive of central administration or academic services costs.* New Zealand support is $8099/7208 (StudyRight/NonStudyRight) for science and computing and $10090/8969 for engineering (UK Arts $6152, NZ Arts $5314/4726).

Tied into the EFTS funding system is a significant proportion of research funding known as the research 'top up'. One of the problems with funding research through this mechanism is that it is inherently dependent on student numbers and therefore is more difficult to predict and guarantee on an annual basis.

**Teac Recommendations: Solving the problems?**

It is very clear from these figures that the funding of science and technology in New Zealand is inappropriately low and it has had a negative consequences on the training of science and technology practitioners. The degree to which TEAC will remedy this situation is unclear, partly due to the fact that the 4th report relating to the funding framework, does not appear to recognise the urgency of the situation:

> .that universities are bleeding now, have reluctantly accepted an interim funding arrangement for next year and simply cannot afford to have that situation continue (McWha, 2001)

While accepting that the current EFTS funding situation does have benefits, TEAC believes that an effective tertiary education system can be redeveloped through the redistribution of existing funds. This means that there will be little or no more funding available to the sector in the foreseeable future. Precisely how the Government will meet its objectives of a 'knowledge society', when it has been proposed that New Zealand needs six to eight universities with around 110,000 EFTS to form the 'powerhouse for a knowledge society' (UoC, 2001) is therefore, unclear.

The proposed model has the majority of tuition funding delivered through a single funding formula (SFF) with indices that can be used to 'steer' the system. The Priority Index (PI) for example allows the government to vary funding according to the perceived value of a programme or discipline in meeting national goals. The Learner Index (LI and Learner Add-on (LA) enable the government to provide increased funding for specific groups of learners, most notably Maori and Pasifika. While the mechanisms seem to be available to correct the imbalance in science and technology funding (and there is some indication in the report of this intention), the actual levels of funding are not made explicit in the report and so comparisons with current funding levels cannot be made. What is clear, however, is that these funding changes will have a negative impact on most universities due to reduced funding in business courses (see earlier comments on explosive growth and associated funding benefits) which, given current enrolment levels in science, will clearly not compensate for the diminished income.

**Teaching Research Nexus**

Possibly the most controversial aspect of funding proposed by TEAC is the separation of research and teaching and its related funding. Admittedly, this is an international trend, adopted to varying degrees by different economies. The main advantage of this separation is that a substantial part of research costs will be funded apart from student numbers which should provide predicability and security of funding for research endeavours.

This aside, TEAC's decision is not simply to separate research and teaching funding. Rather, TEAC appears to have adopted a 'negative or null nexus' model of the relationship between teaching and research, resulting in the recommendation that legislative requirements regarding the teaching of undergraduate degrees be amended. From a situation requiring these degrees to be taught mainly by people engaged in research, TEAC recommends that degree staff have 'comprehensive knowledge of their discipline and the ability to communicate this knowledge effectively' (TEAC, 2001c). The basis of this recommendation is appears to be the so-called 'scarcity model' (Hattie & Marsh, 1996) which argues that teaching and research, being inherently different activities, compete for academic time. As a result neither are done well. Hence, TEAC's arguments that the split of teaching/research funding will encourage quality outcomes in both spheres.

This separation will not support science and technology education. In fact, it suggests a serious misunderstanding of both the theoretical understanding of academic work adopted in the report (ie Boyer's (1990) model of academic work is based in inter-related, not distinctly separate, spheres of academic 'scholarship') and how novices (ie graduates become enculturated into the community of science (Hodson, 1998)). Over the past decade, fundamental changes have occurred in the ways professional qualifications are offered, accredited and related to economic goals and national productivity (Butterworth and Tarling, 1994). These changes have been informed by efforts to adapt, modify and extend traditional models of professional education. It is recognised graduates need to have key professional (or occupational) competencies, a deep appreciation of the relationship of their field to the wider societal, political and historical context, as well as specialised knowledge. For the scientist, although much of that development necessarily takes place in the work environment, economic and social shifts over the past decade have firmly located the initial development of 'practice competencies' as the responsibility of academe. This implies that the primary concern to science educators must be the formation of a full range of capabilities that underpin effective practice. Competence emerges from personal, intellectual and professional development nurtured and urged through learning experiences set in appropriate educational frames of reference. For tertiary science education to effectively deliver 'work-ready graduates', these frames of reference must include interaction with scientific research and practice, and their practitioners. This argument applies equally (and moreso) to the postgraduate research programmes. TEAC uses the term 'research training' throughout its document – a term which fails to address the complexity of the 'apprenticeship' to the community of science occurring during postgraduate studies.

As it stands, the funding and potential number of postgraduate programmes, will undergo significant change if the TEAC report is adopted. In their concern for 'quality' at the top end of the tertiary system, TEAC proposes to restrict postgraduate programmes to academic units which meet a specified 'quality' threshold. 'Quality' will be measured using the quality measure in the Performance Based Research Fund (PBRF), and ultimately whether a programme will continue (or even begin) to be funded will depend on the 'research intensity and quality' being sufficient to support postgraduate teaching. Rather than research 'top-up' accompanying student enrolments in postgraduate programmes, TEAC has recommended the transfer of post-graduate research top-ups into the PBRF. While this fund will be used to 'partly subsidise' research-based postgraduate programmes, the remainder coming from SSF. TEAC in these recommendations attempts to support, and ultimately strengthen, the role postgraduate students play in significant research programmes, particularly in science and technology in New Zealand. However, this is at the risk of damaging the underpinning base of scholarship in a wide rather than narrow variety of fields essential for the development of a 'knowledge society'. There is a sense, also that

Government or its nominated parties, must pick as 'winners' those who currently meet the threshold. This is, despite the fact, that within the research environment foci of excellence often have limited 'lives' as knowledge changes. This may well force individual institutions themselves to support science and technology researchers whose research efforts are predominantly within fundamental research categories. Fundamental research must, by the very nature of the research environment, precede technology transfer which is the research area widely supported by many of TEAC recommendations (nb applied research appears to be redefined and limited to technology transfer by TEAC). This situation must necessarily impact on TEAC's emphasis on encouraging 'multidisciplinary and trans-disciplinary thinking, learning and research, that looks beyond the traditional classifications and boundaries of knowledge for the intersections that can produce new areas of knowledge, services, and products, and which address national priorities' (TEAC, 2001b, p26).

## Conclusion

New Zealand is a small country. We need to make best use of our resources to ensure that the appropriate mix of quality tertiary education and skills training is available throughout the country. The Government wants to build a coherent tertiary education system where each institution is encouraged to play to its strengths according to an agreed nationwide plan ...The Government is clearly signalling that we want to be an active and careful steward of our public tertiary institutions. (Maharey, 2001)

Accordingly, since April 2000, TEAC has released four reports addressing how the tertiary education system might build the quality of learning, focus on the learners at the top and bottom of the system and develop the skills and environment for a distinctive knowledge society.

Based on these reports, New Zealand's tertiary education sector is about to be redesigned (again) – this time into a single integrated system, which the Government will be able to 'effectively steer in a strategic manner'. Given that science and technology are cited as significant contributors to the 'knowledge society and economy', we would hope to see support for encouraging their development within tertiary education so that the limitations currently faced no longer constrain the provision of human capital necessary to achieve a 'knowledge' economy and society. Indeed, there are many recommendations which suggest that this is the case: promises of a higher priority index category; increases in funding for postgraduate programmes; research initiatives for funding 'excellence' etc.

However, the extent to which these measures will support growth in tertiary science and technology education is unclear. Given that these reports are the basis of wide consultation across the range of tertiary education, there are (not surprisingly) internal contradictions within the reports which will have significant impact on tertiary science and technology education. Tensions exist between competition and collaboration - we collaborate with researchers to compete for funding. Between tertiary education and 'research training' – a lack of understanding how professional programmes such as science and technology are not simply 'content' driven. Between funding a broad base of research and 'thresholds' for research funding – there is a very real fear of a diminishing of the base of scholarship necessary for both excellence in research and a populace equipped with the skills to participate in a knowledge society.

TEAC has, by and large essentially redistributed a shrinking cake ..it has failed to address the chronic and worsening under funding of university education in New Zealand. But then, it is clear that TEAC was never given any more ingredients for the 'cake' in the first place ...

## References

CARNEGIE COMMISSION ON SCIENCE, TECHNOLOGY, AND GOVERNMENT (1994) *A Report of the Carnegie Commission on Science, Technology, and Government: Science, Technology, and Congress Organisation and Procedural Reforms* USA, February (ISBN 1-881054-18-7) p77

BOYER, E. (1990) *Scholarship reconsidered: priorities of the professoriate*, Princeton, NJ, Carnegie Foundation for the Advancement of Teaching.

BUTTERWORTH, R. & Tarling, N. (1994). *A shakeup anyway.* Auckland: Auckland Uni Press.

HATTIE, J. & Marsh, H. (1996) The relationship between research and teaching: a meta-analysis. *Review of Educational Research*, 66(4), pp 507-542.

HODSON, D. (1998) *Teaching and Learning Science: Towards a personalized approach.* Philadephia, Open University Press.

KINGSBURY, A. (2001) *Competition, collaboration or control: Competition law and tertiary education in New Zealand.* Accessed from www.teac.org.nz. (Access date: November, 2001)

McWHA, J. (2001). *TEAC Fourth Report: More Resourcing is the Issue.* NZVCC Media Release, 8 Nov, 2001. Accessed from www.nzvcc.zc.nz/pubaffpol/mr08122001.html

MAHAREY, S (2000) Government to place moratorium on further universities. Press Release 16 May 2000.

MARSHALL, R. (2001) Shaping the Funding Framework Speech Notes. Accessed from www.teac.org.nz. (Access date: November, 2001)

MARTIN, B.R. & Johnston, R. (1999) *SPRU Electronic Working Papers No 14* Accessed from (Access date: July, 2000)

MINISTRY OF EDUCATION (MOE) (2000) see figures at

NEW YORK ACADEMY OF SCIENCES (NYAS) (1996) *Technology and Economic Development in the Tri-State Region* March, p38

NZVCC (2001) see figures available from the New Zealand Vice-Chancellors' Committee as quoted in Venture Issue 2 April 2001 Published by Industry New Zealand

PRIME MINISTER'S SCIENCE AND ENGINEERING COUNCIL (PMSEC) (1996) *Key Issues in Australian Science, Technology and Engineering* September (ISBN 0 642 25962 3)

ROYAL SOCIETY OF NEW ZEALAND (RSNZ) (2000a) *A Manifesto for Science, Technology and Innovation* Accessed from (Access date: December, 2000)

ROYAL SOCIETY OF NEW ZEALAND (RSNZ) (2000b) Submission to Parliament's Education and Science Committee's Inquiry into Student Fees, Loans, Allowances. Accessed from www.rsnz.nz

SCOTT, W. & Scott, H. (2000) New Zealand University funding over the last two decades. Access from www.nzvcc.zc.nz/pubs/funding/funding.html Access date: November, 2001

TEAC (2000) Shaping the Vision; TEAC (2001a) Shaping the System; TEAC (2001b) Shaping the Strategy; TEAC (2001c) Shaping the Funding Framework Accessed from . (Access date: November, 2001)

UNIVERSITY OF CANTERBURY (UoC) (2001) *Response to the 3rd TEAC Report.* Accessed from www.teac.org.nz Access date: November, 2001

UPTON, S. (1996a) *RS&T: 2001 Strategic Overview.* Ministry of Research, Science and Technology, NZ, August (ISBN 0-478-06115-3)

UPTON, S. (1996b) *The Future of Science and Technology in NZ* The Second R.D. Batt Memorial Lecture August, Massey University, NZ.

WATSON, J. (2001) Personal comment reported in NZ Herald, March.

See also for a comprehensive overview of reports, consultation process, responses, submissions which have informed this debate.

**Keywords:** funding; tertiary science education, TEAC, knowledge society

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# ARE INTUITIVE RULES UNIVERSAL?

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**Abstract**

In our work in science and mathematics education, we have observed that students intuitively react in similar ways to a wide variety of scientific tasks. These tasks differ with regard to their content area and/or to the reasoning required for their solution, but share some common, external features. We have identified three types of intuitive responses: "*More A - more B*" and "*Same A - same B*" which relate to comparison tasks, and "*Everything can be divided endlessly*" which relate to repeated division tasks. For example, in respect to the first intuitive rule: "*More A - more B*", when students are told that Tom saves 15% of his salary, and Mary saves 20% of her salary, they tend to incorrectly claim that Mary saves more money than Tom, because 20 is larger than 15. This response is in line with the intuitive rule "*More A* (percentage) - *more B* (money)". Similarly, when presented with the task: Is the size of a muscle cell of a mouse larger than/equal to/ smaller than/ a muscle cell of an elephant, students tend to incorrectly argue that the cells of the larger animal are larger ("larger animal - larger cells"). Based on such observations, we developed the Intuitive Rules Theory. This theory explains and predicts students' common responses to science and mathematics tasks. Many responses that the literature describes as alternative conceptions could be interpreted as evolving from the intuitive rules.

The intuitive rules theory is based on data collected in the western world. It is interesting and important from both theoretical and practical points of view to test the universality of this theory. For this purpose, a cross-cultural study was carried out with Israeli, Taiwanese and Aboriginal Australian elementary and secondary school students. A wide variety of comparison and repeated division tasks were given to the participants.

Our findings indicate that Taiwanese and Aboriginal Australian students, much like Israeli ones, are strongly affected by the intuitive rules. Many students provided incorrect responses to the tasks, most of which were in line with the intuitive rules. Also, developmental trends were found to be similar. Consequently, we suggest that the intuitive rules are universal and affect students' responses in different countries in the same manner. Educational implications concerning the learning and teaching of science and mathematics in general and of specific concepts in particular will be discussed. In the lecture we shall describe additional studies carried out in Jordan and Argentina.

## Introduction

In our work in science and mathematics education, we have observed that students react in similar ways to a wide variety of conceptually non-related tasks (e.g., Stavy & Tirosh, 2000; Tsamir, Tirosh, Stavy, & Ronen, 2001). Although these tasks differ with regard to their content area and/or the type of reasoning required, they share some common, external features. So far three types of responses were identified, two relate to comparison tasks (*More A - more B and Same A - same B*) and one to repeated division tasks (*Everything can be divided endlessly).*

When relating to comparison tasks, students who were told, for example, that Tom saves 15% of his salary, and Mary saves 20% of her salary, tended to claim that Mary saves more money than Tom, because 20 is larger than 15. This claim is in line with the intuitive rule *More A* (percentage) - *more B* (money). Similarly, when presented with the task: Is the size of a muscle cell of a mouse larger than/equal to/ smaller than/ a muscle cell of an elephant, students tend to incorrectly argue that the cells of the larger animal are larger ("larger animal - larger cells"). These two tasks share some common features. In each of them two objects which differ in a certain, salient quantity A are described ($A_1>A_2$). The student is then asked to compare the two objects with reference to another quantity B ($B_1$ is not larger than $B_2$). In both cases a substantial number of students responded according to the rule *More A* (the salient quantity) - *more B* (the quantity in question) arguing, incorrectly, that $B_1> B_2$. Similar behavior was observed in many different tasks in different content domains in mathematics, physics, chemistry and biology.

When students are presented with comparison tasks in which two objects are equal in a certain quantity ($A_1= A_2$) but differ in another quantity ($B_1$ is not equal to $B_2$), they often claim that $B_1= B_2$ because $A_1= A_2$. Our claim is that such responses are instances of the intuitive rule "Same amount of A - same amount of B" (*Same A - same B*, in short). For example, when children were told that John saves 10% of his salary, and Donna also saves 10% of her salary, they tended to claim that John and Donna save the same amount of money. This response is in line with the intuitive rule *Same A* (percentage) - *same B* (money). Similarly. when presented with the task: "The common shapes of bacteria are spherical (cocci), rod-like (bacilli) and spiral (spirillae). The cell volume of these bacteria is equal. Is the resistance to dryness of these three types of differently shaped bacteria equal/nonequal? Explain your answer. If you think their resistance is different, which of these bacteria is most resistant? Why?" Students tended to incorrectly claim, in accordance with the intuitive rule "*Same A - same B*" that "the cells have the same volume therefore their resistance to dryness is the same". Such behavior was observed in many tasks related to science and mathematics.

With regard to repeated division tasks students were presented, for instance, with the following task: Consider a line segment, divide it into two equal segments, divide one (half) segment into two equal segments, continue dividing in the same way. Students were asked whether this process would come to an end and also to explain their answer. Similarly, students were asked to consider a copper wire undergoing the same process and to respond to the same question. It was found that the younger students (up to 15 years old) presented finite solutions to both tasks (this judgment is incorrect with respect to the line segment and correct with respect to the copper wire). The older students (15 years and up) tended to provide infinite responses to both the mathematical and material tasks, explaining that *Everything can be divided endlessly*. Similar results were obtained with other successive division tasks such as serial dilution, decomposition of radioactive material and repeated halving of biological objects

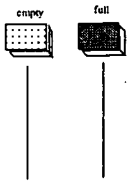
Based on such observations, the Intuitive Rules Theory has been proposed to explain and predict students' responses to mathematics and science tasks. We claimed that many of the responses that the literature had so far described as alternative conceptions could be interpreted as evolving from these intuitive rules, which are activated by specific external task features.

The intuitive rules theory is based on data collected in the western world. It is interesting, from both theoretical and practical points of view, to find out whether the intuitive rules are universal. Are they common characteristics of the human mind or a product of certain cultures and/or educational systems? This paper focuses on an initial examination of the universality of the intuitive rules. For this purpose, studies were carried out with Israeli, Taiwanese, and Aboriginal Australian students in an attempt to examine whether the intuitive rules similarly affect their responses.

## Methods and Samples

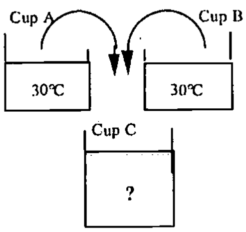
**The Tasks**

Comparison Tasks




*Free Fall*

Two matchboxes, one full of sand and the other empty, are held at the same height above the ground, in the same manner. They are both dropped at a certain point in time. Will the matchbox full of sand hit the ground before / at the same time / after / the empty matchbox? Explain your answer.

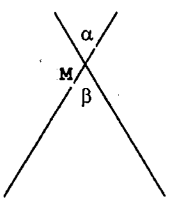



*Temperatures*

Consider the following drawing:

The water from Cup A and the water from Cup B were poured into Cup C. What is the temperature of the water in Cup C?

Explain your answer.




*Vertical Angles*

Consider the following drawing:

Is angle  smaller than / equal to / larger than / angle ?

Explain your answer.

*Volume of Cylinders*

Take two identical rectangular (non-square) sheets of paper (Sheet 1 and Sheet 2):

Rotate one sheet (sheet 2) by 90¼

Is the area of sheet 1 smaller than / equal to / larger than / the area of Sheet 2?

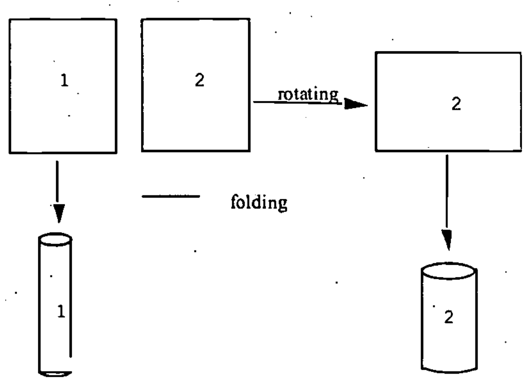
Explain your answer.

Fold each sheet (as shown in the drawing).

You get two cylinders: Cylinder 1 and Cylinder 2.

Is the volume of Cylinder 1 smaller than / equal to / larger than / the volume of Cylinder 2?

Explain your answer.




Repeated Division Tasks

*Line Segment*
Consider a line segment. Divide it into two equal parts. Divide one half into two equal parts.
Continue dividing in the same way.
Will this process come to an end? Yes / No.
Explain your answer.

*Copper Wire*
Consider a copper wire. Divide it into two equal parts. Divide one half into two equal parts.
Continue dividing in the same way.
Will this process come to an end? Yes / No.
Explain your answer.

*Sugar water*
A teaspoon of sugar is put into a cup of water and stirred well into it. Half of the sugar water is poured out, half a cup of water is added to the cup and is mixed thoroughly with the remaining sugar water. This is done again: Half of the sugar water is poured out, half a cup of water is added, etc. This process is repeated.
Is it possible that at a certain stage no sugar at all will be present in the cup? Yes / No.
Explain your answer.

The tasks were originally formulated in Hebrew. The persons who conducted the research in Israel were mathematics and science educators, who were familiar with the Intuitive Rules Theory. They were responsible for writing, editing, and administering the tasks, as well as for analyzing the data.

In order to use these tasks in Taiwan, a 10 weekly four-hour sessions workshop about the Intuitive Rules Theory was carried out by one of the authors. Forty-five Taiwanese mathematics and science educators participated in this workshop. They studied the theory and had to carry out a mini repetitive study in school classes. The tasks were translated into English, and then one of the workshop participants translated them into Chinese. In order to validate the translation, they commented on the translated version. The agreed upon version was again retranslated into English and the meanings were verified. Then, the tasks were administered by the workshop participants, in a printed questionnaire in several cities in Taiwan. The students responded in Chinese and the results were analyzed by each of the participants.

The English version was used on the Australian Aborigines.

**Participants and Process**
*IN ISRAEL:*
(a) Free fall: 186 students from Grades 8, 10, and 12 (33, 109, and 53 students respectively) answered a printed questionnaire;
(b) Temperatures: 120 students, from Grades 2, 3, 5, 6, 7, 8 (20 from each grade) were individually interviewed
(c) Vertical angles: 243 students from Grades 2, 4, 6, and 9 (69, 65, 70 and 60 students respectively) answered a printed questionnaire;
(d) Volume of cylinders: 375 students from Grades 1-6, and 10, 12 (40 students from each of the 1-6 grade level; 110 10th graders and 29 12th graders). In Grades 1-6, were individually interviewed, and the 10th and 12th graders were given a printed questionnaire;
(e) Line segment, Copper wire, and Sugar water: 76 students from Grade 10 answered a printed questionnaire.

*IN TAIWAN:*
(a) *Free fall*: 243 students from Grades 2, 3, 4, 5, 6, 10 (33, 34, 40, 36, 34, and 66, respectively) answered a printed questionnaire;
(b) *Temperatures*: 921students from Grades 2, 3, 4, 5, 6, 10 (33, 197, 210, 205, 209, and 67, respectively) answered a printed questionnaire
(c) *Vertical angles*: 966 students from Grades 3, 4, 5, 6, 10 (206, 339, 345, and 67, respectively) answered a printed questionnaire;

(d) *Volume of cylinders*: 1269 students from Grades 1-6, 10, 11 (28, 33, 34, 117, 443, 428, 65, and 121, respectively) answered a printed questionnaire;
(e) *Line segment, Copper wire, and Sugar water*: 67 students from Grade 10 answered a printed questionnaire.

*IN AUSTRALIA:*
*Free fall, Temperatures, Vertical angles, Volume of cylinders*: 64 Aboriginal students from Grades 2-3, 4-5, 6-7 8-9 (22, 19, 13, and 10, respectively) were individually interviewed by the researcher.

**Results**
*COMPARISON TASKS*

*Free Fall*
Almost all young, elementary-school students in Taiwan and Australia incorrectly answered, in line with the intuitive rule, that the heavier box would hit the ground first, because: The heavier- the faster. In secondary schools, about 50% of the Israeli, 45% of the Taiwanese and 90% of the Aboriginal Australian 9th grade students provided the same, incorrect response.

*Temperatures*
Most young elementary school students in the three countries, answered incorrectly, in line with the intuitive rule, that More A (amount of water) - more B (higher temperature). However, while in Taiwan and in Israel, high percentages of incorrect responses in line with this intuitive rule were observed until grade 4 or 5, respectively, in Aboriginal Australians such responses were very frequent until grades 6-7 (Figure 1).

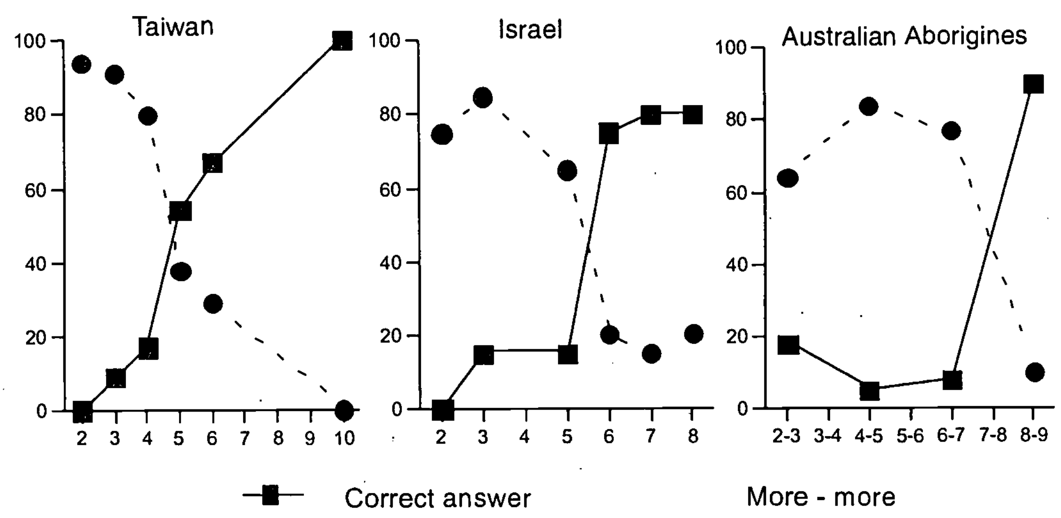



**Figure 1:** Distribution of correct and intuitive responses to the temperature task

*Vertical Angles*
Figure 2 shows that, once more, young students in the three countries, tended to incorrectly argue, in line with the intuitive rule More A (longer arms, larger enclosed area) - more B (larger angle). While only about 30% of the 3rd graders in Taiwan, about 10% of the 2nd graders in Israel and 5% of the 2-3 Grade Aboriginal Australians provided correct responses, most Israeli and Aboriginal Australians 9th graders (over 80%) and all Taiwanese 10th graders correctly responded that the angles were equal.

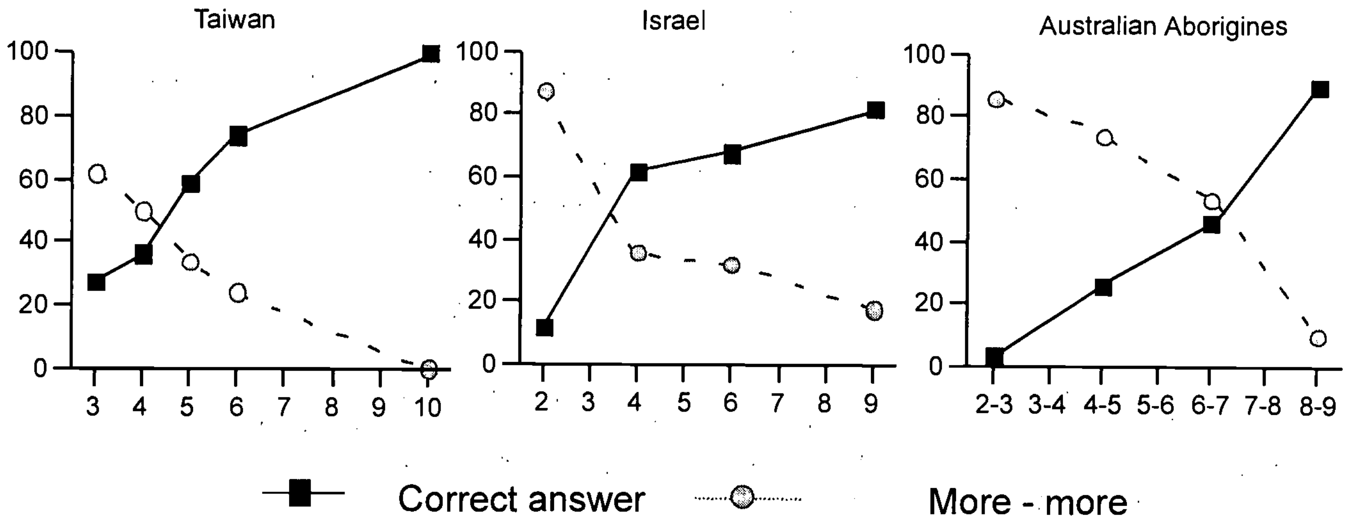



**Figure 2:** Distribution of Correct and Intuitive Responses to the Vertical Angles Task

*Volume of Cylinders*
The findings indicated that in all three countries the tendency to correctly answer the conservation of area task increased with age. It is interesting to note the increase, with grade, in all three countries, in the percentages of incorrect responses: Same A (area, paper) - same B (volume). This incorrect response developed in a parallel manner to the development of conservation of area (see Figure 3).

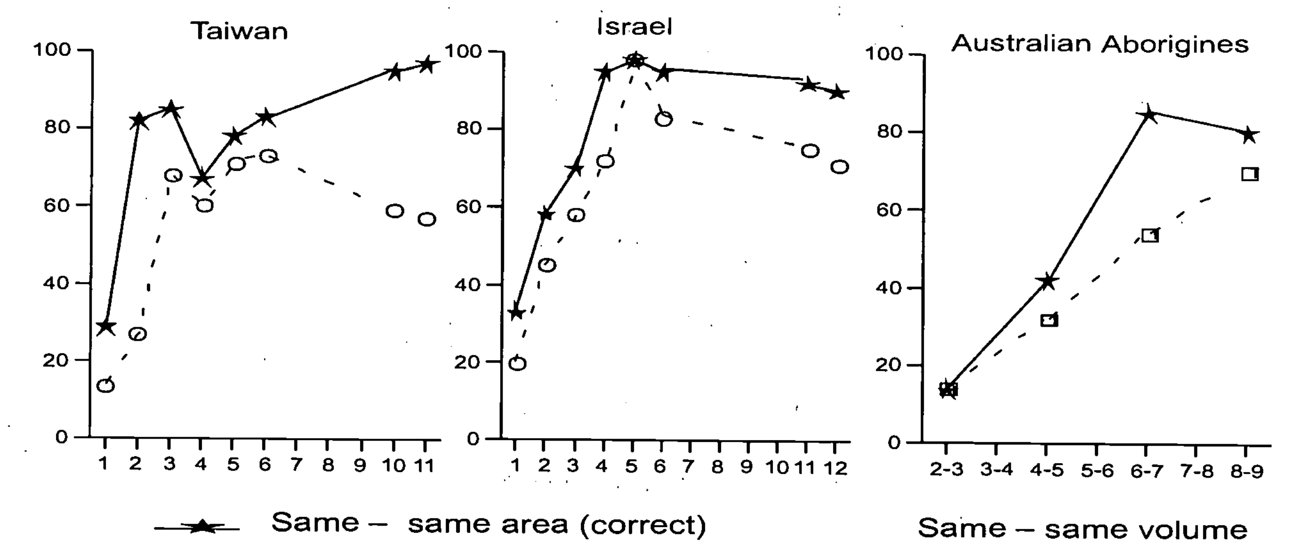



**Figure 3:** Distribution of "Equal" Responses to the Comparison of Area and Volume of Cylinder Tasks.

*Repeated Division Tasks*
Table 1 shows that the majority of 10th graders in both Taiwan and Israel tended to respond in line with the intuitive rule *Everything can be divided endlessly*. They correctly claimed that the repeated subdivision of the line segment could go on forever, but incorrectly claimed that the repeated subdivision of the copper wire will continue endlessly. With regard to the sugar water they incorrectly claimed that sugar would always remain sugar in the diluted solution. This response is an expression of the intuitive rule: *Everything can be divided endlessly* (Table 1).

**Table 1:** Students' Intuitive Responses to the Repeated Division Tasks (in %).

| | Line segment | Copper wire | Serial dilution |
|---|---|---|---|
| Taiwan | 69% | 60% | 83% |
| Israel | 67% | 50% | 58% |

*Final remarks*

The findings of this study clearly indicate that Taiwanese and Aboriginal Australian students, much like the Israeli ones, are strongly affected by the intuitive rules: *More A – more B* and *Same A - same B*, when presented with relevant comparison tasks. In relation to tasks where the correct answer was not in line with the intuitive rules, two main findings should be highlighted. First, for all tasks, two major types of responses were evident – a correct and an incorrect response, the latter in line with one of the intuitive rules. Also, the developmental patterns were rather similar. Differences were found with regard to the rate of developmental change. Consequently, we are able to suggest that the intuitive rules *More A - more B* and *Same A - same B* are universal. The differences in the developmental rate could be explained by cultural and/or educational differences.

Our findings related to the repeated division tasks indicate that Taiwanese and Israeli secondary school students are strongly affected by the intuitive rule *Everything can be divided endlessly*. The influence of this intuitive rule was also remarkable in these students' responses to the sugar water task. It should be noted that an attempt to examine the effect of this intuitive rule was carried out in a similar study in Germany (Buck, Stavy, & Tirosh, 1995). In this study, various repeated division tasks of material and mathematical objects were presented to 10th graders, including the line segment and the copper wire tasks. The findings indicated that about 70% of the participants correctly answered that the line segment could be endlessly divided, and about 50% of them incorrectly claimed that the copper wire could be endlessly divided as well. We are currently undertaking a replication of this study in Jordan and in Argentine. During the conference we'll report on the related results. Clearly further research is needed to enforce our knowledge about the universality of the role of the intuitive rules in students' mathematical and scientific thinking.

## References

BUCK, P., Stavy, R., & Tirosh, D. (1995). Teilbarkeit eines gegenstandes und einer strecke. *Chimica didactica. 21*, 215-227.

GRABER, W., Komorek, M., Kross, A., & Reiska, P. (Eds.), *Research in science education- Past, present and future*. Dordrecht, The Netherlands: Kluwer,

STAVY, R., & Tirosh, D. (2000). *How students (mis-)understand science and mathematics: intuitive rules.* Teachers College Press, New York.

TSAMIR, P., Tirosh, D., Stavy, R., & Ronen, I. (2001). Intuitive rules: A theory and its implications to mathematics and science teacher education. In H. Behrendt, H. Dahncke, R. Duit, W. Graber, pp. 327 –346.

**Keywords:** intuitive rules, cross-cultural study, comparison tasks, repeated division tasks, alternative conceptions

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# A COMPARATIVE STUDY ON RELATION BETWEEN SCIENCE AND TECHNOLOGYCURRICULA IN NORTHERN IRELAND, SCOTLAND, TAIWAN AND JAPAN

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**Abstract**

The purpose of this study is to compare the relationship between science and technology curricula in Northern Ireland, Scotland, Taiwan and Japan. This study focuses on the relationship between science and technology curricula in primary and lower secondary schools. Introduced are problem-solving processes in the science and technology learning activities, significance and problem of Science and Technology education, and suggestions for these subjects' reorganization in the Japanese primary and lower secondary education. This study is summarized as follows: (1) In the Northern Ireland curriculum, technology education is much more than applied science education, and science education is much more than theoretical technology education. The curriculum concept was highly influenced by the following: subject areas are so fundamentally difficult, and that pupils need to develop the knowledge, skills and understanding associated with each, that has helped provide a case for both disciplines to be included. (2) In Scotland, the relationship of skills between science and technology about preparing for tasks in "Environmental Studies" as one of the main learning areas. It was recognized that technology was connected with science, taking each peculiar feature into consideration. (3) In Taiwan, the new curriculum content of "Science and Living Technology" was included in eight indicators of learning abilities and a total of 233 statements of attainment for Science and Technology education were integrated by cross-curricular knowledge and skills.

## 1. Introduction

In Japan, technology education is a new course of study in lower secondary school (13-15 years old). It has been a new course since the 2000 school year and has integrated two strands: 1) technology and making artifacts; 2) information and computers.

The reports published by the Japanese Central Council of Education (JCEE) or the National Curriculum Council (JNCC) showed the backgrounds of subject reform. The turning point is to cultivate "Zest for living." Zest for living was defined as follows;

> "Zest for living' is the ability to identify problems for oneself, learn for oneself, think for oneself, make independent judgements and actions and solve problems well; these are its important pillars, .(JCCE, 1997)"

The question may be asked: is 'Zest for living' cultivated by a conventional style teaching and learning or subjects? This is the teachers' and researchers' concern in school subject reform. Many teachers and researchers in Japanese science and technology education have attended to the relation between science and technology in the school subjects.

From the international trends of technology education, this paper points out two facts. The first point is that many countries have introduced technology as a general subject in upper secondary schools. The second point is that integrated technology with other subjects or areas of learning has been increased in primary schools since 1990s.

This study compared the relationship between science and technology curricula in Northern Ireland, Scotland, Taiwan and Japan. This paper focuses on the relationship between science and technology curricula in primary and lower secondary schools. Accordingly, we give a brief overview of science and technology curricula in those countries, and introduce a problem-solving process in the science and technology learning activities, describe the significance and problems of Science and Technology education, and give suggestions for a reorganization in Japanese primary and lower secondary education.

## 2. Science and Technology Curriculum in Northern Ireland

The Northern Ireland Education Reform Order (1989) originally proposed that two subjects "Science," and "Technology and Design" should be mandatory and taught as separate subjects to pupils aged 4-16 years. However, a series of curriculum reviews in the early 1990s has resulted in some "pulling back" of the original commitment to Science and Technology. The overall effect has been to combine Science and Technology into a single subject in the primary school curriculum, and to make Technology and Design optional for 14-16 year old pupils in post-primary schools.

Key Stage 1 (ages 4-8years) is important in laying the foundations for developing the basic skills in Science and Technology. Through structured play and other suitable activities, pupils should be given opportunities to:

- explore;
- make observations;
- use a range of materials to build and construct.

During these early years, pupils should be given opportunities to develop appropriate terminology associated with Science and Technology by talking with their teachers or other children about their work. They should be given opportunities to increase their awareness of the importance of Science and Technology in everyday life, and the need to conserve the natural environment.

Key Stage 2 (ages 8-11 years) builds on Key Stage 1 by giving pupils opportunities to further develop their skills, and their understanding and knowledge of Science and Technology. At each Key Stage, it is also important that pupils have opportunities to develop an understanding of what Science and Technology are about, and develop skills in the process of Science and Technology in a progressive manner. The data of table 1 show that pupils should be given opportunities.

**Table 1.** Pupils' experiences in the area of study Science and Technology

| Key Stage 1 | Key Stage 2 |
|---|---|
| try things out for themselves;explore;<br>ask questions;record observations;<br>draw pictures to record what they have done;<br>try to explain what they have seen or done;<br>put things together and take things apart;<br>make things (construct);<br>plan and adapt as they construct. | solve problems;<br>carry out investigations;<br>make observations;<br>ask and answer questions;<br>present their ideas;<br>plan independently;<br>record observations;<br>work methodically;<br>interpret evidence;<br>construct using a range of materials;<br>plan and adapt as they work;<br>evaluate and revise their work;<br>make suggestions for improvement;<br>develop oral, written and graphic communication skills. |

In post primary schools (ages 11-16/18 years), Science and Technology and Design are taught as separate subjects. The Programs of Study of Science and Technology and Design at Key Stages 3 and 4 are common topic areas. Table 2 lays out areas of common ground between the Science and Technology and Design at Key Stages 3 and 4.

While there is clearly common ground, as shown above, between Science and Technology, the approach to each, their underlying processes and outcomes, are fundamentally difficult in many respects.

**Table 2.** Areas of common ground between Science and Technology, and Design at Key Stages 3 and 4

| Science | | Technology and Design | |
|---|---|---|---|
| Materials | Use of materials.<br>Man-made materials.<br>Composites<br>Metals | Materials | Wood, materials and plastics.<br>Joining of materials<br>Processing materials<br>Physical properties. |
| Energy | Forms of energy.<br>Energy resources.<br>Work and Power.<br>Energy changes. | Energy and control | Mechanical, electronic and pneumatic systems.<br>Computer control.<br>Alternative sources of energy<br>Energy conversion and storage.<br>Systems input, process and output. |
| Forces | Effects of a force.<br>Hooke's Law.<br>Moments.<br>Pressure | Structures | Stability.<br>Equilibrium.<br>Bending, and shear. torsion, tension.<br>Moments, stress, strain. |
| Electricity | Electric circuits.<br>Ohm's Law.<br>Using electricity.<br>Magnetism.<br>Electromagnetism. | Electronics | Electronic control systems.<br>Electronic components.<br>Ohm's Low.<br>Signal conditioning.<br>Computer interfacing. |

Technology is much more than applied science, and science is much more than a theoretical Technology. Technology is involved with the human, created world and is concerned with "what is". It is the recognition that the subject areas are so fundamentally difficult, and that pupils need to develop the knowledge, skills and understanding associated with each, that has helped win the case for both disciplines to be included in the Northern Ireland Curriculum.

## 3. The Science and Technology Curriculum in Scotland

Technology education in Scotland has been carried out from primary school to upper secondary school. Some countries have been introduced these as an "area of learning" instead of a "subject or academic discipline" in accordance with social constructivism. Technology has been integrated with science in 'Environmental Studies', which is one of five areas of learning.

It is said that the technology curriculum of Scotland is one of the most practical curricula from thirteen countries (OECD) (Black & Atkin, 1996):

> "gtechnology curriculum concentrated in creative, purposeful, practical activity can indeed increase students' interest and motivation, improve students' attitude, and encourage students to become more responsible for their own learning (p.54)."

### 3-1. Contents of "Environmental Studies"

Table 3 shows the contents of "Environmental Studies" in 1993's and 2000's revisions (the Scottish Office Education Department, 1993; Scottish Executive, 2000). Health Education and Information Technology has not been included in 2000's revision. Health Education was shifted over as Religious, and Model Education with Personal and Social Development and Health Education, which is one of the five main curriculum areas in the new revision. Information Technology was translated into Information and Communications Technology (ICT), which was one of the cross-curricular aspects in the new revisions. One of the reasons was to stress a greater coherence between skills accession and the wider use of ICT across the curriculum (Scottish Executive, 2000). That is, it is clear that IT skills are needed as research skills for all subject areas and it that it is useful for pupils to use the skill appropriately.

The data in table 4 is quoted from a part of the National guidelines for Environmental Studies. There have been common features within the framework for skills development, but it also illustrates the distinctive nature of each component, that is, enquiry skills, investigate work and designing and making (Scottish Executive, 2000). It was in order to make pupils become aware of the fact that the skills they learn in one context can be applied in a range of other contexts. Accordingly, it seems that the use of each component was shown more clearly.

**Table 3.** Contents of Environmental Study

| 1993's revisions | 2000's revisions |
|---|---|
| 1. Science<br>2. Social Study<br>3. Technology<br>4. Health Education<br>5. Information Technology | 1. Science<br>2. Social Study<br>3. Technology |

**Table 4.** Overview of 'Environmental Studies' Skills (Scottish Executive, 2000: p.8)

| | Social subjects | Science | Technology |
|---|---|---|---|
| **Preparing for tasks** | Planning tasks;<br>identifying appropriate sources of information | understanding tasks;<br>planning an activity;<br>designing fair tests;<br>predicting | Analyzing;<br>Researching;<br>Planning |
| **Carrying out tasks** | selecting relevant information;<br>Processing information | Observing;<br>measuringusing measuring devices and units;<br>recording findings | developing ideas;<br>creating solutions |
| **Reviewing and reporting on tasks** | Presenting findings;<br>presenting conclusions | describing tasks;<br>presenting findings;<br>evaluating;<br>identifying patterns | Testing;<br>Evaluating |

**3-2. The Relationship between Technology and Science**

The data in table 5 shows the relationship of skills between science and technology about preparing for tasks (Scottish Executive, 2000). Skills of technology progressed from the suggestion of uses for given resources to the investigation and selection of a range of resources and processes. Regarding science, for example, level F was required to plan an appropriate strategy to investigate a hypothesis. Consequently, Science was a research process (to suggest questions) while technology education was a design process (to investigate resources and processes). As for carrying out tasks, developing ideas and creating solutions was stressed in technology. For example, level A used ideas and suggestions to try out possible solutions to brief practical tasks. In contrast, level F used ideas demonstrating a range of techniques and presentation skills. As for Science, level records observations in a simple form. And, level F is to select and use appropriate forms of graphical presentation. It seems reasonable to suppose that technology was connected with science taking each peculiar feature into consideration.

**Table 5.** The Relationship of Skills between Science and Technology (Scottish Executive, 2000)

| **Preparing for tasks, Carrying out tasks** | **Level** | | |
|---|---|---|---|
| | **A (Low)** | **C** | **F (High)** |
| 'Technology'<br>• analyzing<br>• researching<br>• planning<br>• developing ideas<br>• creating solutions | • suggest uses for given resources<br>• use ideas and suggestions to try out possible solutions to a brief practical task | • select possible resources and processes<br>• use ideas, including any new suggestions, to represent a solution to a practical task | • investigate and select a range of resources and processes<br>• use ideas, demonstrating a range of techniques and presentation skills |
| 'Science'<br>• understanding tasks<br>• planning an activity<br>• designing fair tests<br>• predictingo observing<br>• measuringo using measuring devices and units<br>• recording findings | • record observations in a simple form | • record findings in a greater variety of ways | • select and use appropriate forms of graphical representation |

### 4. Science and Technology Curriculum in Taiwan

The newly revised national curriculum that is anticipated to be put into effect in 2001, emphasizes curricular coherence and integration as well as more school-based development and management. The new national curriculum set up seven learning areas: language, mathematics, science and living technology, social studies, arts and the humanities, health and physical education, and comprehensive activities. Figure 1 shows the organization of the new curriculum.

| **Learning areas** | **Grades** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1st** | **2nd** | **3rd** | **4th** | **5th** | **6th** | **7th** | **8th** | **9th** |
| Language | Chinese | | | | Chinese | | | | |
| | | | | | English | | | | |
| Health and physical education | Health and physical education | | | | | | | | |
| Social studies | Living | | Social studies | | | | | | |
| Arts and the humanities | | | Arts and the humanities | | | | | | |
| Science and living technology | | | Science and living technology | | | | | | |
| Mathematics | Mathematics | | | | | | | | |
| Comprehensive activities | Comprehensive activities | | | | | | | | |

**Figure 1.** The organization of seven learning areas

#### 4-1. Science and living technology (SLT)

The predecessors of SLT entitled "handicraft," "industrial arts," etc., existed in schools for around 100 years. Technology education in Taiwan is a new area that has evolved from its predecessors. Presently called "living technology" it is implemented at the secondary school level, and integrated with arts at the primary school level. Technology education is expected to unify science, and has been renamed as "Science and living technology (SLT)" at the primary and secondary school levels. Compared with industrial arts/craft arts, living technology is more systematic and design-oriented and has an emphasis on gender equality. The learning area of SLT has four basic philosophical concepts:

(1) SLT is a basic course for grades 1-9 students.
(2) SLT is conducted by ways of exploration and performance that are emphasized on knowledge, attitudes, design and production, and action-oriented.
(3) SLT emphasizes the open learning and topic-oriented methods that need to match with learners' activities.
(4) SLT needs to be cultivated with the spirit and literacy of science and technology.

**4-2. The goals of Science and living technology**

SLT is to assist students:

(1) in cultivating an enthusiasm and interest in exploring science and to form the habit of active learning.
(2) in learning the basic knowledge and the explorative ways of science and technology, and to be able to apply them in their daily lives.
(3) in cultivating the attitudes of protecting the environment, treasuring resources, and respecting life.
(4) in cultivating the abilities of communicating, cooperating, and treating people harmoniously.
(5) in cultivating the potentials of independent thinking, problem-solving, and the creativity.
(6) in exploring and observing the relationship between human beings and technology.

**4-3. The content of SLT learning area**

The new curriculum content of SLT includes eight indicators of learning abilities and a total of 233 statements of attainment. The eight indicators of learning abilities are introduced in table 7. From the viewpoint of educational contents, the indicators of learning abilities of SLT learning area were categorized in 4 types (See Table 2, Types). Science and Technology education was integrated by Cross-Curricula knowledge and skills, "The attitudes of science", "The knowledge and skills of thinking" and "The skills of process."

**Table 7.** The indicators and sub-indicators of learning abilities for SLT learning area

| The indicators of learning abilities | The sub-indicators of learning abilities | Types |
|---|---|---|
| The essence of science | (0) | Science 1) |
| The application of science | (0) | Science |
| Design and production | (0) | Technology 2) |
| The knowledge of science and technology | Knowledge level, Know the animals and plants that are seen frequently, Phenomena and the observation of phenomenal change, Know the technological products that are used frequently, Know the matter, Know the environment, Know the interaction, Know the growth of animals and plants, Know the technology that is seen frequently, Know the ecology of animals and plants, Know the physiology of animals and plants, The spectacles of energy, Reorganization and balance (13) | Science & Technology3) |
| The development of technology | Essence of technology, Evolution of technology, Technology and society (3) | Science & Technology |
| The attitudes of science | Like to explore, Discover new interests, Deliberate and exact, Seek the truth and exactness (4) | Cross-Curricular 4) |
| The knowledge and skills of thinking | Creative thinking, Problem-solving, Comprehensive thinking, Inferential thinking, Critical thinking (5) | Cross-Curricular |
| The skills of process | Observation, Comparison and classification, Organization and connection, Induction and inference, Communication (5) | Cross-Curricular |

1) Science: science only; 2) Technology: technology only; 3) Science and Technology: integrated science and technology educational contents; 4) Cross-Curricular: Cross-Curricular educational contents

## 5. Science and Technology Curriculum in Japan

Japanese primary schools follow closely a statutory national curriculum comprising Japanese language, arithmetic, science, social studies (grade 3-6), life environment study (grade 1-2) music, drawing and handicrafts, physical education and homemaking (grade 5-6). On the other hand, lower secondary school subjects are comprised of Japanese language, mathematics, science, social studies, arts, music, technology and home making, physical education and English (foreign language). Japan has only just put into effect a technology subject at the lower secondary level (see figure 2).

<table>
<tr><th rowspan="2">Learning areas</th><th colspan="9">Grades</th></tr>
<tr><th>1st</th><th>2nd</th><th>3rd</th><th>4th</th><th>5th</th><th>6th</th><th>7th</th><th>8th</th><th>9th</th></tr>
<tr><td rowspan="2">Science (Rika)</td><td colspan="2" rowspan="2">Life Environment study</td><td colspan="4">Science</td><td colspan="3">Science</td></tr>
<tr><td colspan="4">Social studies</td><td colspan="3">Social studies</td></tr>
<tr><td>Social studies</td><td colspan="4" rowspan="2">none</td><td colspan="2" rowspan="2">Homemaking without Technology</td><td colspan="3" rowspan="2">Technology and Homemaking</td></tr>
<tr><td>Technology and Homemaking</td></tr>
</table>

**Figure 2.** Science and Technology Education in Japan

### 5-1. Technological contents and designing in Japanese primary schools

According to the report of the Scottish Office Education Department's visit to Japanese schools in 1992, it was pointed out that 'the work gave little scope for teaching the processes of design as in the English or Scottish technology curriculum.' On the contrary, many Japanese pupils, teachers and parents have not been aware of technological content and designing in Science or Fine Arts in Japanese primary schools. It is clear that Fine Arts has stressed fine arts rather than handicrafts. This problem is one of being the vague relation in between Science (*Rika*) and technology education.

In fact, what was shown in our study was that there were the design and technological materials in Science or Fine Arts in Japan. For example, there were car models, for which the energy source could be either a battery or a solar cell. And, some kinds of materials were dealt with in Fine Arts. As the Scottish Office Education Department points out, no designing work was given in both Science (Rika) and Fine Arts. As only scientific activities were stressed, observation or experiment was taken in Science (Rika). As a result, it should be noted that pupils have not understood what or why they studied, that is to say, the relationship between their study and real daily life.

### 5-2. Technology and Homemaking

Technology and Homemaking was comprised of 11 areas in the previous National Curriculum.

Of those 11 areas, the six areas of technology are woodwork, metalwork, machines, cultivation and the fundamentals of information. The new course of study for Technology and Homemaking integrates the above six areas into two integrated strands:
(1) technology and making artifacts;
(2) information and computer.

The overall objectives in Technology and Homemaking were as follows (in English):

> To make students acquire fundamental knowledge and skills regarding making products, energy, utilization, putting into practical use a computer and other thoroughly practical and experimental learning activities, thereby making them cultivate a better understanding of technology, and to develop an ability to put them into practical use.

### 5-3. The Relationship between Technology and Science

The Ministry of Education, Culture, Sports, Science and Technology (MECSST) has been studying the research of reorganization and integration of subjects for the next curriculum in Japan. Five learning areas have been introduced from the 3rd grade through the 9th grade in 3 schools that were appointed by the MECSST in 2001. Hence, the curriculum development concerning the relationship between technology and Science has been required.

## 6. Comprehensive discussion

### 6-1. Relationship between Science and Technology education

*6-1-1. DESIGNING*

As for technology education as a general education, design has been carried out technology education of Northern Ireland and Scotland. On the other hand, the learning to use tools or techniques has been emphasized in technology education in Japan to increase efficiency. In other words, designing has not been carried out in technology education in Japan, because the concept of design or designing is only included in one element, that is to say, in drafting or planning and so on.

> "Designing requires pupils to make judgements and to be creative. This means that design activities should not be constrained by a need to work towards a pre-determined 'right' answer. Any solution that is arrived at during designing will be a compromise, and so, pupils should be encouraged to think of solutions in terms of 'most appropriate' or 'best', rather than as 'right' or 'wrong' (Northern Ireland Curriculum Council, 1992, p.12)."

From the above, designing could be summarized as a creative problem-solving process. NCCI (1992) pointed out opportunities provided by designing as follows;

> "In undertaking designing, pupils should have opportunities to:
> - determine and define problems;
> - model possible solutions, both mentally and physically;
> - make value judgements in selecting solutions;
> - realize the most promising solutions; and
> - evaluate what is produced and introduce modifications, if appropriate (p.12)."

We must note that designing skill, as a creative problem problem-solving skill, did not only relate to technological subject but also to the other school subjects in this paragraph.

*6-1-2. PROBLEM-SOLVING SKILLS OF SCIENCE AND TECHNOLOGY*

It has sometimes been argued that there is a general problem-solvin g process in the science and technology learning activities. In order to explore this matter, it is helpful to compare models of the processes which have some foundations in observations of pupils' working on science and technology problems (see Figures 3 and 4).

It would seem that the 2 activities share several common features. They are purposeful activities that involve value judgements and require the modeling of ideas and "visionary thinking." Furthermore, the descriptions of the activities employ common terms, as "generating a problem/detailing a problem" and "planning" and "evaluating."

### 6-2. Significance and problems of science and technology education

What is the merit of integrating science and technology in school subjects? At first, science and technology are different, yet there are symbiotic areas where both overlap and contribute to each discipline. Technology is much more than an applied science. Science is quite different from theoretical technology. When one alters the natural world using technology, it impacts both science and technology. Science is dependent on technology to test, experiment, verify, and apply many of its laws, theories, and principles. Likewise, technology is dependent on science for its research, laws, principles, and knowledge base (see table 8).

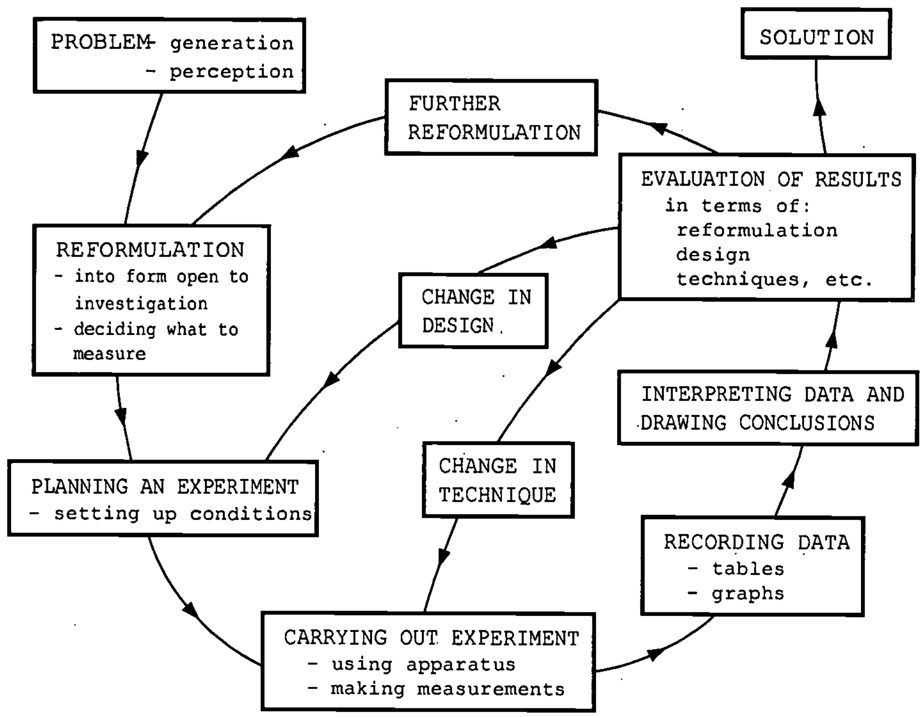


**Figure 3.** Assessment Performance Unit (APU) science problem-solving model (Layton, 1993: p46).

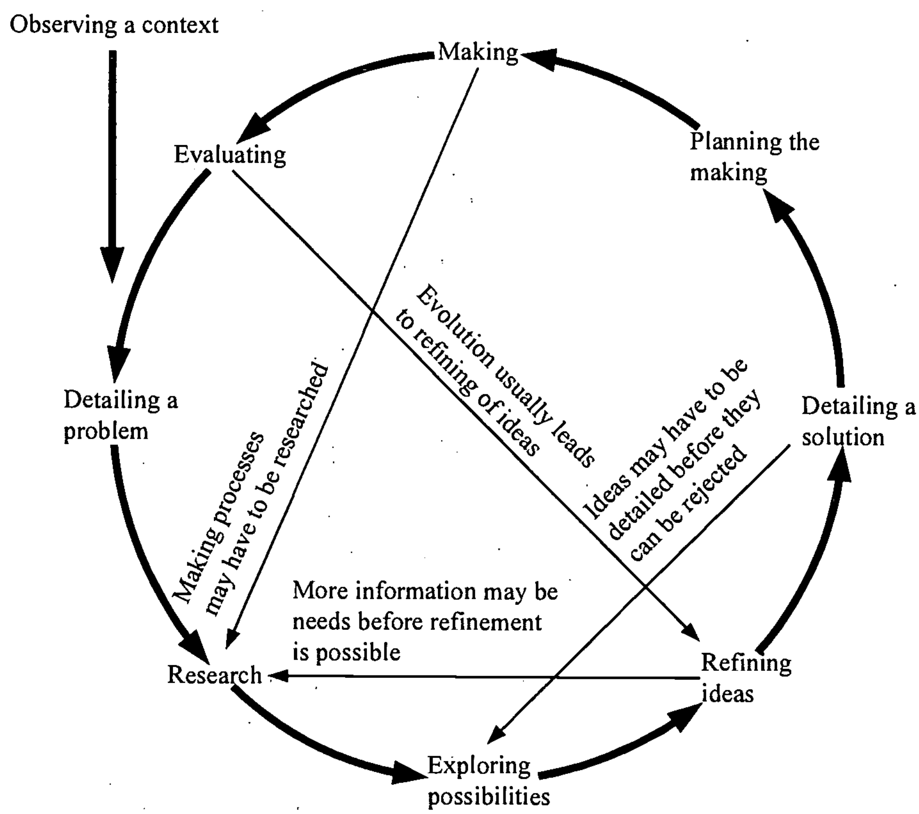


**Figure 4.** An interaction design cycle (Layton, 1993: p47).

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The second point is a constructivist instructional model, such as the Science-Technology-Society (STS) approach. A constructivist philosophy is embraced and ideas are put into practice by using the STS approach. This approach focuses on teaching and learning science in the context of human experience. The STS concept has been defined by National Science Teachers Association as;

> "Teaching and learning of science / technology in human experience; the inclusion of technology as well as natural science; and the importance of human experience as requisite for learning (NSTA, 1992: p.22)."

It seems that a constructivist philosophy suggests the significance of integrating science and technology in school subjects.

However, there are many matters about integrating science and technology as primary and secondary school subjects. One of those matters is the teacher. In other words, who should teach this? Introducing integrated subject like science and technology will give teachers serious problems in lower secondary school rather than primary school, because all teaching in lower secondary school is undertaken by specialist teachers. This problem is also associated with the teacher training system.

**Table 8.** Comparison of Technology & Science (Dugger, 1994: p. 8)

| TECHNOLOGY | SCIENCE |
|---|---|
| Involved with our human created world. | Involved with our natural world/universe. |
| Concerned with 'How to.' | Concerned with 'What is' |
| Knowledge created and being created. | Knowledge discovered and being discovered. |
| More directly involved. | Detached ..Generates Knowledge for its own sake. |
| Guided by trail and error or skilled approaches derived from the concrete. | Guided by hypotheses deduced from theory. |
| Concerned about the solution of problems and application of knowledge to that solution. | Concerned about the solution of problems and application of knowledge to that solution. |
| Used in combination with such words as: Application, Instrumental principles, Tools, Responses to perceived needs, Artifacts, Practice, Effectiveness, Empirical laws, Invention, Innovation | Used in combination with such words as: Theory, Theoretical principles, Research, Generalization from theory |
| Its success or failure is usually determined by social acceptance and success in the marketplace. | Its success is not judged by social utility. |
| Action oriented & requires intervention. | Research/theory oriented. |
| Involved constantly in studying mean-ends relationship. | Remains separate from what is being investigated. |
| Systems oriented. | Laws/principles oriented. |
| Making/doing things. | Understanding things. |
| Philosophical relation: pragmatism | Philosophical relation: realism |
| Dependent on Science and Mathematics. | Dependent on Technology and Mathematics. |

**6-3. Suggestion for subject reform in Japanese primary and lower secondary education**

In conclusion, this study has indicated three points for subjects' reform in Japanese primary and lower secondary education:

(1) From "Subject" to "learning area" at primary the level.
In Northern Ireland, each "Area of Study" consists of one or more contributory subjects and together they form a framework of teaching and learning. Northern Ireland Curriculum Council (NICC) defined "Area of Study" as follows:

> "The broad aspects of the curriculum which, taken together, are integrated to provide pupils with a balanced curriculum (NICC, 1990: p.25)".

"Area of Study", "area of learning" and "leaning area" emphasized on "contexts for learning." In this background, there was the constructivist view of learning. Their theory suggests that as pupils learn, they do not simply memorize or take on others' conceptions of reality. Instead, they create their own meaning and understanding. It is important for teachers to develop the curriculum to meet their pupils' individual needs and circumstances. Therefore, the learning area was focused on the view of learner rather than teacher. However, all of curricula at the primary and secondary levels in three countries has not been organized by learning areas. One of the reasons was that the difference between primary level and secondary level was based on pupils' developmental stage. Consequently, it seems that learning area was a helpful perspective for primary subjects' reform.

(2) Focusing on cross-curricular learning skills.
Cross-curricular knowledge and learning skills were key-concepts in integrating science and technology in school subject. From comparison of problem-solving skills of science and technology, both activities shared several common features. Focusing on cross-curricular learning skills might be helpful for subject reform in Japan.

(3) Top-down curriculum development
Japan has a traditionally strong national system of education, which is supported by top-down management. From Japan's government education policy, however, the national curriculum standards will be clearly specified and more flexible. In order to carry out this policy, we must reform educational management to build-up systems. By doing this, each school will be able to make its own curriculum in accordance with the actual situations of the community, school and pupils. Furthermore, it seems that we should establish an external evaluation system to obtain a national consensus and to ensure accountability to the society.

**References**

BLACK, P. & ATKIN, J. (Eds.) (1996). *Changing the subject, Innovation in science, mathematics, and technology education*. London and New York in association with OECD, London, U.K.:Routledge.

DEPARTMENT OF EDUCATION (DENI). (1989). The Education Reform (Northern Ireland) Order 1989. URL http://www.hmso.gov.uk/si/si1989/Uksi_19892406_en_1.htm

DUGGER, W. E. JR., (1994). The Relationship between Technology, Science, Engineering, and Mathematics. *The Technology Teacher*, 53(7), pp.5-8.

ISOBE, M. AND YAMAZAKI, S., (2001). The Comparative Study of Technology in the Scotland National Guidelines in between 1993 and 2000's Revision, *Proceeding of the 4th International Conference on Technology Education in the Asia-Pacific Region*, Daejeon, Korea, pp.163-169.

KAO, W. M., HUNG, C. S. and CHEN, Y. H., (2001). The Status of New 2001 National Curriculum or Primary and Secondary Technology Education in Taiwan, *Proceeding of the 4th International Conference on Technology Education in the Asia-Pacific Region*, Daejeon, Korea, pp.44-57.

KING, C., (1994). Providing Advice and Support for the Technology Curriculum, A Northern Ireland Perspective. *The Technology Teacher*, 53(5), pp.23-26.

LAYTON, D., (1993). Technology's Challenge to Science Education. Open University Press, Buckingham, U.K.

NATIONAL SCIENCE TEACHERS ASSOCIATION (NSTA). (1992). Scope, Sequence and Coordination of Secondary School Science. Vol. 1. The Content Core: A Guide for Curriculum Developers. Washington, DC,USA.

NORTHERN IRELAND CURRICULUM COUNCIL. (1992). A Report on the Statutory Consultation for Programmes of Study and the Attainment target for Technology and Design, Belfast, U.K.: NICC.

The Scottish Office Education Department. (1993). Curriculum and Assessment in Scotland National Guidelines, Environmental Studies 5-14, Edinburgh, U.K.: Author.

**URLs**

JAPANESE CENTRAL COUNCIL FOR EDUCATION. (1997). The model for Japanese education in the perspective of the 21st Century (The 2nd Report by the Central Council for Education).
URL http://www.mext.go.jp/english/news/1997/06/970601.htm

SCOTTISH EXECUTIVE. (2000). The Structure and Balance of the curriculum, Guide for Teachers and Managers. URL http://www.ltscotland.com/guidelines/index.htm

**Keywords**: Reorganization of School Subjects, Science and Technology Education, Northern Ireland, Scotland, Taiwan

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# ECOLOGICAL THINKING: AN ALTERNATIVE PARADIGM FOR ENVIRONMENTAL EDUCATION AND STS AN INTERACTIVE SYMPOSIUM

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**Abstract**

A brief historical sketch of Science Education discloses a clear trend of change from Science as an objective neutral body of knowledge, to Science as an ongoing process of discovery, a human endeavor to understand and cope with the world, and thereby subjective, context bound, and value laden. The STS movement accordingly, regarded science and technology as part of our social discourse namely, relevant, interdisciplinary, context-bound and dynamic. Yet, our argument in this paper is that the STS movement has not ventured far enough on the axis of the relationship between man and the system, neglecting *the issue of our role as humans in the system.*

Stemming from the modern ecological conception of *open instead of closed systems*, **Ecological-thinking** emphasizes our double role as both actors and reflectors in the system. As actors, we interact with the other components of the system, while as reflectors, we are able to reflect on this interaction, conceptualize it and take responsibility for our knowledge constructions, conceptions and understanding of our world.

Ecological thinking is our metaphor for both the process and the product. Responsibility is a key word in both STS and Environmental-education (EE). It is our responsibility as educators, to develop our students, the citizen of the future, to cope with the poor conditions of our postmodern world, due to our faulty actions, governed by having misunderstood our world. As STS and EE educators, we are committed to introduce ecological thinking as an alternative epistemology, and educate our students to realize their responsibility as part of their double role. How to acquire Ecological Thinking is the focal question of this paper. We contend that rather than taught theoretically like logical or critical thinking, it should be practiced within a framework we term a 'community of learners'. A **'community of learners'** is a self-organizing group, creating its own agenda and assuming responsibility and ownership for its mode of functioning as well as for its 'products' (Herbst. 1986). Led by open conversation rather than by pre-defined goals and objectives, participants indulge in mutual reflection and knowledge reconstruction, as a result of which new understanding emerges. We believe that such communities of learners form an optimal framework for the dialectical learning process between the individual as an agent within, and as a reflective participant of the community, without.

We open the symposium with a theoretical introduction that underlines our rationale. To illustrate what we mean, four case studies are then presented, taken from different educational settings. They illustrate each, a community of learners as context for the development of the participants' ecological thinking. Finally, by analyzing the four different examples, ecological thinking emerges as a new metaphor for both the conception and action, in terms of our role

## Introduction

The changes Science Education has undergone during the past five decades, I suggest to regard as a trend along the axis of man reality relationship. Starting with the Russians Sputnik, Schwab's response was to 'teach science as an enquiry' rather than as a rhetoric truth. Yet, the assumption that new inquiry-based curricula would improve scientific literacy, was soon found faulty, and teachers were blamed for distorting the curriculum. The next step was 'Teacher-proof curriculum', enhancing a direct interaction between students and knowledge in the form of learning materials. Yet, neither the introduction of computers nor the accessibility of various sources of knowledge, succeeded to increase the attractiveness of science education. Indeed, the number of students, both in high-school and the university, who chose to study Science, kept declining.

The STS movement, which rose as a response, indicates a paradigm shift, in terms of regarding science and technology as part of the social discourse, rather than as an objective, disciplinary body of knowledge.

The new assumptions were relevancy, interdisciplinarity, context-bound knowledge and dynamism, characterizing the constant process of change of post-modern society.

This brief historical sketch, discloses a trend, which I would like to highlight in this paper: From Science as an objective neutral outside entity, to Science as an ongoing process of discovery, a human endeavor to understand and cope with the world. In other words, on the relationship between man and the system axis, *the emphasis moves from the system to man*.

Our main argument in this paper is that the STS movement has not ventured far enough on this trend. Whether intentionally or not, it has avoided the issue of *our role as humans in the system*..

**Ecological thinking**, is our term for the double role we humans are committed to, as both actors and reflectors. The concept stems from the shift in the ecological conception from 'closed systems' to 'open systems'. Accordingly, humans are no more regarded as outsiders, 'disturbing' the ecological equilibrium, but rather as important components of the system (Davis, 1986). Thus, we interact as *actors* with the other components, while as *reflectors* we are aware of the system and ourselves as an active part within, and are therefore responsible for our understanding and actions (Keiny, Shachak & Avriel-Avni, 2001). As STS and EE educators, we see it as our responsibility to introduce *ecological thinking as an alternative epistemology,* and educate our student to realize their responsibility as part of their double role. We argue that to develop ecological thinking a self-organizing framework is required.

**Self-Organization**, was introduced by Prigogine as an open-ended concept, implying that *the future evolves from the present* namely, is dependent on interactions that have happened and are continually happening. It is a 'becoming' process that is *both determined and unpredictable*. Maturana and Varela, who used the term **autopoietic system** instead, saw self-organization as the *basic principle of the living system.*: "The living system is an autopoietic system that originates a recursive enactment of materials by which its structure is constituted" (Maturana & Varela, 1998).

By extending the idea of self-organizing systems, from the natural to social systems, humans who share a system of signs or a language, as a framework in which they interact or behave with respect to each other, are **semiotically coupled**. (Pierce in Guddemi, 2000). Semeiotic coupling creates a **community,** and when the participants of a community share their interpretants in conversationing, they develop **a culture.** In this way, the system of signs (or language) which emerged from the community of speakers, develops its own existence that in many ways determines the speakers way of thinking (Maturana & Varela, 1998).

A **community of learners** is a heterogeneous group, consisting of different participants that interact on an equal level. It is a self-organizing system, in the sense of creating its own agenda and assuming responsibility and ownership for its mode of functioning as well as for its 'products' (Herbst. 1986). The participants or learners of the community, are led by an open conversation rather than by pre-defined goals and objectives. Knowledge is reconstructed out of their dialectical process of reflection, and new understanding is gained.

The four of us are all members of a community of learners, which meets regularly for more than three years. Each of us participants, acts also as facilitator of a learning group, or an STS or EE classroom. From the start, we refrained from defining our joint learning in terms of goals or objectives. We carry an open conversation feeding in episodes from our field of action, namely our various group work. Theoretical knowledge is also introduced by reading and discussing a relevant paper or book and trying to integrate it with our experiential knowledge.

As a self-regulating group, we see in our conversationing a growing system of shared interpretants. These develop into a rich language of the profession, that now also influences our way of thinking. Thus our conversation becomes a source of mutual new understanding in terms of knowledge reconstruction.

Our community of learners serves as an optimal medium for each of us to experience the double role, of being both a group facilitator, as well as an outside reflector within our group. It is a medium in which we experience the mutuality, the interdependence between the group as context of learning, and the individual learner, who is responsible for creating it. As such, it is a medium for developing Ecological Thinking.

Finally, Ecological thinking should be understood as both the framework, the multi-level processes, and the product namely, the knowledge construction of each participant as well as that of the group. Using the term construction may be misleading for there is nothing stable about this knowledge which is constantly dynamically changing

The purpose of this symposium is to illustrate the dialogic discourse within such a community-of-learner. Three episodes were chosen by the facilitators, from their different learning contexts to show how the community of learners actually develops the participants' Ecological Thinking

*Ety Hagai (Ben-Gurion University, Beer-Sheva ety@subjective.co.il)*
As an organizational developer, my aim is to facilitate change processes that are initiated in different educational settings. Though triggered usually by the school-principle, such change processes entail participants' involvement in multi-level learning processes. Namely, in individual learning; group learning; and in some cases the institution as a whole indulges in organizational learning.
My aim is to develop these different contexts of change to become 'communities of learners', where participants can engage in open conversation. By questioning their behavior and reflecting upon their actions, members of the community are able to conceptualize it into theories-of-action. In this way I believe, they become responsible for their newly reconstructed systems of knowledge as well as for their future actions.
I see my facilitative role as a pre-requisite for such learning processes to develop. Thus I conceive self-awareness as an important part of my role. In other words, I saw it as my responsibility to be fully aware of my own behavior as group facilitator, to reflect upon the interpersonal relationships among participants, and the ways it is related to me as a person .The following case study illustrates how my collaboration with a community of learners, led to my own conceptual change in the way I conceive my role as a facilitator.
My case study is about a community-school, that strove to become a self-management school. Our collaborative work focused on developing the school as a system, rather then as a hierarchical pyramid-like institution, which involved the establishment of subsystems namely, different groups of teachers, and examining the relationships between them. An 'ecological-bubble', purchased by the school for ecological studies, served the teachers as a pedagogical laboratory. Applying ecological relationships to their school organization, they developed a system conception of the communal school.

*Noa Avni-Avriel (Ben-Gurion University, avrielav@bgumail.bgu.ac.il)*
Environmental Education is a dominant and popular issue in Israel, yet, most EE curricular units adhere to the conventional ecological conception of Nature Preservation. Accordingly, man is conceived as an outside intruder that distorts the natural ecological equilibrium.
My idea was to develop a new type of Environmental Education curriculum, based upon an alternative ecological conception, whereby man is seen as an integral part of the system, rather than an outsider.
My developing team consisted of a voluntary group of High school teachers of various subjects, and a corresponding voluntary group of students who chose to participate in the project. The developing site was Mitzpeh-Ramon, a small town in the Negev desert. Being myself an inhabitant of the town, I acted as the group facilitator.

We met regularly as a curriculum developing team, generating new ideas, which were tested simultaneously in the classroom. All teachers took part in teaching, as well as in reflection-on-action on the teaching and learning processes of the students and of ourselves as teachers.

The rationale of the curriculum, which gradually emerged, was based on students' investigation of their town or their environment. Encouraged to choose their topic of inquiry, they formulated research questions and collected relevant data. In other words, students actually studied different subsystems of their urban system. After reporting their findings in the plenary, a whole network of relationships was disclosed, among the different subsystems and most importantly, between the natural and human systems.

My aim in disclosing the different relationships, was to develop the students' awareness to our important role as humans in the system. Our double role as active participants within, as well as a reflective agent from without, who are able to understand the complexity of the environment, to construct system models and act responsibly towards its welfare.

The paper illustrates the process of curriculum development as coupled with teachers professional development, which entailed a paradigmatic shift in terms of man environment relationship. This conceptual change was also reflected in the teachers' pedagogy, in their conception of their teachers' role.

*Judith Zamir, (Ben-Gurion University, jzamir11@bezeqint.net)*

My context is an STS project, which involved 3 universities collaborating with several High schools. The idea was to involve the teachers in STS curriculum development, and thereby enhance their professional development. This was defined by the principle as: *moving from teaching to learning.* In other words, to conceive their role as promoting students' learning, instead of as transmitters of knowledge.

I acted as a facilitator of one such group, which consisted of 10 teachers of different disciplines. They were all keen to change, but (as I soon found out) were completely unaware of the implications of that change. They did not realize the different assumption of knowledge underlying this new pedagogy. Namely, knowledge as dynamic and subjective, constructed and reconstructed by the student, instead of knowledge as an objective neutral entity, a one and only truth .

To introduce the new pedagogy of 'student inquiry study' into their classroom, I had to facilitate a long process of learning within the group which eventually led to their conceptual change.

My first aim was to develop the group into a community-of-learners, by encouraging them to bring up issues or problems from their classroom experience. I refrained from solving problems or giving advice, choosing instead to reflect, to linger and elaborate on the problem in order to gain a deeper understanding. My assumption was that teachers have to become learners themselves, before they can promote their students to become autonomous learners, capable of inquiry study.

**Keywords:** Ecological-Thinking; self-regulation; community-of-learners; STS; Environmental-education

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# STUDIES OF HOW STUDENTS AND SCIENTISTS EVALUATE SCIENTIFIC CLAIMS FROM THE WORLD WIDE WEB: A METHOD FOR FORMULATING GOALS FOR SCIENTIFIC LITERACY AND CRITICAL INFORMATION LITERACY

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**Abstract**

This study examines how 16 subjects (including 10 17-year-olds and 6 scientists and policy analysts) evaluated questionable scientific claims made in materials found on the World Wide Web. The materials, which all concerned global warming, included an article from a city newspaper and an editorial from the Web site of an oil company. The study exemplifies an empirical strategy to serve as a component to movements to develop curriculum standards for scientific literacy and information literacy. Some high school student protocols illustrate ways that a non-expert can be adept at critically evaluating scientific claims, while other student protocols illustrate areas of difficulty. The study supports some recommendations of earlier standards documents and also suggests refinements.

The skill to critically evaluate scientific claims from electronic sources takes on increasing importance in an era of rapidly expanding information technologies and changing scientific knowledge. This study compares how a group of high school students and specialists (scientists and policy analysts) evaluated material found on the World Wide Web making dubious scientific claims. The topic of the materials concerned global warming, and thus the study is set in the context of evaluating information relating to an international issue involving science, technology, and society.

The World Wide Web is a technology that can dramatically increase access of the public to scientific information. The Web encompasses material from such a broad variety of sources—including materials from scientific agencies, advocacy groups, corporations, traditional print media such as newspapers and magazines, and even personal home pages—that it is essential for public education to foster the development of skills to critically evaluate all such materials. Even before the advent of the Web, the ability to evaluate claims from traditional print media would have to be considered a vital part of scientific literacy. Now that the Web is increasing the availability of such information, critical evaluation skills take on increasing importance. As classroom access to the World Wide Web increases, teachers may more readily incorporate such materials (including materials also published in print media) into lessons. Further, the ability to evaluate information sources is key to lifelong learning.

This paper is framed as part of ongoing dialogues among scientists and educators about what scientific and information literacy should include and what goals it should serve. In the United States, the American Association for the Advancement of Science (AAAS) has developed works delineating the knowledge and skills comprising scientific literacy including <u>Science for All Americans</u> (<u>SFAA</u>) (Rutherford & Ahlgren, 1990) and its companion volume, <u>Benchmarks for Scientific Literacy</u> (AAAS, 1993). The National Research Council (NRC) developed the <u>National Science Education Standards</u> (<u>NSES</u>) (National Research Council, 1996), although the AAAS works mentioned earlier give greater attention to critical evaluation of scientific claims. Also, the International Society for Technology in Education (ISTE, 1998) and American Association of School Librarians (AASL, 1998) have published standards documents which incorporate as a goal skills to evaluate electronic information sources. Table 1 gives examples of standards or performance indicators from a selection of standards documents pertaining to the skill of evaluating material presented in electronic information sources.

**Table 1.** Examples of Standards Pertaining to Critical Evaluation of Arguments

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|---|
| AAAS (1993)<br>By the end of the 12th grade, students should:<br>• Notice and criticize arguments based on the faulty, incomplete, or misleading use of numbers...<br>• Be aware, when considering claims, that when people try to prove a point, they may select only the data that support it and ignore any that would contradict it.<br>• Suggest alternative ways of explaining data and criticize arguments in which data, explanations, or conclusions are represented as the only ones worth consideration. (p. 300) |
| ISTE (1998)<br>• Prior to completing of Grade 8 students will:<br>• Research and evaluate the accuracy, relevance, appropriateness, comprehensiveness, and bias of electronic information sources concerning real-world problems. (p. 13) |
| AASL (1998)<br>• The student who is information literate evaluates information critically and competently.<br>• The student who contributes positively to the learning community and to society is information literate and recognizes the importance of information to a democratic society. |

I argue that empirical study of how high school graduates (and scientists) perform the task of critically evaluating scientific claims from mass media sources is a useful but underutilized resource for formulating goals for scientific and information literacy. The study of high school students who are relatively competent at critically evaluating media articles can be useful in identifying what is possible for students to achieve, while the study of students who are relatively less competent at the task can be useful for illustrating possible pitfalls. The study of scientists can illustrate what is possible with more specialized knowledge, and can also illuminate possible goals for high school students, provided that judgments are made about scientists' knowledge and skills that are appropriate and accessible to high school students.

In the present study, high school students and scientists (and policy analysts with scientific knowledge) were interviewed as they evaluated articles about global warming. Global warming was chosen as an exemplar of a contemporary scientific issue that involves controversies and new scientific developments and is frequently mentioned in the media. One reason to use global warming as a focus for an inquiry into goals for scientific and information literacy is that it is a critical scientific and societal issue of our time. Given the potential impact of global warming (IPCC, 2001), it is imperative that citizens be prepared to make judgments about policies that would affect it. Moreover, I argue that the task of making judgments about claims about global warming from mass media sources lies squarely within the realm of what one might propose as goals for (or definitions of) scientific and information literacy.

A growing body of research examines how lay persons understand concepts associated with climate change. The lay persons studied have included adults (Bostrom, Morgan, Fischhoff, & Read, 1994; Doble, Richardson, & Danks, 1990; Kempton, Boster, & Hartley, 1995; Read, Bostrom, Morgan, Fischhoff, & Smuts, 1994), high school students (Adams, 1999a, 1999b; Boyes, Chuckran & Stanisstreet, 1993; Gowda, Fox, & Magelkey, 1997), middle school students (Meadows & Wiesenmayer, 1999; Rye, Rubba, & Wiesenmayer, 1997) and even elementary school students (Francis, Boyes, Qualter, Stanisstreet, 1993). Morgan and Smuts (1994) developed a brochure about global warming for on lay persons based on mental models research (Bostrom, Morgan, Fischhoff, & Read, 1994) and survey studies (Read, Bostrom, Morgan, Fischhoff, & Smuts, 1994). This body of literature provides a useful perspective on how lay persons view global warming. In contrast, the present study illustrates how the issue of global warming can serve as a lens for formulating goals for scientific and information literacy. The intent is draw out issues which may be more general than the issue of global warming per se.

Another view of scientific and information literacy comes from the small amount of existing research on how students evaluate science articles in the media. It is surprising that little research is available specifically concerning how high school students evaluate or should evaluate such articles, since one of the most useful things that an education concerned with scientific and information literacy can do is to prepare students to critically evaluate reports of science in secondary news sources. An article by Korpan, Bisanz, Bisanz, & Henderson (1997) studied how college students evaluated scientific news briefs. Whereas the present study emphasizes the role of subjects' prior scientific knowledge in this process, the Korpan et al. study de-emphasized it. Korpan et al. used short (3- sentence), fictitious articles because of a concern that the science content of real articles could mask more general critiquing skills. In contrast, the present study uses real (and longer) articles with the aim of eliciting and evaluating science knowledge. In addition, the use of real articles provides a complex task that more closely resembles the scientific and information literacy goal of critiquing real articles.

## Method

### Subjects

Sixteen subjects participated in the study, including 10 high school students and 6 specialists. The students were all 17 years old and seniors from a high school in the United States San Francisco Bay Area. They were drawn from science classes having students of mixed ability levels. Four students were male and six were female; two were African American, and one was Asian American. They were paid $5.75 per hour.

The 6 specialists included three scientists, two policy analysts, and one engineer. The scientists were all actively involved with research connected with climate change. One of the scientists worked at a major national research laboratory, one was a postdoctoral researcher at a major research university, and one was a doctoral candidate at a major research university. The policy analysts both had experience with policy issues connected with climate change. They were included for their perspectives not as scientists practicing in the area of climate change but as subjects with scientific expertise about climate change derived from working in a professional capacity with the issue. The engineer had studied climate change independently. Except for the post-doctoral researcher, all of the specialist subjects participated on a volunteer basis. The postdoctoral researcher, who participated in subsequent experimental activities, was paid $12.50 per hour. The ages of the specialists ranged from 27 to 65. One specialist was a woman and the others were men.

In the recruitment process, specialists were told that the topic of the study concerned global warming, in order to make it clear why their particular expertise would be helpful. However, high school they were not told the topic of the study in order to avoid biasing the sample towards students with particular interests in the topic.

### Articles

Subjects were asked to read a variety of real articles taken from the Web, which make various dubious scientific claims about global warming. It was expected that many of the claims would be new to the high school students but familiar to the specialists. The articles discussed here came from the web site of an oil company (Mobil Corporation) and a city newspaper (The San Francisco Chronicle). The articles selected represent different kinds of information sources that lay persons might encounter. They differed in the nature and quality of their arguments, their presumptive reliability, and their points of view." A brief description of the articles follows.

**Oil Company editorial.** Mobil Corporation (1996, July 18). "Less Heat, More Light on Climate Change." [on-line]. Available: http://www.mobil.com.

This editorial from Mobil Corporation, which is framed as a public service, provides background information about the causes of global warming. Information given in the editorial, while accurate, could give a misleading impression. In particular, the editorial notes that more warming is caused by natural water vapor then by man-made causes and that greenhouse gases are building up slowly. This well-crafted editorial was chosen because it presents scientific evidence in a selective and "slanted" fashion.

**City newspaper article.** Marshall, Jonathan (1997, January 27). "Warming Not a Global Problem." San Francisco Chronicle. [on-line]. Available: http://www.sfgate.com/search.

This article reports on supposed benefits of global warming. The author notes that agriculture would benefit from global warming, just as plants thrive in greenhouses. The article reports on a study affiliated with the Electric Power Research Institute, suggesting that global warming would result in a $174 billion increase in agricultural productivity in the United States in the next century. Describing global warming as an economic "win" for the United States, the article does concede that there would be "losers" elsewhere. The article was chosen because of its distressing perspective that global warming was not a U.S. problem.

**Procedure**

The interviews were semi-structured. An overall script was used, but the experimenter would ask clarifying questions and/or follow-up questions. The benefit of this approach is increased flexibility and information, but the drawback is reduced experimental consistency. The increased flexibility of a semistructured interview was judged to be a higher priority, given the goals of the study. Table 2 gives the questions of the Media Interview.

**Table 2.** Interview Questions For Media Interview

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|---|
| What did you think of the article / editorial? |
| Are there parts of the article you agree with? (Why?) |
| Are there parts of the article you disagree with? (Why?) |
| What would you say the purpose of the article / editorial is? |
| How would you rate reliability of the article / editorial, on a scale of 1 to 6, where 1 is least reliable and 6 is most reliable? (Why?) |

This study was part of a larger study of how high school students and specialists evaluated issues associated with global warming. Prior to the interview discussed here, participants were given questionnaires about policy options to ameliorate global warming and interviewed about their beliefs about the science and uncertainties of global warming.[1] To ensure that the high school students were familiar with basic information about global warming, they were asked to read an informational brochure about global warming prepared by researchers at Carnegie-Mellon University (Morgan & Smuts, 1994). This was done to ensure that subjects had a foundation of contextual information prior to being asked to evaluate the new information in the articles. After the Media Interview, some of the subjects participated in additional experimental activities including discussing policies affecting automobiles designed to ameliorate global warming; these are discussed in Adams (1999b).

The interviews were audiotaped and transcribed. The discussion that follows illustrates ways in which the specialists and students evaluated claims in the articles. A limitation of the analysis involves the process of selecting the excerpts. A different coder might have selected different excerpts. However, for the initial purposes described here, the methods were judged to be appropriate to the task. The goal of the discussion is not to attempt to make generalizations about the cognition of all high school students or scientists, but rather to identify kinds of responses that may be considered more or less scientifically literate.

## Results

As we shall see, in some cases, the better student critiques paralleled those of the specialists. However, we shall also see that the specialized scientific knowledge of the experts was not essential for students to successfully critique the claims made in the articles.

[1] Adams (2001) discusses these subjects' views of the uncertainties of global warming.

### Oil Company Editorial: "Less Heat, More Light on Climate Change"[2]

The oil company editorial served as a prompt for probing how subjects interpreted "slanted" scientific claims. One of its claims is that the greenhouse effect is due to natural causes: "Naturally occurring greenhouse gases—predominantly water vapor—account for 95 to 97 percent of the current effect. The other 3 to 5 percent is attributable to man's activities." Although this claim is true, emphasizing the relative amount of the human contribution may tend to obscure its significance. Specialists responded to this statistic by clarifying that the issue is not natural warming due to water vapor; the issue is adding to the greenhouse effect via human activities:

> Water vapor is, you know, predominantly responsible for the current greenhouse effect, but that's not what we're worried about, not the current effect. We're worried about perturbing that, and adding to it. (Sue, scientist)

> It doesn't matter if it's a 1% or a 20% [change]... it's the impact of the perturbation, not that the change is small. (Ron, scientist)

The response of one student, Marie, echoed that of the specialists in distinguishing between the natural and the man-made greenhouse effect:

> I mean the earth does warm up gradually by itself. We've just sort of hurried it up a little bit. (Marie, student)

Both Marie and Kyle considered issues of scale in interpreting the claim:

> I don't know about these numbers that they have, that "naturally occurring greenhouse gases account for 97% of the current effect." I don't know if those are true, they could be outright lying. If it is true, I still think it's kind of alarming that 3-5% is attributable to humans. Even though that seems like a small amount, there's so much air in the atmosphere that that's actually a lot. (Marie, student)

But with the amount of gas in our atmosphere, it's still a large amount. (Kyle, student)

On the other hand, the student Thomas drew the inference that the human contribution to global warming is not significant:

> I think there was one part which I was kinda shocked by. That like, what is it, $CO_2$ only produces—water vapor will account for 95-97% of the current effect? The other 3-5% is attributable or whatever to man's activities...And if that's true what we do doesn't really matter. (Thomas, student)

This student got the idea that perhaps a big dehumidifier (!) would be a way to ameliorate global warming:

> If that issue of 3-5% is true, then we should definitely be working on the 95-97% water vapor causes in the greenhouse effect. That's what we should be working on. Maybe we should put a big dehumidifier somewhere, something like that. See what that does. (Thomas)

His response thus illustrates a rather colorful mis-consideration of issues of scale.

Another claim of the oil company editorial was that since greenhouse gases are building up slowly, we have time to mitigate the problem: "The concentration of greenhouse gases is building up slowly — less than 0.5 percent

[2] The discussion of subjects' responses to the oil company editorial given here draws upon the brief discussion given in Adams (1999a).

seemingly small rate of increase of carbon dioxide may tend to obscure critical factors such as the effects of the carbon dioxide on the climate system, the amount of time required to reduce carbon dioxide levels, and the amount of time required by humans to make significant infrastructure changes to reduce greenhouse gas emissions. One scientist used knowledge of the residence time of carbon dioxide to critique this claim regarding the rate of increase of the carbon dioxide buildup:

> I mean the $CO_2$ lifetime is 40 years in the atmosphere. It doesn't matter if it's going up 0.5% annually, that's a long time. . . if you make a change now, the effects of the things you did last year are gonna be felt for the next 40 years. That's not "time to implement effective mitigation measures." (Ron, scientist)

A policy analyst referred to the concept of equilibrium to argue that a 0.5% change isn't automatically unimportant:

> What's the sensitivity of the environment to that level of $CO_2$? You know, is 0.5 percent a big change or a small change? [If] something is balanced, you know, two weights are balanced, then 0.5 percent may be enough to topple the whole thing off and make it fall. It all depends on whether 0.5 percent is insignificant noise or is enough to totally destabilize a system. (Lee, policy analyst)

Students did not refer to these concepts of residence time and equilibrium, but Marie competently critiqued the claim by considering changes over time. She argued that a small annual contribution could accumulate into a large contribution, and she also evaluated the rate of increase relative to geological time scales:

> Point five percent annually is a lot to me, I don't know. It seems like a whole bunch, in ten years you'd have, what, 5% of carbon dioxide. That's only ten years, and that's nothing in the span of the earth's lifetime. (Marie, student)

She made another good point by comparing the rate of change of carbon dioxide levels to the rate of change of human responses:

> And it doesn't seem like that'd be at all enough time to implement measures to stop that from happening...I mean you have to make tests, and you have to sort of try it out in certain places, and then even once you get started in implementing it all over the globe, it's going to take a while for it to be effective. (Marie, student)

Other student responses illustrated strategies or heuristics for evaluating the overall reliability of the editorial, e.g., the idea that if you can't trust one piece of information, why trust the whole thing:

> What they say is sort of opposite to what I was thinking. But what they say is that it's predominantly water vapor, and only 3-5% is man's activities, but I think this could be a little biased...Most of the information sounds about right, but...if you can't trust one thing, why should you trust it all? (Dan, student)

Another response indicated a student saw the informational tone of the editorial as a kind of red flag:

> I think it's interesting how they make it sound like they're trying to educate people? I feel like it's definitely a lot more one-sided. It's trying to change my opinion more, I think. It's like, when I read it I feel like I have to have a little bit more, be a little more on the defensive (Tara, student).

Overall, specialists identified the editorial as having an advocacy purpose and also commented upon the relatively subtle approach:

> It's well written in the sense of getting a message across without slamming you in the teeth. (Sue, scientist)

Specialists also identified the use of statistics as a rhetorical strategy:

> As soon as you start to throw around numbers, in some respects numbers are often used to help build credibility (Mike, policy analyst)

Some student responses, like those of the specialists, illustrate identifying an advocacy purpose to the editorial:

> I think it's to put doubt in your mind. (Dan, student)
>
> The purpose of the article I think is to sort of defend oil corporations, foresting companies, the other side of the argument, the non-environmentalists as it were...I mean they have a point that maybe should be expressed, and so I think that this accomplishes it. (Marie, student)

On the other hand, other students seemed to accept the article whole-cloth, citing its informational quality:

> Well, as they say here, "We were presenting this editorial series in the hope that it will help contribute to rational and productive discussion on global climate change." I mean I thought it was pretty non-biased... I didn't feel like there was a real opinion here. (Kyle, student)

A further pitfall was assuming that the editorial was reliable because it contained statistics. Bonnie noted she felt the editorial was reliable, "because of the information and the statistics that it gives me." She continued, "They gave a lot of information, they gave their statistics with it...I guess they were like more of a, research with a foundation."

**San Francisco Chronicle Article: "Warming not a Global Problem"**

The Chronicle article reported that a study, which used computer models, found that global warming will benefit agriculture:

> A recent study by Robert Mendelsohn at Yale University's school of forestry and EPRI's [Electric Power Research Institute's] [Larry] Williams looked at farm impacts in the United States under 16 different climate models, assuming nothing is done to curb carbon dioxide. Some models showed gains, some showed losses, but on average they estimated a $174 billion increase in farm values by late in the next century due to increased food production. Why? Mainly because carbon dioxide is a basic plant food, essential to photosynthesis. Plants flourish in greenhouses, and actually use less water, when grown with high concentrations of $CO_2$ (Marshall, 1997).

Responses from the scientist, Ron, illustrate a variety of possible criticisms about the article:

> They quantify what we expect to gain, but they don't quantify what we expect to lose.
>
> They say, "Plants flourish in higher concentrations of $CO_2$." But that's not necessarily true, if there's not enough nitrogen, and if other things are going on too.
>
> Is there anything in here about diseases? You know, not just diseases for humans, but agricultural disease spread. (Ron, scientist)

The student Marie's critique involved challenging the notion of averaging disparate findings from different computer models:

> It was saying, "Oh, we ran several test models about agriculture, and some of them said we'd have an increase, and some of them said we wouldn't." You know, "some of them said we'd have a loss. But we averaged them out—" and it seems so widely different, I don't see how they could make that kind of generalization. (Marie, student)

The concept of interdependence of life in ecosystems was used in another student critique:

> [Farm production] may or may not be higher. Even if it is, you have to realize that by changing your environment, you're gonna affect something else. And a lot of the plants in the world are very climate-specific, and by changing the climate, you could kill plants, you can kill an ecosystem, which can drastically affect, I mean we don't know enough about the earth to begin changing it. (Kyle, student)

Another tack was to accept the claims of the article but fault it for missing the "bigger picture":

> They didn't give us the bigger picture, though. What I'm saying is that they gave us one very focused aspect of why global warming is not a problem, they didn't say why global warming is a problem. (Thomas, student)

On the other hand, some student responses were entirely uncritical:

> It said that you have a lot of food and stuff like that, because plants grow better in greenhouses...It was pretty good. It had a lot of information about farmers and their plants and stuff...There's nothing I disagree with, really (Tara, student).

Another interesting response was a student who felt that since he was unfamiliar with the information in the article, he did not have a platform from which to agree or disagree:

> I mean I can't agree or disagree with the facts they give me, because I haven't done any research in that area...I don't have a platform from which to disagree (Howard, student).

As has been illustrated, some students gave effective critiques even without having direct knowledge about the topic of the article. A belief that such direct knowledge is essential to forming an opinion about an article could pose a barrier to utilizing the knowledge that one does have that could be useful in making a judgment.

## Discussion

This study has used a task—critically evaluating scientific claims from actual mass media sources—which closely resembles a desired outcome of scientific and information literacy. For high school students, scientific perspectives that were seen to differentiate more or less successful responses to the experimental task involved fluency with themes of science (scale, changes over time) such as has been described in Benchmarks and NSES. The theme of scale, which is included in Benchmarks but not NSES, was especially prominent. Marie's critique of the oil company editorial—that a 3-5% anthropogenic contribution to global warming could have a large effect even though it is a relatively "small" percentage—illustrates fluency with considerations of scale. On the other hand, the suggestion of the student Thomas, to try a "big dehumidifier" as a solution to global warming, reflects some problems with issues of scale. The ability to think about changes over time, a theme described in Benchmarks as well as NSES, was also noteworthy. Marie productively considered rates of change in noting that a buildup of carbon dioxide of 0.5% annually would accumulate into a significantly larger amount in 10 years. The concept of the interdependence of life in ecosystems, mentioned in both Benchmarks and NSES, proved useful to Kyle's critique of the claim, reported in the San Francisco Chronicle, that global warming would benefit agriculture. Although some views of scientific literacy treat it as merely constituting the ability to repeat a set of scientific facts or concepts, the examples of successful student critiques just cited stand in contrast with this more limited view. Rather than simply repeating concepts mentioned in a standards document, the successful student critiques used those concepts in the process of thinking about new situations. In large measure, the keys to more or less productive student critiques were not specialized knowledge of global warming per se, but rather the application of more general scientific perspectives.

The study also highlights ways in which more general critical evaluation skills are vital to scientific and information literacy. For example, some students were attentive to the possibility that the oil company editorial might be influenced by corporate interests, whereas others viewed the editorial as a kind of public service announcement. Clearly, part of being able to successfully critique claims made about an issue is being alert to the possibility that those claims may be colored by the interests of the author. Surprisingly, such a critical point as this—identifying the interests of an information source—has not been emphasized by either Benchmarks or NSES.

As an overall recommendation, I would also suggest a standard such as the following. By the end of the 12th grade, students should:

- Demonstrate the ability to evaluate the credibility of scientific claims made in mass media sources, and demonstrate the ability to apply scientific concepts and skills to the task of evaluating such claims.

I further propose that a criterion for adding or retaining a concept to standards documents should be whether there are grounds to make a judgment that a particular concept would be beneficial to the process of critically evaluating scientific claims from mass media sources. In fact, such a criterion might tend to further prioritize scientific knowledge of wide applicability.

The study has also identified student conceptions that may be pertinent to educational efforts aimed at improving students' ability to critically evaluate scientific claims in the mass media. The view (illustrated in a remark made by Bonnie) that an article is more reliable if it is one-sided could work against accurately identifying a one-sided article as such. The view (illustrated by a remark made by Howard) that without expertise about the topic of an article, it is not possible to evaluate it, could also work against the process of evaluating new information. Large scale survey studies could investigate the prevalence of views like these.

The present study supports the overall goal for educational research to inform science content standards (Linn, diSessa, Pea, & Songer, 1994). This empirical approach offers several benefits:

- Validation. The empirical approach offers a way to validate recommendations or to identify their limitations.
- Analysis of expertise. Like expert-novice studies (Chi, Glaser, & Farr, 1988; Glaser, 1992), the approach of the present study permits identifying ways that experts take advantage of specialized domain knowledge. It can also identify ways that students can perform effectively without such specialized knowledge. Scientists (and even knowledgeable high school students) can serve as models of competent performance for critically evaluating scientific claims from media sources.
- Instructional application. By identifying students' cognitive resources and difficulties, the empirical approach can provide information useful for teachers and curriculum developers.

In closing, this study contributes to efforts to formulate goals for scientific and information literacy by illustrating how students (and specialists) critically evaluate scientific claims about global warming from mass media sources. More broadly, it exemplifies a strategy for formulating goals for scientific and information literacy.

## References

Adams, S. (1999a). Critiquing claims about global warming from the World Wide Web: A comparison of high school students and specialists. Bulletin of Science, Technology, & Society, 19(6), 539-543.

Adams, S. (1999b). Views of policies affecting automobiles: A comparison of high school students and specialists. Bulletin of Science, Technology, & Society, 19(5), 372-380.

Adams, S. (2001). Views of the uncertainties of climate change: A comparison of high school students and specialists. Canadian Journal of Environmental Education, 6, 58-76.

American Association for the Advancement of Science. (1993). Benchmarks for Scientific Literacy. New York, NY: Oxford University Press.

American Association for the Advancement of Science. (1997). Resources for scientific literacy. New York: Oxford University Press.

American Association of School Librarians. (1998). Information power: Building partnerships for learning / prepared by the American Library Association and the Association for Educational Communications and Technology. Chicago: American Library Association.

Bostrom, A., Morgan, M. G., Fischhoff, B., & Read, D. (1994). What do people know about global climate change? 1. Mental models. Risk Analysis, 14(6), 959-970.

Boyes, E., Chuckran, D., & Stanisstreet, M. (1993). How do high school students perceive global climatic change: What are its manifestations? What are its origins? What corrective action can be taken? Journal of Science Education and Technology, 2(4), 541-557.

Chi, M., T. H., Glaser, R., & Farr, M. J. (1988). The Nature of Expertise. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Doble, J., Richardson, A., & Danks, A. (1990). *Science and the public: A report in three volumes. Volume III: Global warming caused by the greenhouse effect.* New York: Public Agenda Foundation.

Francis, C., Boyes, E., Qualter, A., & Stanisstreet, M. (1993). Ideas of elementary students about reducing the "greenhouse effect". Science Education, 77(4), 375-392.

Glaser, R. (1992). Expert knowledge and processes of thinking. In D. F. Halpern (Ed.), Enhancing thinking skills in the sciences and mathematics (pp. 63-75). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Gowda, M. V. R., Fox, J. C., & Magelkey, R. D. (1997). Students' Understanding of Climate Change: Insights for Scientists and Educators. Bulletin of the American Meteorological Society, 78(10), 2232-2240.

International Society for Technology in Education. (1998). *National Educational Technology Standards for Students.* Eugene, OR.

IPCC (2001). Climate Change 2001: The Scientific Basis. Working Group I Contribution to the IPCC Third Assessment Report. Summary for Policymakers [On-line]. Available: http://www.ipcc.ch/.

Kempton, W., Boster, J. S., & Hartley, J. A. (1995). Environmental Values in American Culture. Cambridge, Massachusetts: MIT Press.

Korpan, C., Bisanz, G., Bisanz, J., & Henderson, J. (1997). Assessing literacy in science: Evaluation of scientific news briefs. Science Education, 81, 515-532.

Linn, M., diSessa, A., Pea, R., & Songer, N. (1994). Can research on science learning and instruction inform standards for science education? Journal of Science Education and Technology, 31(1).

Meadows, G., & Wiesenmayer, R. (1999). Identifying and addressing students' alternative conceptions of the causes of global warming: The need for cognitive conflict. Journal of Science Education and Technology, 8(3), 235-239.

Morgan, G., & Smuts, T. (1994). Global Warming and Climate Change. Pittsburgh, PA: Department of Engineering & Public Policy, Carnegie-Mellon University.

National Research Council. (1996). National Science Education Standards. Washington, DC: National Academy Press.

Read, D., Bostrom, A., Morgan, M. G., Fischhoff, B., & Smuts, T. (1994). What do people know about global climate change? 2. Survey studies of educated laypeople. Risk Analysis, 14(6), 971-982.

Rutherford, F. J., & Ahlgren, A. (1990). Science For All Americans. New York: Oxford University Press.

Rye, J., Rubba, R., & Wiesenmayer, R. (1997). An investigation of middle school students' alternative conceptions of global warming. International Journal of Science Education, 19(5), 527-551.

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# WHAT CAN WE LEARN FROM THE LEARNERS? SOME RESULTS AND IMPLICATIONS FROM "SCIENCE AND SCIENTISTS" A COMPARATIVE STUDY IN 22 COUNTRIES

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## Abstract

By comparing your national or local situation with the state of affairs in other countries, you come to see your own choices and priorities with new eyes. There are, however, many different approaches to international and comparative studies. Some studies rank countries by level of achievement, and may indirectly define norms and universal standards. Other studies may open up for cultural variation and provide options for different choices. This paper presents a study of the latter category.

The study is called Science And Scientists (SAS). The SAS-study explores cultural and gender differences on topics that are of relevance for science teaching. More than 40 researchers from 22 countries have collected information from some 10000 13-year old pupils from all continents. This paper presents selected results from three different items in this study. The three (out of seven) items that are considered here are related to the pupils' prior *experiences*, their profile of *interests* and their expressed *plans and motivations* for their own future. The results shows that are some rather universal trends in the gender profile of children's' experiences as well as their interests in science topics. Gender differences are particularly (and surprisingly) high in some of the North- European countries and in Japan. These findings are discussed in some detail.

The SAS-study provides empirical evidence for an informed deliberation about priorities in the school curriculum. The purpose of the study is to stimulate the debate on how science curricula can be made more relevant and suited to fit the experiences and the needs and interests of different learners in different countries. The SAS-study was meant to be only a modest and exploratory study, but has become a rather large undertaking. Plans for a more detailed and carefully planned study of a similar nature are also presented.


## Large-scale comparative studies. Limitations and side-effects

Science curricula and textbooks in different countries have striking similarities. Some consider this fact to be a reflection of the cultural neutrality and universality of science, while others see it as an unwarranted consequence of the cultural domination of some countries over others. Large-scale comparative studies like the IEA TIMSS (Third International Mathematics and Science Study) (se e.g. TIMSS 1998) may have as a (possibly unintended) side effect a pressure to harmonize or universalise science curricula across nations. Test format as well as curricular contents may provide standards, 'benchmarks' or norms for participating countries as well as for other countries. Furthermore, the international and cross-cultural nature of TIMSS-like studies has necessarily implied the development of items that can be used independent of educational or social context to avoid cultural bias. Hence, test items tends to become decontextualized and rather abstract. This development runs contrary to recent thinking in teaching, learning and curriculum development. The publication and availability of TIMSS items in many countries provides an 'incentive' to use tests that both in its closed multiple choice format and its lack of social context run contrary to national or local traditions.

Comparative research in education is important, but there is an obvious need to complement the valuable data from TIMSS-like studies with more open and culturally sensitive information and perspectives (Atkin and Black 1997). The recent OECD PISA study (Programme for International Student Assessment) is an ongoing attempt to widen the scope of such large-scale studies, and the underlying framework for PISA is, in contrast to TIMSS, not bound to the school curricula. The publication of the first results from PISA (OECD 2001) indicates that the PISA studies will meet some of the criticism raised against the IEA-based studies like TIMSS.

But TIMSS and PISA still have some common characteristics. They are both high-level initiatives 'from the top' to monitor scholastic achievement, and the main results are various rankings on league-like tables. The studies are also (with some exceptions) confined to rich countries in the OECD. In most countries these studies are initiated and (rather heavily!) funded by governments and ministries of education. Such studies stem from the decision-makers' and politicians' (legitimate!) need to have comparable data on the scholastic achievement of their pupils and to have some measures of efficiency and cost-benefit aspects of their national educational system. In an age of globalisation and economic competition, the national authorities are increasingly concerned about how their own system compares with other systems, measured against common standards or 'benchmarks'. Similarly, national authorities have a legitimate need to get international comparable data on unit costs, about the effects of teacher training, class size, effects of resource usage etc. One may, of course with some exaggeration, characterize projects like TIMSS and PISA as the educational parallel to what is known as Big Science. The scale and costs of these studies are many factors higher that the kind of research that most science educators are involved in. The institutions that perform these studies are often government agencies for research and development, or research institution from which the government may expect a certain degree of loyalty. Such research does not emerge from an independent and critical academic research perspective.

**The SAS-study: a small-scale comparative study**

The comparative study reported here is very different from the large TIMSS and PISA studies. It is low-cost, it is emerging from the 'bottom' instead of from governments and ministries, it includes not only the wealthy nations but also developing countries, and its prime purpose is to open up for critical discussions about priorities and local variation in the science curricula. The concern is *not* about any ranking from good to bad, or comparisons with given standards or benchmarks. The purpose is to open up for critical discussions abut priorities, based on empirical evidence gathered in diverse cultures.

In many countries, mainly the industrial, there is currently a kind of disenchantment with science. There is a fall in the recruitment to (some) science-related studies and careers. The SAS-study emerges partly as an attempt to understand these trends, but also from the perspectives of critical pedagogy and with a critical perspective on the role and function of science curricula. There is today a widespread concern to try to make science curricula meaningful, relevant and adapted to different groups and different cultures (Cobern and Aikenhead 1998, Ogawa 1995). *The lack of relevance* of the S&T curriculum is probably one of the greatest barriers for good learning as well as for interest in the subject. In any discussion about *relevance*, it becomes important to know more about the views, experiences and perspectives of the learners.

The present study is a modest attempt to shed light on differences as well as similarities in what pupils bring to school, what perspectives and plans they have and what kind of interests they have. The study is called *Science And Scientists, the SAS-study*. The prime concern is about diversity due to different cultures and gender. The intention is to provide data and perspectives that may give an empirical foundation for an informed discussion about the relationship that the learner has to the science curriculum and science teaching. The development of the SAS-project is a joint undertaking, involving science educators from very different cultures.

**Methods and Samples**

The SAS project used a questionnaire that was developed, piloted and finalized in a cooperation between this author (from Norway), Jane Mulemwa from Uganda and Jayshree Mehta from India. We met for on several occasions through our joint engagement in organizations like GASAT and IOSTE, and we were also jointly involved FEMSA (Female Education in Mathematics and science in Africa) a large African project to address gender equity in science education in Africa. The SAS questionnaire consisted of 7 groups of items. The aspects that were studied were the following: The pupils' science-related out-of-school *experiences*, their *interests* in learning about different topics in science, their *perceptions* of science as an activity and *images* of scientists as persons – and their *priorities* for future life or work. The questionnaire also consisted of some open-ended questions, like "What would you like to do if you were a scientist?" The "draw-a-scientist- task" was also included, and the pupils were asked to comment on their drawing in writing.

The final instrument was made available to researchers from other countries through various science education networks like IOSTE and NARST. The participating researchers collected national data, following agreed procedures for sampling, administration, data collection and coding. Empty data files in SPSS and Excel were provided by the project, which also refunded some costs, in particular for researchers in developing countries. Data files were returned to this author, merged into a larger file and recoded for analysis. Details of procedures, sampling etc are given in Sjøberg 2000a.

Some 40 researchers from 22 countries provided data from about 10 000 pupils at the age of 13. The countries are, in alphabetical order: *Australia, Chile, England, Ghana, Hungary, Iceland, India, Japan, Korea, Lesotho, Mozambique, Nigeria, Norway, Papua New Guinea, Philippines, Russia, Spain, Sudan, Sweden, Trinidad, Uganda and USA.*

Several national reports have been published; the participating researchers and the list of publications are given in the SAS-report (Sjøberg 2000a). A brief report is also available as chapter in a recent book (Sjøberg 2000b). The data files for the SAS-project are now available from the author for further analysis by the participants. This paper mainly presents data that are not published before.

## Results: General observations

The data document that children in different parts of the world come to school with a variety of different science-related experiences. Their interests in science topics show great variations, and their plans and priorities differ. If one wants to build on children's experiences and meet their interests and perceived needs, such information is of crucial importance. In spite of the variations within each country, the participating countries seem to come out in clusters on many aspects, often reflecting the country's level of development. Children from African countries seem to share many background experiences, and they also seem to have the same interests, similar priorities for future job and they have the same (very positive) image of science and scientists etc. There also seem to be gender-related differences that follow similar cultural patterns. This means, among other things, that the definition of feminine and masculine behaviours and attitudes seems to follow cultural patterns. Also developed countries have some likenesses with each other, and the Nordic countries come out as a group with strong similarities. In the following, some more detailed results are given, although the available space does not permit complete tables or graphs.

## Results: Prior experiences

One group of items is called *Out of school experiences: What I have done.* This is an inventory of 80 activities that may have bearing on the teaching and learning of science. This item has also been used in previous research in a slightly different form. (Sjøberg and Imsen 1987, Whyte, Kelly and Smail 1987). Attempts were made to sample activities that might be of relevance for the learning of science, and to try to make the list balanced with regards to gender and cultural differences. The calculated overall score (Sjøberg 2000a) showed that we had been successful in this respect; most countries had similar averages and most countries had only small differences in the overall activity score for girls and boys.

On this item, we often observed what we might call a traditional gendering pattern. Boys in nearly all countries have considerably more experience with activities such as these: Using guns, bows and arrows, using new technologies, car-related activities, (using car jack, charging batteries etc.), mechanical activities (using pulleys and levers) electrical activities (fixing leads, using batteries, motors, bulbs) using tools (saw, hammer etc.), mending bikes.

Girls had in general more experience with nature-oriented (and more peaceful) activities like collecting gems, flowers, mushrooms, observing the sky, the moon and the stars. Girls also had more experience in household-related activities like *preparing* food. On the other hand (and maybe surprisingly?) boys had, in most countries more experience than girls in *preserving* and *storing* food (salting, smoking, drying etc)

Some sorts of experience had different gendering patterns in industrialized and developing countries. Caring for animals and other farming activities are boys' activities in developing countries, while the same activities are typical girls' activities in industrial countries. The underlying reason may be that agricultural activities are basic economical, life-sustaining activities in developing countries, while they are more related to leisure and hobby in industrialized countries.

Some typical experiences among the Nordic (here: Norway, Sweden and Iceland) children seem to be strongly related to outdoor life. Nordic children (girls and boys) have more experience than others in activities like setting up tents, making fire, using binoculars, making flute of straw or wood, collecting mushrooms and edible berries. We also note that Norwegian children (in particular boys) have the highest score of all on "using air-gun and rifle" – possibly a reminiscent of an old hunting (and fishing) tradition, still surviving as a leisure activity?

**Results: Interesting science topics**

This group of items is called *Things to learn about* and is a similar list to the one about experiences. It is an inventory of possible topics for inclusion in the science curriculum. 60 topics are listed. Some results from the analysis of interests in science topics have been published elsewhere (Sjøberg 2000a and 2000b). Here follows some general observations.

Children in developing countries are interested in learning about nearly everything! This is possibly a reflection of the fact that for them, education is a luxury and a privilege, and not seen as a painful duty, as is often the case in more wealthy nations! Japanese children are less interested in S&T than children in other countries — in particular about the car, new technologies and communication! We return briefly to this at the end of the paper. The Nordic countries (and Japan) are more gendered in children's interests than other countries! We also comment on this observation at the end of the paper.

This item provides a wealth of data that may be of value for a discussion on how to construct a science curriculum that meets the interests of different learners in different cultures. To illustrate this point, we give one example, see table 1, where some of the data for two selected countries are contrasted – based on the gender difference.

**"What I want to learn about" Data from Norway and Japan.**
**The list is sorted by the *difference* between boys and girls.**

| "Girls' science" Norway | M-F | | "Girls' science" Japan | M-F |
|---|---|---|---|---|
| AIDS: What it is and how it spreads | -24 | | How to heat and cook food the best way | -26 |
| The rainbow, what it is and why we can see it | -22 | | The rainbow, what it is and why we can see it | -26 |
| Why people in different parts of the world look different and have different colours of the skin | -19 | | Why the sky is blue and why the stars twinkle | -18 |
| What we should eat to be healthy | -18 | | What are colours and how do we see different colours? | -17 |
| Why the sky is blue and why the stars twinkle | -17 | | Music, instruments and sounds | -16 |
| Birth control and contraceptives | -16 | | Sounds and music from birds and other animals | -15 |
| What are colours and how do we see different colours? | -15 | | Plants and animals in my neighbourhood | -13 |
| Sounds and music from birds and other animals | -12 | | How birds and animals communicate | -12 |

| | | | | |
|---|---|---|---|---|
| How birds and animals communicate | -12 | | How science and technology may help disabled persons (blind, deaph, physically handicapped etc.) | -11 |
| How we can protect air, water and the environment | -11 | | What we should eat to be healthy | -9 |
| "Boys' science" Norway | | | "Boys' science" Japan | |
| How radioactivity affects life and my own body | 11 | | How science and technology may help us to get a better life | 13 |
| The possible dangers of science and technology | 12 | | Satellites and modern communication | 13 |
| New sources of energy: from the sun, from the wind. | 15 | | The possibility of life outside earth | 13 |
| Important inventions and discoveries | 17 | | The origin and evolution of the human being | 15 |
| How science and technology may help us to get a better life | 18 | | New sources of energy: from the sun, from the wind etc. | 16 |
| Light and optics | 20 | | Rockets and space travel | 17 |
| How things like telephone, radio and television work | 20 | | The possible dangers of science and technology | 17 |
| Acoustics and sound | 21 | | How things like telephone, radio and television work | 17 |
| Atoms and molecules | 22 | | Important inventions and discoveries | 18 |
| Computers, PCs and what we can do with them | 23 | | Computers, PCs and what we can do with them | 19 |
| What an atomic bomb consists of and how they are made | 24 | | What an atomic bomb consists of and how they are made | 19 |
| Chemicals and their properties | 25 | | Atoms and molecules | 20 |
| Rockets and space travel | 26 | | How a nuclear power plant functions | 21 |
| Electricity, how it is produced and used in the home | 27 | | Lightning and thunder | 24 |
| How a nuclear power plant functions | 27 | | X-rays and ultrasound in medicine | 24 |
| Satellites and modern communication | 29 | | Electricity, how it is produced and used | 24 |
| Latest development in technology | 37 | | Latest development in technology | 27 |
| The car and how it works | 43 | | The car and how it works | 30 |

**Table 1** "What I want to learn about" – (part of the list) sorted based on the *difference* between girls and boys. The list shows data from Norway and Japan. For each country, the topics with the most female gender difference are shown (on top) and (at the bottom) the topics with the strongest boys' profile are shown. The number is the difference in percent between boys and girls who have indicated that are interested in the topic.

The list of possible science topics in this item consists of 60 items, and only the top and bottom parts of the list are shown in table 1. In this table, only the *difference* between girls' and boys' score is shown. We note that the actual gendered differences at the ends of 'the spectrum' are extreme. This means that in both countries there are topics in science that stand out as exceptionally gendered in the favour of girls (the top of the list), and even more topics with a very strong boys' profile (the bottom of the list). We also note that there are strong similarities between the lists for the two countries, in spite of the large cultural difference between these countries. For both countries, *girls* show a greater interest than boys in aspects of biology, health and nutrition. They are also more interested in aspects with a possible aesthetic dimension (colours, sound, music, blue sky, twinkling stars etc.) Boys in both countries, however, express much greater interest than girls do in cars, technology, PCs, rockets, nuclear power plant, electricity etc.

Some of these results are hardly surprising; they actually fit well with what one stereotypically calls girls' and boys' interests. The surprise is, however, that the actual difference is so *extreme*. Take learning about "The car and how it works" as an example. In Norway, 76 % of the boys and 33 % of the girls are interested. Japan is even more extreme, although the actual numbers are much smaller: 36 % of the boys, and only 6 % of the girls are interested! Similar details can be noted at the other extreme of the spectrum.

What we can learn from this is that the 'ideal' science curriculum for girls and boys are indeed very different – although they may both be considered good and valid science! Data like these should be kept in mind when curricula are written and textbooks produced. If one puts early emphasis on the technological aspects of science, one will definitely turn off the potential interests that girls might have in the subject!

The data also contains some surprises. *Boys* are in most countries more interested than girls on topics like
- The possible dangers of science and technology
- How science and technology may help us to get a better life
- How science and technology may help handicapped
- New sources of energy, from the sun, from wind etc.
- How radioactivity affects life and my own body
- Famous scientists and their lives

These results run contrary to what is often assumed, e.g. that girls are more interested in the possible misuses of science, that they are interested in the human and historical aspects of science and that they are interested in how science and technology may improve life and help people. The SAS data do *not* give support to these claims, at least not as general claims.

In spite of the great gender disparities, some topics seem to be high on the list for girls as well as boys in most countries. (Then we focus on actual percentages, and not on *differences* in score!)

**Most popular** among girls *and* boys in most countries are the following topics:
- The possibility of life outside earth
- Computers, PC, and what we can do with them
- Dinosaurs and why they died out
- Earthquakes and volcanoes
- Music, instruments and sounds
- The moon, the sun and the planets

Similarly, one can identify a list of the **least popular** (for girls and boys) in most (mainly the rich) countries:
- How to improve the harvest in gardens and farms
- How plants grow and what they need
- Plants and animals in my neighbourhood,
- Detergents, soap and how they work
- Food processing, conservation and storage
- Famous scientists and their lives

From this list we see that the concern to make science more relevant by concentrating on what is "concrete, near and familiar" is not necessarily meeting the interests of the children. They may, in fact, be *more* interested in learning about the possibility of life in the universe, extinct dinosaurs, planets, earthquakes and volcanoes!

**Results: Important for future job**

This item is called *Important for a future job* and consists of a list of 15 factors that might be important for the choice of a future job (if such a choice exists!). The pupils are invited to judge the personal relevance of each of these factors. An example of the data is provided by Table 2

| Of importance for choice of job | Girls | Boys | Boys-Girls | Total |
|---|---|---|---|---|
| Have an exciting job | 0,94 | 0,94 | 0,00 | 0,94 |
| Have more time for my family | 0,94 | 0,92 | -0,01 | 0,93 |
| Get a secure job | 0,92 | 0,91 | -0,01 | 0,92 |
| Have more time for my friends | 0,91 | 0,88 | -0,03 | 0,89 |
| Have more time for my own interests and hobbies | 0,82 | 0,84 | 0,02 | 0,83 |
| Use my talents or abilities | 0,78 | 0,81 | 0,04 | 0,79 |
| Make my own decisison | 0,77 | 0,80 | 0,03 | 0,78 |
| Help other people | 0,82 | 0,73 | -0,10 | 0,77 |
| Earn lots of money | 0,71 | 0,82 | 0,11 | 0,76 |
| Developing new knowledge and skills | 0,64 | 0,71 | 0,08 | 0,67 |
| Work with people instead of things | 0,66 | 0,55 | -0,11 | 0,61 |
| Make and invent new things | 0,41 | 0,63 | 0,22 | 0,52 |
| Have an easy and simple job | 0,44 | 0,52 | 0,08 | 0,48 |
| Become famous | 0,31 | 0,51 | 0,20 | 0,41 |
| Control other people | 0,14 | 0,29 | 0,15 | 0,21 |

**Table 2.** Factors of importance for future job. Norwegian SAS-data. The columns show results for girls and boys and total. A separate column gives the difference between the boys' and girls' score. The factors are sorted by decreasing importance, based on the total score. (The maximum possible score is 1,0, details of scoring are given in Sjøberg 2000a))

We see from this list that although there is general agreement between girls and boys on the importance on some of the factors, there are also remarkable differences on other aspect between the priorities of girls and boys. We see that the difference is 'in favour' of boys on factors like "Make and invent new things", "Become famous", Control other people", "Earn lots of money", while the girls put considerably more emphasis on "Working with people instead of things" and "Helping other people".

In order to simplify these matters, a factor analysis was performed. We identified the following four components. (The suggested name is 'invented' as a label that seems to fit with the contents.)

1. **Ego-orientation** (famous, rich, controlling others, easy job)
2. **Time and security** (time for friends, family, myself – and a secure job)
3. **Self-development** (using talents and abilities, developing knowledge and skills, taking decisions, exciting job)
4. **Others-orientation** (Helping others, working with people)

When applying this to the participating countries, we find that factors 2 and 3 ("Time and security" and "Self-development") are rather gender neutral in practically all countries. The other two factors are strongly gendered.

In all but 2 countries, boys seem to be "Ego-oriented", with Iceland, Sweden, England and Norway as the most extreme! On the other hand, in all but two countries girls seem to be much more "Others-oriented" than boys. Also on this aspect, Norway and Sweden are the most strongly gendered. Details are given in table 3.

| **Other-orientation (helping others, working with people)** | | | | |
|---|---|---|---|---|
| ***Sorted* by gender difference** | | | | |
| **COUNTRY** | **Girls** | **Boys** | **Boys-Girls** | **Total** |
| Sweden | 0,78 | 0,59 | -0,19 | 0,69 |
| Norway | 0,75 | 0,64 | -0,11 | 0,69 |
| Hungary | 0,82 | 0,73 | -0,09 | 0,78 |
| Chile | 0,84 | 0,75 | -0,09 | 0,80 |
| Uganda | 0,85 | 0,77 | -0,07 | 0,81 |
| Japan | 0,73 | 0,66 | -0,07 | 0,70 |
| Iceland | 0,74 | 0,67 | -0,07 | 0,70 |
| USA | 0,76 | 0,70 | -0,06 | 0,73 |
| Australia | 0,80 | 0,75 | -0,05 | 0,77 |
| Philipines | 0,84 | 0,80 | -0,05 | 0,82 |
| England | 0,73 | 0,69 | -0,04 | 0,71 |
| Spain | 0,77 | 0,74 | -0,03 | 0,76 |
| India | 0,78 | 0,75 | -0,03 | 0,77 |
| Papua New Guinea | 0,74 | 0,72 | -0,03 | 0,73 |
| Sudan | 0,79 | 0,77 | -0,02 | 0,78 |
| Nigeria | 0,82 | 0,80 | -0,02 | 0,81 |
| Mozambique | 0,87 | 0,86 | -0,01 | 0,86 |
| Lesotho | 0,86 | 0,86 | -0,01 | 0,86 |
| Trinidad | 0,75 | 0,76 | 0,01 | 0,75 |
| Korea | 0,68 | 0,70 | 0,02 | 0,69 |

**Table 3:** "Other-orientation" (Helping other people, working with people) among children in different countries SAS-data. Data are given for girls, boys and total as well as the gender difference. The list is *sorted* by gender difference. Maximum score is 1,0

## Discussion: Some paradoxes and surprises

Many findings in the SAS-study are hardly surprising. The overall gender profile follows a pattern that is well documented. But some results are rather unexpected (at least for this author). Two such examples will be briefly discussed here: (1) The low interests in science and technology among Japanese children and (2) the seemingly paradoxical situation regarding gender equity in the Nordic countries.

***Japan: Top in score – lowest in attitudes and interests!***

Many results from Japan call for attention, in particular when they are seen in connection with other kinds of information. Let us look at some of the paradoxes: Japan tends to be on top on most international tests on pupils' achievement in science and mathematics (SISS, TIMSS etc.). Even on the recent PISA (2001) study, Japan comes out on the international top on achievement in mathematics and as number 2 in mathematics (right behind Korea). In spite of the high scores on achievement testing, the TIMSS data (TIMSS 1996 p 121 ff.) also indicate that Japanese children have more negative *attitudes* to both mathematics and science than pupils have in any other (of the nearly 50) TIMSS countries.

The data presented in this paper and in the other SAS-reports (Sjøberg 2000a and b) support and give more detail to this observation. Item by item, we find similar results: Japanese children are much less likely than others to be interested in most science items – in particular those related to modern advances in technology – an area where Japan is among the world leaders, and an area of prime economical importance for Japan.

Gender differences are in many aspects large in Japan. According to our study, Japanese girls are at the lowest place when it comes to interest in science, both when the question is a global one like "Is science interesting?" and on the very specific topics briefly mentioned in this paper. Japanese girls also state that they find science more difficult to understand than any other group in this study. (Sjøberg 2000a) (In spite of this, they actually score higher than girls in most other countries!)

Science educators in Japan have recently become very interested in these matters, since the low interest in science and technology and the lack of interests to pursue studies and careers in these fields may create serious problems for Japanese economy. The low birth rate in Japan and the highest life expectancy in the world further exacerbate the problem. Possible explanations as well as possible policies and remedies are debated. It falls beyond the scope of this paper to explore this issue, but it is expected to be an area of interesting debate and an area where one can learn from cross-cultural research. Professor Masakata Ogawa has recently initiated an international comparative research to shed light on science education and the importance of gender, language and culture. He was also the Japanese partner in the SAS-project. Perspectives and results from the SAS study and the planned ROSE-project (see the last paragraph) will be an important input in the ongoing Japanese project.

***Norway and the Nordic countries: What about the gender equity?***

The SAS-study has shown that the Nordic countries (here represented by Norway, Sweden and Iceland) on many aspects come out with greater differences between girls and boys than most other countries. In particular, we have documented large differences in the interest to learn science (Sjøberg 2000a). The data presented in this paper about priorities for a future job also indicate a very strongly gendered value profile among Nordic children: Girls as "others- oriented"; they want to help other people and work with people instead of things. Boys, on the other hand, are "ego-oriented"; they are more oriented towards making money and getting personal benefits. The analysis of children's drawings and their free writing on "Me as a scientist" (both reported in Sjøberg 2000a) also documents large gender differences in values and perspectives among the Nordic children. Data from TIMSS and PISA provides similar evidence on large gender differences in achievements as well as attitudes to science.

The Nordic countries are often considered "world champions" in gender equity. Gender equity has been a major political concern since the mid 70-s. Much has been accomplished, and the overall picture is undoubtedly rather positive. Legal barriers have been removed a long time ago; laws against discrimination and unequal pay are in operation. Female participation in politics and the labour market is among the highest in the world. In the education system, girls and women dominate the overall picture, with some 56% of tertiary students being female.

Official statistics and international reports confirm the leading position of the Nordic countries regarding gender equity. UNDP (United Nations' Development Program) publishes an annual Human Development Report. The analysis and conceptual development behind these reports is well respected. The main indicator that is developed by UNDP is the *Human Development Index* that is used to describe and monitor progress in this complicated area. All the 5 Nordic countries are among the 15 on the top of this list, which includes nearly 200 countries. In 2001 Norway was no 1 on the list.

The UNDP report has also developed indices that describe the situation of particular social sectors. In 1995 the focus was on gender, and from that year, UNDP has also reported on a so-called *Gender Empowerment Measure*. This index measures the degree of achieved equity regarding aspects like health, education, salaries, participation in politics and on the labour market etc. In the 2001 report, the Nordic countries have the following ranks on this list: 1 Norway, 2 Iceland, 3 Sweden, 4 Finland and 12 Denmark (UNDP 2001). As one can see, the overall picture seems to be positive, and the three Nordic countries taking part in SAS are actually the first three on this list of gender empowerment. *But equity does not exist in the field of science*. The percentage of women in science and engineering is very low – lower than in most other parts of the world. The enrolment of women into these fields has actually gone down the last years. And the gender difference in achievement and attitudes are large, also in the TIMSS and PISA studies.

The issue is of great political concern in these countries, where the gender equity is considered a pride. The reason for the observed differences in career choice does not seem to be the girls' lack of ability or lack of self-confidence! Even very able girls turn their backs to science and engineering. The girls' choices seem to be rather deliberate, based on value-orientations and emotional, personal factors. Some of the underlying values for girls are indicated above: The girls' high person-orientation and relatively low orientation towards money, career and things.

If this is correct, it shows that we should pay more attention to the underlying values, ideals and ideologies in science education. Textbooks as well as classroom teaching carry implicit (sometimes also explicit) messages about the nature of the subject and the underlying values. If we believe that these values are not strictly determined and logically deduced from the nature of science per se, we should analyse, discuss and possibly reconsider these aspects.

We have through the SAS-study documented large differences between the experiences, values and interests of girls and boys. It is very likely that girls encounter a science curriculum that neither builds on their prior experiences or fits well with their profile of interests. We hope to use the SAS data to argue for a reorientation of the Norwegian science curriculum.

## Some conclusions and implications

It is evident from this study that children come to school with a rich variety of relevant *experiences* that could and should be utilized in the teaching and learning science at school. This study does not indicate whether this resource is actually used in a systematic way or not, but it may indicate how this might be done.

The *interest* in learning seems to be much higher in developing countries than in the rich and technologically developed countries. An explanation for this may be that education in developing countries is largely seen as a privilege that everybody strive for, while many pupils in the rich countries see school as a tedious duty that is imposed on them. The same perspective may explain the strong interest in science expressed by girls in developing countries: Girls in these countries often have less access to all sorts of education than boys have, therefore learning science may be seen as a very positive option.

The profile of the experiences and interests does, however, vary strongly between *countries*. This fact should call for caution when it comes to "importing" foreign curricula and it should indicate a need for some scepticism against the pressure to "harmonise" science curricula against universal common standards or benchmarks. Although science *per se* may be universal (a debate that is not pursued here!), *science curricula* for children should reflect the needs and priorities for children in each country. Data from projects like SAS may provide a basis for deliberations about curricular priorities.

It is also evident that the profile of experiences as well as interests is rather different for *girls and boys* in most countries. In general, the gender differences in interests are greater in rich countries than in developing countries, both when summed over all topics and when these are studies separately. Gender differences are very high in some North-European countries and in Japan, an aspect that is discussed a little above. If gender equity in science education is a national concern, one should go in some detail in analysing possible biases in the curricula, textbooks and classroom teaching. A study like SAS may be one approach to such issues, because it can shift the debate from a general theoretical level to a more concrete level, based on empirical evidence.

The *image* of science and scientists is more positive among children in developing countries than in the rich countries. Children in the developing countries seem to be eager to learn science, and for them, the scientists are the heroes. This is in marked contrast to at least a significant part of the children in the rich countries, who often express sceptical and negative attitudes and perceptions in their responses to several of the SAS items. The notion of the crazy or mad scientist is often found in rich countries. Very few children in the rich countries envisage the scientist as a kind, human and helpful person, whereas this is often the image of scientist in developing countries. (Details are given in Sjøberg 2000a)

This study does not tell which image is closer to "reality". But many of the data indicate that science has a problem with its public image in many developed countries. Most OECD countries are currently worried about the falling recruitment to science and technology studies. Why do children develop these critical attitudes to science and technology, although they live in societies based on such knowledge and its applications? One possibility is that this is a result of low public understanding of science, caused by bad teaching as well as a low or negative profile in the media. Many scientists hold on to explanations like these. But there is another possibility: It may be seen as an indication that many young people have a rather well informed sceptical attitude towards certain aspects of modern society. Maybe their doubts are based on real fears about an unknown future that scientists may lead them into?

Comparative research is important, and it is important for science educators to get involved in cross-cultural research. It often helps you see your own culture from outside, and it may open up for new insights and new alternatives. Data from the large-scale studies like TIMSS and PISA are valuable and important, but should be complemented by less ambitious and more explorative studies like the one presented here. Together, they may provide a foundation for informed debates about priorities and alternatives in science education.

## Future plans: The ROSE project

The SAS-study was planned as a modest and exploratory study. The overwhelming international interest in joining the study took us by surprise. As it stands today, the study has several weaknesses stemming from its somewhat ad hoc development. But the results have received great attention, and there is a widespread interest in the further development of a joint study like this, catering for participation from all sorts of cultures.

Plans for a more systematic follow-up study of the SAS-project have been developed under the acronym of ROSE: The Relevance Of Science Education. The target population will be 15-16 year old pupils, i.e. towards the end of the compulsory school in many countries, and before streaming usually takes place. (A description is given at http://folk.uio.no/sveinsj/) Researchers and research institution in more that 30 countries have expressed their interest in participating in this project. The Research Council of Norway will fund this project for a period of three years, and other funding sources are now approached. An international workshop with participants from all continents took place in Oslo in October 2001. Here the research hypotheses were discussed, the research instruments were refined and the logistics was developed. Data collection will start in 2002, and researchers with an interest in the project should contact this author.

## References


Atkin J.M. & Black P.(1997) Policy Perils of International Comparisons. *Phi Delta Kappan* (September 1997), 22-28

Cobern, W. W., & Aikenhead, G. (1998) Culture and the learning of science. In B. Fraser, & K. G. Tobin (eds), *The international handbook on science education*. Dordrecht: Kluwer Academic Publishers.

OECD (2001) *Knowledge and skills for Life – First results from PISA 2000*, Paris, OECD (Reports are available at http://www.pisa.oecd.org/)

Ogawa, M. (1995). Science education in a multi-science perspective *Science Education* vol 79, 583-593

Sjøberg, S. (2000a) *Science And Scientists: The SAS-study Cross-cultural evidence and perspectives on pupils' interests, experiences and perceptions— Background, Development and Selected Results* — Acta Didactica no 1. University of Oslo. (Available at http://folk.uio.no/sveinsj/)

Sjøberg, S. (2000b) Interesting all children in the 'science for all' curriculum –in Millar, R.; Leach, J.; Osborne, J. (ed.): *Improving Science Education — the contribution of research*, Buckingham, Open University Press

Sjøberg, S and Imsen, G. (1987): Gender and Science Education in Fensham (ed.): *Development and Dilemmas in Science Education*, London, The Falmer Press

TIMSS (1998) *Mathematics and Science Achievement in the Final year of Secondary School* TIMSS International Study Center, Boston College, MA, USA

Whyte, J. Kelly, A. and Smail, B. (1987) *Girls into Science and technology: Final report in Science for Girls*, Milton Keynes, Open University Press

UNDP (2001) *Human Development Report 2001* New York and London, Oxford University Press (Available at http://www.undp.org/)


**Keywords:** science curriculum, children's' experiences, interests, priorities, international comparisons

# 069 TEACHERS' AND TEACHER-EDUCATORS' FORMATION AND PROFESSIONAL IMPROVMENT IN THE NPADC/UFPA EXPERIENCE: FROM PARTNERSHIPS TO A PROGRESSIVE PROFESSIONAL AUTONOMY

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**Abstract**

This article presents narrative research that demonstrates how both science and mathematics teachers thought about their educational formation in the Science Club - a pedagogical support group that promotes Science Education - either in the teachers' initial formation, or in their professional improvement as teacher educators. They worked for the Continuing Education Program in partenership with some other local institutions. In this paper, I discuss five formative processes that were very important in the professional life history of eight teachers. With that purpose in mind, I'm using information from teachers' group work – especially projects and reports, and their professional life histories, as well as some interviews with them. I discuss the assisted teachers' initial formation, as well as the partnerships which were made by students in the Science Club, without any curricular promotion but as imprintings, as partnerships, of any other strategy on the shared educational formation like readings, seminars, workshops on researching teaching. In this way, their educational formation occurs at the same time, and through interaction with their professors, and with other students and their pupils. The formation of the teacher educator begins during their early educational formation whenever they become partners of the newly graduated students, and while they're searching for stimulating situations, and even when they're facing them on the worktime teachers' "twilight zone" as a teacher educator or in community interacting situations – events where knowledge is spread such as Science Fairs. Such teachers can recognize their own professional development, they can notice their own new-conquered autonomy and at the same time that they become aware of their (trans)formational and unaccomplished professional trajectories.

## Introdution

The Federal University of Para's Science Club has been an initial and continuing space for the formation of science and mathematics teachers. In this research, I studied how this formation happens. For that, I analyzed the professional life history of eight participating teachers. I tried to determine from those histories what was considered important for their education and professional improvement. I organized the results in five formative processes, which I explain as follows.

I present the data through a narrative research approach (CONNELY E CLANDININ, 1995). The history is at the same time an investigative context — the history of a workgroup and the teachers' participated professional life histories and their initial education processes. For that, I examined some group material, like work projects and reports.

The period of my analyses was from 1979 - when the Science Club was created - to 1995, when I left of the workgroup to pursue doctoral studies. When we – my pupils and I – created the Science Club, we wanted to have a place to perform a new science teaching; we wanted to have an opportunity to develop science and mathematics classes with innovation, with college students, as a laboratory in which to learn how to teach. As POPHAM (1978) says, we needed to have "adequate practice", before we actually started to teach and from the very beginning of our undergraduate courses.

The Science Club is today part of the Pedagogical Nucleus for Scientific Development Support, but in this article, to better comprehension, I used only the expression Science Club.

Science and mathematics, however, wouldn't be taught in a traditional way. It wouldn't be like all students know. No! We wanted to teach "stimulating the scientific education, the children's inquisitiveness, that can help their mental and social improvement"(UFPA/CLUBE DE CIÊNCIAS, 1979:1)

The pedagogical way to carry out this new method of teaching – as a laboratory in which students learn how to teach – would be a "global and experimental way, through investigation projects, problem solving and discovery, because these ways are very important for significant learning (UFPA/CLUBE DE CIÊNCIAS, 1979:1). We believed that in working in this way with the children, we would give them the possibility to make cognitive relationships. We believed we would help them construe an important life and cognitive experience from which they would be able to anchor the new information and experiences, as AUSUBEL (1968) has said. We wanted both pre-college and college students to learn at the same time. We had the clear idea that the Science Club's existence would be an experience. In the beginning, we didn't have either adequate space or didactic materials. But we were positive that: "a Science Club should be a very agreeable space, where the children would love to be and would be able to do whatever they wanted to, developing themselves in social and intellectual ways (UFPA/CLUBE DE CIÊNCIAS, 1979:1). Our belief was that a club with only people – college and pre-college students – and a natural environment, would not be satisfactory 'ad infinitum'. "In our mind we could see adequate spaces and materials. We knew that science and technology improve rapidly and that the teaching process gets further removed from this progress each time". In that beginning we already knew that "the student isn't a passive knowledge storekeeper or a special recipient that never overflows." (UFPa/Clube de Ciências, 1979: 2)

The college students have formed the basis of the Science Club since its beginning, in 1979, as co-authors of initial projects and continued progresses. Our goals have been to "offer them opportunities of challenging learning, giving them feedback on all activities and stimulating personal construction as a science or mathematics teacher. Also, giving them the opportunity to participate as an active producer of their own constitution as teachers while at the same time developing activities with children in class. This would be done from very early moments in their undergraduate study. In our point of view, the Science Club would be a pedagogic space where the college student could start the process of learning and teaching early. They would begin their formation assisted by a professor, working with partners with whom to plan, discuss and do short scientific projects. All of this would be important for the college students because they would be constructing a 'singular teacher' in themselves, as CLARKE (1994) says. We could see this space as an opportunity for students to construct their teaching philosophy in a way that is coherent with educational principles which would only be developed if they could practice them". (CLUBE DE CIÊNCIAS, 1979: 2) The process of learning and teaching was understood as research in teaching. We were constructing a new model which was not ready, but one in which each one was required to construct it. Each one needed to construct it for himself/herself; to construct a different perspective than that one they had as a model since their first years of in school. (MALDANER E SCHNETZLER, 1998; GALIAZZI, 1998, among others).

## The Formative Practices and the Progressive Professional Autonomy

After hearing and analyzing the professional life histories of eight teachers, I am presenting evidence in this paper of five important formative processes that were present during 16 years of the Science Club history. These formative processes were present in all investigated teachers and contributed to their initial formation and professional improvement.

**a) Assisted teachers' initial preparation as well as the partnerships with experienced partners.**
The Science Club started in 1979 and since then has had, as a very strong characteristic, the partnerships between learners. Since the second class, the partners in general are between students and another person usually more experienced. So, the students can create a model, they can discuss what happened in class, can prepare activities for classes, and can make reflections about their practice teaching. The Science Club has been a learning space where the college students of science and mathematics are able to start teaching earlier. Vicente, one of the participating teachers said in his professional life history:

> *I feel that I was a privileged student when I first started working at the Science Club, because I began doing work with two professionals who I have great respect for. They gave me big support in my teaching career. They gave me the freedom to suggest some activities and to work with pupils. Those teachers are biologists but some students wanted to do projects in Exact and Natural Science. Then, they stayed under my orientation, since my major was in chemistry. It was wonderful because I had their company and, at the same time, they gave me the freedom to work with some of their pupils. (...) The experience was such that the work happened in a way in which I was a student, but I had a smaller pupil group to orient than they did (...) but so, I already began (...) Always seeking their support. Slowly, I was feeling freer and I was gaining independence from them and had no problems. ( Vicente, 1997)*

Vicent's words suggest a progressive achievement of autonomy through his partnership with the two teachers with whom he worked. That partnership gave him conditions in which he could improve his teaching practices and enhance his identity as a teacher. The teachers gave Vicente responsibilities "slowly", in his own words. This process was very good for him, because he "gained independence". He was becoming self-reliant and beginning to see himself as a teacher. I agree with FREIRE (1999:121) in the understanding that *autonomy (...) is a process, it is a coming into being. It does not happen on a scheduled date. It is in this way that pedagogy of autonomy must be centered on stimulating experiences involving decisions and responsibilities that are, in experiences that respect freedom.*

Moving towards autonomy, the students discuss and plan their class sessions with their partners, reflect about facts and problems, and share experiences and feelings, frights and doubts. They also decide on pedagogical approaches, including teaching through inquiry. With their partners, the students attempt new challenges. In these partnerships, both participants benefit from the experience. However, the partnership is not a one-sided experience. It is an exchange between teacher and student or between more and less experienced partners, as SCHÖN (1992) says. Like Vicente, all participating teachers mentioned how important this experience was in their education and professional development. Despite being a licensed teacher when she began working in the Science Club, Anita emphasized how important the partnerships with more experienced individuals were to her as she constructed her identity as a science teacher, especially in her ability to use research as a pedagogical tool. In her professional life history she said:

> *Something that I also think was interesting was the process of the beginning work in the Science Club. Because, although you are already a teacher, you dominate the content matter (...) it is important that you have someone who dominates the methodological proposal. In this process I think the Science Club did very, very well. When we began, we always began with someone more experienced and those who were beginning the process worked in an interactive way. After this initial step we took us to assume our children group, with personal characteristics, with our own direction, with our charisma, with our individual work proposal. I think the fact that we spent some time together with someone more experienced gave us more security in that way of working. And this happened with children and with teachers, when we began the proposal of continuing education for teachers. I remember the first teacher course we went to São Miguel do Guamá. We worked together, in the same teacher group, you and I. Fernando worked with Luci. There were four of us working in two groups. Each couple of us was responsible for a teacher class. It was very good to learn and we adopted this process. (Anita, 1997)*

Anita finds the partnership period to be a very meaningful formative period. She considers the partnership process to be a strong characteristic of the teacher formation-process in the Science Club. The purpose was not one of duplication, as Anita says. During the second phase Anita was teaching her own class, with her own charisma, with an individual work proposal for basic school pupils. She was developing some work initiatives with the confidence that she had someone to share ideas and doubts with and with whom to discuss her professional practice. Moreover, she remembers that we adopted the partnership process as a working methodology, using it in teachers' continuing education programs.

**b) Group Interactions**

The second formative process, which was important for the students during their professional life, has been named group interactions. In this process the students participated in groups in order to study or work, to read and discuss, and to write manuscripts as a group. The solidarity in this practice, through the sharing of experiences between novice students and students with more professional experience, afforded group members the opportunity to participate in scientific events, reporting on teacher research and on teaching with, about, and through research. We can notice by what the participants reported, that these experiences contributed to the emergence of a new culture of teacher education and teaching (IMBERNON, 1994). This occurred not only in the Science Club of UFPa, but also in the students' future institutions where they took on roles as teacher-educators. We also find that they try to develop, with their own students, practices like the ones they experienced during their own professional development. These experiences allow the participants the opportunity to become reflective teacher-researchers regarding their teaching practices, as suggested by SCHON (1992), and ZEICHNER (1993). Similar thoughts from the work of DEWEY (1976) served as the springboard for beginning our own work in 1979.

We thought we needed a "common culture" for the group, but we knew there were and should be differences among participants. We didn't want everybody to be the same, but we needed to become a coherent group of teacher-educators. We got together every week for seminars, discussing what we had read, designed projects and planned actions, resulting in a collective productivity. Also with all the group activities, there was a strong feeling of solidarity. Geraldo assessed this as follows:

> *(...) It was a great moment when we achieved a lot in the Science Club. My partner is in trouble, what can I do to help her/him? That is what I felt, and it is really important when you work as a group. That was an important point. This became our practice(...) initially through the seminars and later through our working groups (Geraldo, 1997).*

Solidarity occurred in several ways, and was achieved by sharing experience and knowledge. When someone speaks about their experiences they 'live it again' while they talk (CONNELLY and CLANDININ, 1995) and the listeners, based on what they have experienced, experience the situation in another way. The experience results in personal knowledge for those who lived it (LARROSA, 1996). As a person narrates his experience I see that they bring much knowledge from that experience which can be shared with other people. During our study this always happens, especially among the partners in the group. This 'shared experience' happened at all levels, either with those students who had lot of experience or with those who had just started in the Science Club. There was sharing between all students even in different areas such as Arts, Pedagogy, Psychology and Language. They had different life experiences, but they all related with the teaching of Science and Mathematics that was being developed in the Science Club. Thus, the teachers as a group and the teachers as individuals could develop.

Other significant interactions occurred during the writing and discussion of texts during meetings. Participants value these formative experiences as important to professional development (CLARKE, 1994), both individually and in the group process.

**c) Participation in the community and the school community:**

Another formative process that is important in the histories of professional life' described by participants is the work with communities. This process is developed at two levels. The first is one wherein the college students, along with students from pre-college settings, research problems in the community. At the second level there are culminating events for the activities, consisting of community events. Those events, like Science Fairs, are used to show papers to the community – developed either by the students or professors or different institutions. These events served as a means of disseminating knowledge, as well as moments to present problems in their socio-political-economic-environmental contexts.

Science Fairs became formative for both teachers and teacher-educators. The Fairs integrate the work with children throughout the year and culminated in the presentation of the work of the children. The Fairs provide the opportunity for the integration and evaluation of the pedagogical process. They consist of forums for the debate and discussion of knowledge, teaching and learning, as well as for the evaluation of the research projects presented. For teacher-educators, there is an opportunity for evaluating the process as a whole, for self-evaluation, and for further development of relationships among teachers, children and the community.

Within this perspective on professional development, the social and political commitments of practitioners, is highlighted in relationships between teachers and teacher-educators, teachers and children, and even among teacher-educators, teachers, and children, through a continuous process.

**d) Challenging situations**

The teachers' "professional life histories" indicate that they had great importance for the challenging situations that were present in the Science Club's former practice, as well as in the initial and continuing education programs. Analyzing the teachers' speech, the word *challenge* is a *trademark.* It can make people improve. MORAES (1991) says that challenges are *"permanent impulses to go ahead".* That is a characteristic of good teachers who are always looking for high professional quality. The author says that challenges are *opportunities to go ahead, to achieve professional improvement. However, they require risk taking, which means facing unknown situations, and having the courage to perform actions about which we are not sure of success. (p.225)*

Thus, when I decided to investigate teacher and teacher-educators' formative experiences, I considered situations that required risks, produced feelings of apprehension and insecurity, and also required certain ability to search for the solution and get success.

All participating teachers considered these situations to be very important formative elements in their professional lives. For them, these situations were present in all of the Science Club's formative experiences giving them the opportunity for professional improvement.

From this study, I can find three kinds of challenging situations:

- Teachers accept a new situation as a challenge, and take the risks that it involves and prepare themselves to face it.
- The teacher educator perceives challenging situations during professional development activity, reflects about them, makes decisions regarding further action and develops the ability to manage unexpected situations. SCHÖN (1992) called this type of situation a "twilight zone".
- Teacher-educators pose challenges for themselves, with aims previously defined. In this case, the person reflects on the design of the action and instigates situations that are new to their practice. It appears the processes of reflection about action, reflection in action, and reflection about reflection in action, seem to be present since (SCHÖN, 1992) the person designs the action and at each moment evaluates it to continue its development.

**e) Perception of the (trans)formational and unaccomplished professional trajectories**

It is very important to recognize one's own professional development and to have awareness of one's own (trans)formational and unaccomplished professional trajectories. These conditions are necessary for teachers to develop an attitude of continuing education as science and mathematics teachers and as teacher-educators. These two feelings are present in the participating teachers as individual and collective characteristics. Teachers reveal this in their own way, warranting the unit in the diversity, as suggests Morin (1995).

The participating teachers recognize their professional development while telling their professional life histories. They perceive their professional and personal transformation in different ways. This transformation reflects a new point of view about learning-teaching-knowledge as teachers become aware of their role as models for the group of new teachers and students. This happened to Vicente, Anita, Fernando, Georg and Geraldo. Their own points of view became larger and stronger while new challenges are accepted and new experiences are lived in a teacher science education practice able to transform the local context.

The awareness of unaccomplished professional trajectories are found in professional life histories as feelings of professional development of the present and contemplation of the future, in both a personal and a collective level. They expressed such views through expressions such as: *grow more in my profession, search more, achieve more, understand more, pursue more, do a postgraduate course...*

At least three teachers revealed the wish to amplify the Science Club's epistemological approaches. Geraldo seemed committed to understanding Science Education as a more global and holistic process than he had considered it previously.

The group's questioning attitude about individual and collective practice is a constant stance in the working group, revealing, in my point of view, reflections about one's own teaching practices. In this sense, Geraldo highlights the process of continuous evaluation by the group as a process of individual and collective growth.

According to Anita, being in a group provides a great opportunity in which to achieve professional growth, because the group's power can help each group member grow and the group to grow as a whole. The unity of the group towards common goals is very important to the group's growth as a unit.

The group and individual development is expressed by the participating teachers through personal feelings, such as: *to have the perception of greater professional equilibrium, a feeling of greater professional respect; feeling more temperate, to become proud of belonging to the group and to make the contribution of the group.*

## Final Considerations

With this paper, my purpose is to contribute to the teacher education processes, especially in science and mathematics education. For this, I analyzed the participating teachers professional life histories. All of them have achieved professional distinction. In general, they are currently professors in public or private universities.

The novice teachers' initial experiences and in their partnership with experienced teachers present evidences of an important professional development process. Nowadays in Brazil we have a national education law – LDBN/96 – that recommends that novice teachers' become involved in pedagogical projects from the first moments of their undergraduate courses. We need to think of ways to multiply meaningful educational spaces and thereby increase the possibilities for initial preparation for novice teachers' as well as the possibilities for partnerships with experienced teachers. Some ideas can be made explicit here, such as community services, university extension projects and association of initial preparation and continuous teacher educator programs.

Participation in working groups enables novice teachers to develop some important formative processes, such as professional support, attitudes of solidarity, academic discussions, spontaneous and shared lectures, and collective intellectual production. It can facilitate the writing of texts and the production of other didactic materials.

The participation in scientific congresses, seminars and academic groups emerges as important formative elements that contribute to the professional development of teacher researchers, enabling teachers to reflect about their work, comparing one's own teaching to the practice of other practitioners and to actual theories.

All these elements come together to provide the professional development of teachers as persons, and as teachers and as researchers. The teacher becomes a critical, autonomous and unique professional. However, being a teacher is a process of continuous construction and reconstruction which is never ready or complete.

The participating teachers in this research seem to constitute themselves as teacher-educators while progressively taking up more complex situations. When the challenges succeed, they can lead to other challenges, which can be of even higher levels of complexity.

The participating teachers seem to contribute to the construction of a new model of teacher-educators with new methods and innovative practices. This new model is one that emerges from the value attributed to one's own professional development experiences through the Science Club.

The different kinds of challenges taken by the participating teachers, and their interactions with other teachers as well as other persons of the local community, help them and the children become real citizens. This practice is a way to accomplish the social and political Science Club's goals in its initial and continued teacher education programs.

The research in teaching is always present in inquiry projects with the purpose of getting to know about social and natural local contexts in which to find improvement in the quality of life. The social and political engagement regarding questions of "learning-teaching-knowledge relationships" have been the trademark of this work, from the perspective of teachers educators as well teachers and students.

The participating teachers reveal some professional autonomy in making decisions when confronting new and challenging situations. Along with FREIRE (1999), I understand that making decisions means the teachers considers themselves as professional teachers. Such decisions require reflection in action about action, and reflections about the reflections in action (SCHÖN, 1992) to happen.

The teachers understand their own professional development as process-products of multiple relationships, but situate them in the Science Club experiences. The autonomy can also be revealed, as FREIRE (1999) suggests, through feelings and impulses of questioning and searching, by considering the future as having various possibilities and by constructing it, despite the social, economic, cultural, political and epistemological obstacles that condition the process.

The participating teachers can recognize their own professional development, they can notice their own new-conquered autonomy at the same time that they are aware of their (trans)formational and unaccomplished professional trajectories.

## References

ARAGÃO, R.M.R.de. *Reflexões sobre ensino, aprendizagem, conhecimento.* São Paulo: Revista de Ciência e Tecnologia, 2(3): 7-12, 1993.

ASSMANN, H. *Reencantar a educação: rumo à sociedade aprendente.* Petrópolis/RJ: Vozes, 1998.

AUSUBEL, D. P. *Educational Psycology: a CognitiveView.* New York, Holt, Hinehart e Winston, 1968.

CLARKE, A. Student-teacher Reflection: developing and defining a practice that is uniquely one's own. IN: *International Journal of Science Education.* London, UK: Taylor e Francis, vol.16, Nº 5, 497-509. Ste-oct. 94.

CONNELLY, F. M. e CLANDININ, D.J. Relatos de Experiência e Oinvestigación Narrativa IN: LARROSA, J. (org) *Déjame que te cuente. Ensayos sobre narrativa y educación,* Barcelona: Editorial Laertes, 1995.

DEWEY, J. *Experiência e Educação.* Trad. de Anísio Teixeira. 2 ed. São Paulo: Nacional, 1976.

FREIRE, P. *Pedagogia da Autonomia.* Rio de Janeiro: Paz e Terra, 1999.

GALIAZZI, M. do C. *Professor-pesquisador: é preciso mudar de paradigma.* IN: Ciência, Ética e Cultura. São Leopoldo/RS. Ed. UNISINOS, 1998.

IMBERNÓN, F *La formación y el desarrollo profesional del profesorado. Hacia una nueva cultura profesional* Barcelona: Ed. Graó, 1994.

LARROSA, J. *La Experiência de la Lectura: Estudios sobre Literatura y Formación*. Barcelona: Laertes Editorial, 1996.

MALDANER e SCHNETZLER, R. *A necessária conjugação da pesquisa e do ensino na formação de professores e professoras.* IN: CHASSOT, A e OLIVEIRA, R. ( org. ) São Leopoldo/RS: Ed UNISINOS, 1998.

MORAES, R. *A Educação de Professores de Ciências: uma investigação da trajetória de profissionalização de bons professores.* Porto Alegre, UFRGS, 1991. (Tese de Doutorado).

MORIN, E. *Introdução ao Pensamento Complexo.* Lisboa: Instituto Piaget, 1995.

POPHAM. e BAKER. *Como Planejar a Sequência de Ensino.* Porto Alegre/RS: Editora Globo, 1978.

SCHÖN, D. A. *La Formación de Profesionales Reflexivos. Hacia un nuevo diseño de la enseñanza y el aprendizaje en las profesiones.* Barcelona: Paidós, 1992.

UFPa/CLUBE DE CIÊNCIAS. *Projeto de Criação do Clube de Ciências.* Documento interno. Belém/Pa:1979.

ZEICHNER, K. M. *A formação reflexiva de professores: Idéias e Práticas.* Lisboa: Educa Professor, 1993.

# 070 EXPLORATORY LEARNING ABOUT FRACTALS AND CELLULAR AUTOMATA USING A WEB BASED EDUCATIONAL MODULE

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**Abstract**

This paper presents the planning, development and preliminary evaluation of a Fractals and Cellular Automata WebSite aiming at constructing a Web Based Educational Module about Complex Systems, Fractals and Cellular Automata for Physics Curriculum. This website is available in the web address http://www.modelab.ufes.br/automato. A system is said complex when the number of variables that describes it is very large. It is possible to treat the systems found in the nature through differential equations, however if the number of involved variable is very large, the handling through these tools becomes highly difficult. There is a kind of tool that can handle these systems called Cellular Automata: with these tools it is possible to study complex systems trough the interactions between its basic units. Examples where this occurs are predator-pray interaction, economic systems and social events. Cellular Automata can generate images that present a peculiar structure called fractal structure that is extremely broken and present not an entire dimension. The Website Fractals and Cellular Automata was developed aiming at constructing an instructional material on the subject by the fact that there are many informative website available about it but few with a curricular focus. This paper presents a description of the construction of the website, its content and design and also a preliminary evaluation carried out. Based on the results of this evaluation the website will be reorganised to be included in the Physics Curriculum.

## 1. Introduction

This work reports the planning, development and preliminary evaluation of a Fractals and Cellular Automata Website aiming at constructing a Web Based Educational Module on Complex Systems, Fractals and Cellular Automata for Physics curriculum. This website is available in the web address http://www.modelab.ufes.br/automato.

Initially a theoretical introduction will be presented about the topics that constituted the Module database. Proceeding will be presented the website's structure where both the design and the structure of the content are described. At the end the results of a preliminary evaluation carried out with teachers and students, specialists or laymen, are presented and comments about the website restructuring are made based on these results.

### 1.1. Theoretical Framework

#### *1.1.1. COMPLEX SYSTEMS*

There are a number of phenomena that happen in the nature. Some of them can be studied through mathematical models such as the Maxwell's equations that explain the electromagnetic phenomena. There are also other phenomena such as earthquakes, turbulence, dynamics of populations and growth of bacterial that can be studied through the use of differential equations. However, to use this kind of tool it is necessary that the model of the system be extremely simplified so that the equations have a viable solution. The use of differential equations for a system with an elevated number of variables makes the resolution extremely difficult. When the number of variables grows in the modelled system its solution can be obtained using numerical methods of integration usually using computational resources that still demand a long time in its resolution.

When a system contains a great number of variables it is denominated Complex System because the prediction of what can happen with such systems is too difficult. The Complex Systems Theory is a new scientific field that studies how is the influence of the parts of a system in its collective behaviour. Thus it would be possible to foresee, with a certain range of error, what happens in the evolution of such systems. This theory can be applied to study the relationships among the individuals of a society, to study economic systems to foresee the behaviour of a certain investment or in medicine to predict the development of an outbreak of infectious disease. That theory has the focus on the parts, on the whole and on the relationships between part-whole.

*1.1.2. FRACTALS*

Usually geometry is through concepts such as point/dimension=0, line/dimension = 1, plane/dimension =2 and space/dimension=3. All these perceived dimensions are entire numbers but will nature obey these concepts? Bernoit Mandelbrot, a mathematician, in your book The Fractal Geometry of the Nature, published in 1975, declares a sentence that has been influencing the study of nature since then: "Clouds are not spheres, mountains are not cones." In his work he questions the approximation done for studying nature, declaring that nature does not have a geometry that can be inserted in whole dimensions but instead in fractional dimensions. Therefore, for the first time he introduces the word "fractal" that means: to break into fragments or to produce in small pieces.

The fractals can present a list of characteristics shown below:

- **Self-Similarity**: The whole is similar to the parts, if a piece of the figure is analysed, and soon after is analysed the whole figure it will be seen that they are similar. Only the deterministic fractals present this characteristic;
- **Extreme irregularity:** High roughness and fragmentation;
- **Fractional dimension:** They have not whole dimension that can quantify in a certain way how irregular or broken into fragments is the studied figure.

An example of self-similarity is the mathematical fractal called *Sierpinski's Triangle.* One of the simplest ways of obtaining that figure is described below: when seeing a equilateral triangle link the vertices to the opposite sides and remove the piece of the triangle that is upside down in the centre: three smaller triangles will remain. The same rule is applied to the smaller triangles, such us shown in the Figure 01.

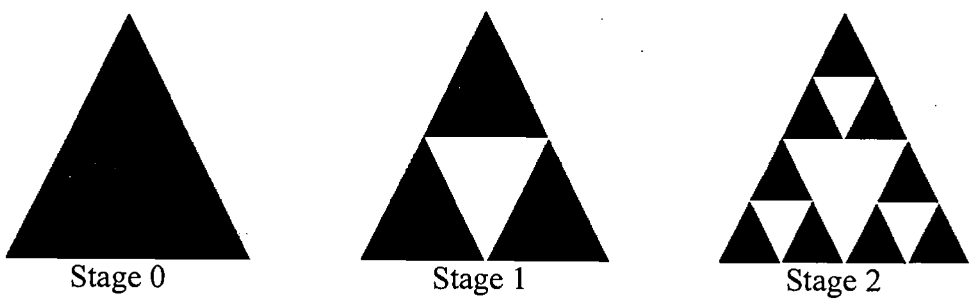


**Figure 01**: *Representation of the three first stages of Sierpinski's Triangle*

Some structures in nature present fractal structure so that it could be studied using the theory of fractals. The coast of a country, the path travelled by a ray, the Brownian Motion presented by pollen particles in the surface of the water are examples of these structures.

Many natural processes can be represented using theoretical models with fractal structure. Some of the fields where the fractals theory can be used are quoted below:

- Physics of the Materials: studies the ramified structures and growth of structures, e.g., crystals and fluid penetration in a very dense liquid;
- Geologic Phenomena: studies the geologic flaws, earthquakes, volcanic eruptions, mineral deposits and formation of rivers, formation of the coastal line;
- Cosmology: studies of the distribution of galaxies in the universe;
- Landscapes Fractals: studies the recognition of images for war strategies.

There are several forms of obtaining fractal figures. One of them is with the use of a tool called Cellular Automata that will be described in the next topic.

#### *1.1.3. CELLULAR AUTOMATA*

Cellular Automata are virtual systems formed by basic units that interact ones with each other. Those interactions generate graphic patterns or figures obtained by the disposition of the basic units in the space. Besides they can be good to simulate several physical, biological, economic systems with a high speed for getting data.

The Cellular Automaton – AC - most known is the Von Neumann's "Game of Life". It is consisted of a square lattice, where the positions and time are discreet. Initially some cells in the lattice are randomly filled and the evolution of the system happen in agreement with the following rules:

- If a cell of the lattice square contains an individual and its neighbourhood has less than 2 or more than 3 individuals, this individual disappears of the lattice, representing its death.
- If a cell of the lattice square contains an individual and its neighbourhood contains 2 or 3 individuals, this individual stays in the lattice, meaning its survival.
- If a cell doesn't contain any individual and its neighbourhood contains 3 individuals, in this cell appears an individual, representing its birth.

This AC behaves in agreement with those three rules and with an initial condition: each step is a consequence of the previous step. Making the system to develop it will tend to reach critical states of self-organisation. Those critical states generate interesting formation's patterns for the study of the complex systems. A drastic change will happen in the patterns or images if a small change is made either in the rule or in the initial conditions. It is interesting to see that those patterns will occur in many phenomena in nature such as the organisation of a community of ants or of bees.

The ACs can be one, two or three-dimensional: the one-dimensional ACs develops along a discreet line; the two-dimensional ACs develops in a lattice that can be, for example, square, triangular or hexagonal; the three-dimensional ACs develops in a three-dimensional lattice. Stephen Wolfram wrote many works about the one-dimensional ACs also called of lineal Eve.

## 2. Motivation

The motivation for constructing a web website about Complex Systems, Fractals and Cellular Automata was based on the fact that there are an enormous amount of material diffused by the Internet which are basically informative and just a few of them presenting a curricular focus.

The project started with a search for resources about the subject aiming at building the data base. After building the data base the project of construction of the website began. In its first version were used some advanced resources like DHTML, JavaScript, and ASP. There was a page within the website where visitors was asked for answering a questionnaire focusing at the web design, the content and writing their suggestions in a designed area. These questions were used to carry on the first evaluation that will be described later.

## 3. The Website Structure

The description of the website structure will be broken in two pieces: Design and Content. This report shows only the structure of the first version, because the next version is still in an implementation phase.

### 3.1. About the Design

The website's home has an animation of the 4 first stages of the Sierpinski's Triangle developed in Flash. Clicking on the animation the visitor enters in the website that is divided in two frames: a top frame where the menu is situated and a bottom frame where the text is situated such as shown in the Figure 02.

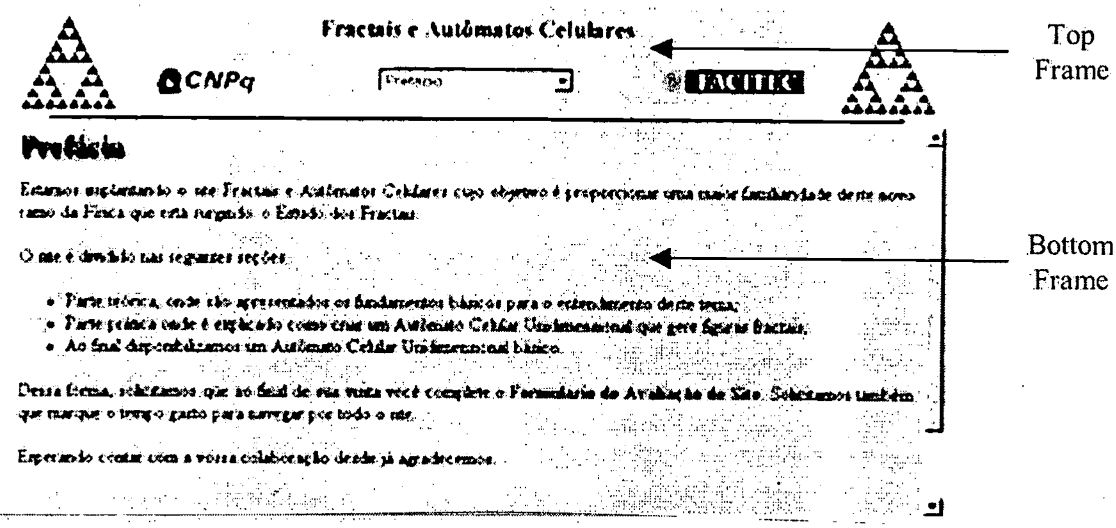


**Figure 02**: *Layout of the Website*

The menu located on the top frame is a pop-up menu: when it is clicked it makes available the possible options of navigation as shown in the Figure 03. It means that the visitor can navigate over all the content of the web website without necessarily following a standard sequence.

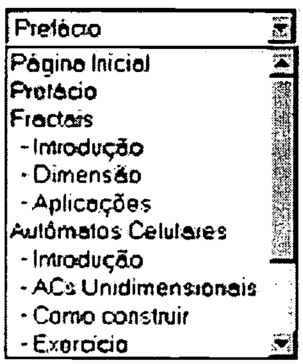


**Figure 03**: *Pop-up Menu*

Inside the website the preface is the first content to appear where both the objectives of the website and some necessary information are described so that the visitor can continue its course. At the bottom of each page there are arrows of "next page" and "previous page" for the visitor at his/ers choice may follow the content around the suggested sequence. The text tries to present a clear, direct and brief description of the information seeking both to moderate the visitor's cognitive load and consequent interest in keeping the navigation. Based on these two aspects the text was structured so that the visitor does not have to click many times in the scroll bar that is the whole content of the page can be seen at once decreasing the stress of the reading. This situation does not happen only when the development of the text could be harmed. This same style appears in the whole website and at the end of the text about Cellular Automata it is found an exercise where resources of JavaScript were used. The exercise is shown in Figure04.

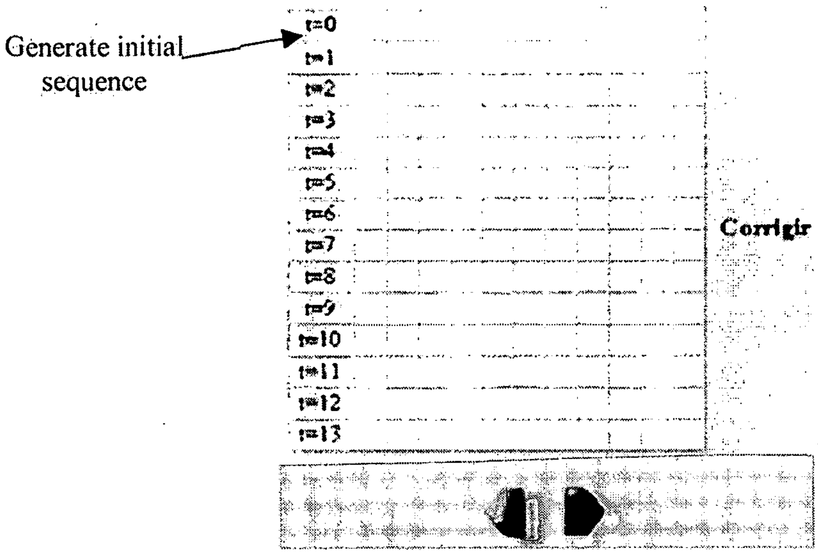


**Figure 04**: *Creation of Rule Number 90 Exercise*

In this exercise the visitor is asked for creating a random initial sequence by clicking in the link t=0 and starting the completion of the next stages in agreement with the rule denominated by Wolfram of 90th rule. Taking on that a cell can have two either empty or filled states:

If the state of the right cell is different of the state of the left cell in the next time the centre cell will be filled;

If both states of the neighbourhood cell the state of the centre cell will be occupied.

If a cell is white when it is clicked it changes its colour from white to black indicating that the cell is filled; clicking it again the cell goes back to white indicating that it is empty as shown in Figure 05 the visitor. Thus, with the mouse the visitor can build the pattern generated by that rule.


**Figure 05**: *A click on a Cell changes its State*

It is possible to request the correction of the part of the exercise that have already been done and will be indicated the line where happened any mistake. Thus it is allowed to the visitor to go back and correct any possible mistake. After having completed all the stages correctly and having requested for the correction the "next page" arrow becomes available.

When the "nest page" arrow becomes available the website allows the visitor to enter in the only hide page of the website. Inside this page there are a Cellular Automata written in JavaScript similar to that built by Wolfram with which the visitor can verify all the rules with range equal to 1 and number of possible states equal to 2. See the Figure 06.

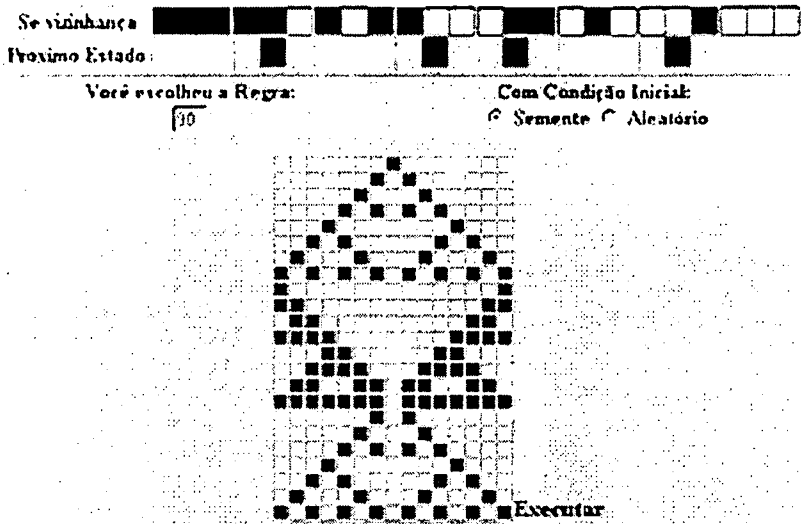


**Figure 06**: *The 90th Rule Pattern, with a seed initial state.*

With the aid of this script the visitor can test the several patterns formed by these types of Automata because it allows the visitor to choose the next states in agree with certain neighbourhood. The Figure 06 shows an example with the application of the 90th rule. The evolution of this rule in a lineal lattice of infinite elements for an infinite time generates the already mentioned Sierpinski's Triangle.

Another characteristic presented by the website is a commented bibliography where each reference is accompanied of a comment. That facilitates to the visitor to select the reference according to his/er interest to complement the knowledge.

### 3.2. About the Content

The content of the website was developed based on a friendly environment presenting a logical sequence. The exhibition of the content begins with an introduction about Fractals where it is explained basically what is a fractal, how it is formed, how to calculate the fractal dimension and its applications in several areas.

The text proceeds with an explanation about ACs describing what they are, how they behave, a deeper explanation about one-dimensional ACs and an explanation of how to build one. The objective of this explanation is to lead the visitor to learn, step by step, how to create a computational AC but it is necessary that the visitor know a programming language.

## 4. Preliminary Evaluation

### 4.1. The Instrument

Aiming at evaluating both the content and the design of the website it was elaborated a questionnaire and made available in the website. This questionnaire, written in ASP programming language, could be filled and sent from the website and the answers were stored in a database. The questionnaire was composed of 12 questions in a Likert-like Scale style, from 1, lowest grade to 5, highest grade. The questionnaire also included an area for being filled with the spent time with the navigation and another area where the visitor could write both critiques and suggestions. The questionnaire is shown in the Figure 07.

| **Design Evaluation** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| 1. How do you evaluate the presentation of the website? | | | | | |
| 2. Is the website easy-to-navigate? | | | | | |
| 3. Are the instructions of the website supporting the navigation? | | | | | |
| 4. Does the website design make the reading of the text easy? | | | | | |
| 5. Does the sequence of the content make difficulties to text understanding? | | | | | |

| **Content Evaluation** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| 6. Is the written text easy to understand? | | | | | |
| 7. Is the content written in advanced way? | | | | | |
| 8. Is the language of the website clear? | | | | | |
| 9. Did this website give you a better understanding about this subject? | | | | | |
| 10. Does the presentation of the content lead you to seek for more information about the subject? | | | | | |
| 11. Is the content of the website enough for the proposal of an introduction about the subject? | | | | | |

| **Website General Evaluation** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| 12. What is your final grade about the website? | | | | | |

**Spent Time:**

**Write down your critiques and suggestions:**

**Figure07**: Questionnaire of Evaluation

### 4.2. Sampling

The assessment of the website was made through an e-mail invitation. Thirty people were invited to participate of this evaluation: 21 teachers and 9 students, among them there were specialists and non-specialists about the subject.

### 4.3. Data Analysis

Ten out of thirty invited people answered the questionnaire: 6 teachers and 4 students. All of them sent critiques and suggestions and only 8 answered the objective questions. The quantitative evaluation was based on the objective questions and the Table 01 shows the average grade for each question.

| Question | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Grade | 4,6 | 4,9 | 4,6 | 4,4 | 4,6 | 4,0 | 2,9 | 4,3 | 3,7 | 4,3 | 4,4 | 4,3 |

**Table 01**: *Average Grade per Question*

Although this analysis is based on only a third of the overall sample these results show that the evaluation of the website was fairly good. It is important to highlight that the text of Question 7 was problematic by the fact that the structure of its text was in the reverse way in relation to the structure of the other questions. This fact may have misled the respondents.

The qualitative evaluation was based on the sent critiques and suggestions. These were categorised as described below:

Evaluation about the Content:
- The content is enough for a basic understanding about the theme;
- The language needs a reformulation so that becomes friendlier for the visitor.

Evaluation about the Design:
- It drives the visitor perfectly;
- The programming resources were good explored;
- The background colour used in the website gives a cleaner character and accommodates the vision well;
- Contains animations, giving a dynamic appearance to the website;
- The interactive resources, like the exercise and the automata, show itself attractive for the visitors.

One respondent raised the necessity of the use of a theory of learning to aid the restructuring of the website aiming at helping the visitor to have a better understanding of the subject.

## 5. The Restructuring of the WebSite

Based on this preliminary evaluation the restructuring of the website will be made according to the information gathered from the questionnaire plus additional information from readings and experiences obtained along the research.

### 5.1. Structure of the Content

Regarding the suggestion related to the use of a theory of learning it seems that the David Ausubel's Theory (Ausubel et all, 1963) is the more suitable for the aim of this study. According to Ausubel human beings organise their knowledge in a hierarchical way. This principle could be the guideline for restructuring some of the topics of the website: the related concepts of these topics could be organised in such way.

Ausubel also says that the most important factor that determines the learning process is what the learner already knows, 'find it and teach him accordingly' (Ausubel et all, 1963). If the learner doesn't have any previous knowledge about the subject, Ausubel says it is necessary to help him/er to create new structures of knowledge for linking the new information to these new created structures. He labels these new structures *previous organisers*. As the subject of the website is a new area of knowledge and quite a few people know about it; the restructuring of the website could include a link where previous information about the subject could be available. For instance, information about Euclidean Geometry could help people to understand the idea of fractal dimension.

### 5.2. Design

Regarding the design of the website it will be made changes in the disposition of the text, which will have larger margins aiming at decreasing the reading stress. Another change will be the insertion of a link in each page that leads the visitor to a form where questions about the information in that page can be asked. A specialist will receive the question and an answer will be sent to the visitor's e-mail. The frequent asked questions will be classified in topics and they will be available in the website in a FAQ page.

## 6. Final Considerations

All these possible new improvements will be followed by another assessment to determine its real effects on the learning about this subject. After that this website will be available as an web-based educational module as a tool for exploratory learning about the Complex Systems, Fractals, and Cellular Automata theories.

Nowadays Physics Courses already include disciplines of Computational Physics in its curriculum that tackle the theory of the Complex Systems using computational tools as a complement to the Numeric Calculation focused on the Statistical Physics. In these disciplines the proposal is to lead the student to work with theme through, for instance, the creation of computational Cellular Automata and analysis of properties of Fractals images. This website can be a complement for these disciplines.

After the restructuring an English version of the website will also be available.

## 7. Bibliography

GLEICK, J. (1987). *Chaos: Making of a New Science.* New York: Viking.

MANDELBROT, B. (1977). *Fractals: Form, Chance and Dimension.* San Francisco: W. H. Freeman and Company.

________. (1985). *The Fractal Geometry of Nature.* New York: W. H. Freeman and Company.

MARTINS, M. L. (1999). *Autômatos Celulares: Teoria e Aplicações - Notas de Aula.* Departamento de Física, Universidade Federal de Viçosa.

MOREIRA, I.C. (1999). Fractais. In NUSSENZVEIG, H. M. (1999) (org.). *Complexidade & Caos.* Rio de Janeiro: Editora UFRJ/COPEA. p.276, 1999.

OLIVEIRA, P. M. C. (1999). Autômatos Celulares. In NUSSENZVEIG, H. M.. (1999) (org.). *Complexidade & Caos.* Rio de Janeiro: Editora UFRJ/COPEA. p.276.

WOLFRAM, S. *Publications by Stephen Wolfram, Articles on Cellular Automata* [online]. Available: http://stephenwolfram.com/publications/articles/ca/ [captured on 28th dec. 2001].

AUSUBEL, D. P., Novak, J. D., Hanesian, H, (1978). *Educational Psychology: A Cognitive View.* 2ª ed. New York: Holt, Rinehart & Winston.

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071

# SATISFIED OR DISSATISFIED WITH THEIR SCIENCE TEACHING? WHAT DISTINGUISHES BETWEEN TEACHERS WHO EVALUATE THEIR TEACHING POSITIVELY FROM THOSE WHO EVALUATE IT NEGATIVELY?

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**Abstract**

A curriculum reform was carried out in 1997 in Norwegian primary and secondary schools. This reform aimed to fortify the position of science, especially in primary school. We carried out a study in 1998 and 1999 to see how the reform was implemented by the science teachers in primary schools. In this paper we focus on the differences between teachers who are satisfied with their science teaching and those who are not in terms of teacher characteristics, teaching methods, attitudes towards science teaching and how they experienced their own teaching. We found that the satisfied teachers use varied teaching methods and activate students more. Further, the dissatisfied teachers show a more negative attitude towards science teaching in general. No differences were found in terms of teacher gender, age or formal education in science.

## Introduction

For many years, science has held a weak position in Norwegian primary schools. It was not a separate subject, but part of an interdisciplinary subject along with history, geography and social sciences. The result of this was that science was given a low priority from teachers who very often did not have any educational background in science (Sjøberg, 1994).

In response to this, the authorities wanted to fortify the position of science in the curriculum reform (Reform 97) that was implemented in 1997 (KUF, 1999). One important consequence of this was that science became a separate subject in primary school. Science was also emphasised as a practical subject where the students are to be active participants.

We were interested to know how the teachers who taught science responded to the reform, their attitudes towards it and whether or not they were satisfied or dissatisfied with the way their science teaching had turned out after the reform. In this paper, we look for differences between the teachers that are satisfied with their science teaching and those who are dissatisfied. Are there any differences with respect to teacher background (gender, age, education, teaching experience), teaching practice in science, attitude towards science and experience with their science teaching? In short, what separates the satisfied science teacher from the dissatisfied one?

## Methods and samples

The data in this study were collected in 1998 and 1999 by way of a questionnaire to science teachers teaching fifth grade in primary school (10-year-old students). The questionnaire was sent each year to 450 different schools from all parts of Norway. The schools were randomly chosen. We asked the schools to choose a teacher to answer the questionnaire who taught science in fifth grade. This grade was chosen because the curriculum reform (Reform 97) was gradually implemented and in the first year (1997/1998) only the first, third and fifth grade were included in the reform. We also anticipated that the change, as the result of the reform, would be most clearly expressed at this grade.

All together we received 360 responses from the schools, which is a response rate of 38 per cent. In addition, some of the questionnaires were incompletely filled in and had to be discarded from the analysis. The response rate is low, and this puts the validity of the results in question. However, in this study we divide the respondents into two groups and compare the answers they give. These results are less vulnerable to a low response rate than survey studies which aim to say something about relative frequencies in the studied population.

The questionnaire contained questions concerning the school, the class and the teacher in the form of multiple choice questions grouped into categories. Frequencies were calculated for each category. Further, we asked the teacher how the science teaching was organised, how the teacher had experienced the science teaching, what attitudes the teacher had towards science teaching and how the teacher evaluated his/her science teaching and to the extent to which they had achieved goals in science teaching. Here we used a 5 or 6-graded scale (e.g. strongly disagree – disagree – undecided – agree – strongly agree). The response categories were numerical values from 1 to 5 . Mean scores were calculated and used to compare the different groups of teachers. All calculations and statistical analysis were carried out using the SPSS 10.0 statistical program.

## Results and discussion

Is the teacher satisfied or dissatisfied with his/her science teaching?

The teachers were asked to give an overall evaluation of their science teaching in the year the study took place. This was done by judging the statement "*I am satisfied with the way my science teaching has been carried out*" by giving a value on a 5-graded scale from strongly disagreeing (1) to strongly agreeing (5). The distribution among the teachers is given in Fig. 1. It shows that there is a clear distribution towards the agreeing side of the scale, meaning that the general tendency is that the teachers are positive to the way their science teaching has turned out. However, the largest group of teachers (45.1 per cent) were undecided (middle score), and a significant proportion (13.6 per cent) said that they disagree or disagree strongly with the statement, i.e. they were not satisfied.

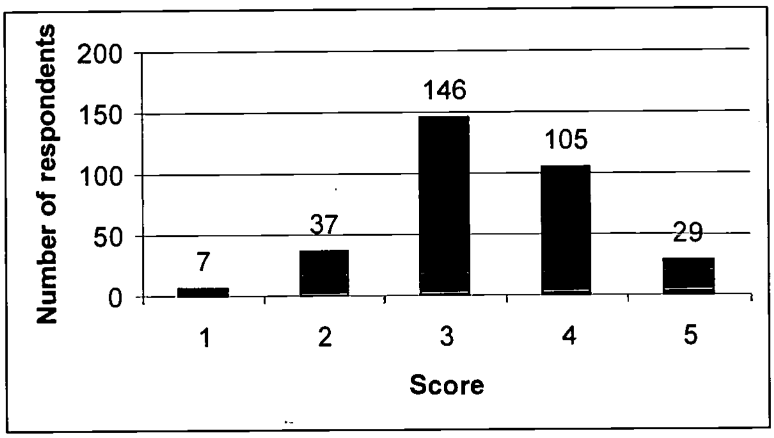


**Figure 1.** Distribution of teacher satisfaction with own teaching

We wanted to see if we could find underlying differences between the teachers that stated that they were dissatisfied (score value 1 and 2) with the teachers that were satisfied (score value 4 and 5). So we excluded the teachers in the middle group and made two new groups; "Satisfied with my science teaching" and "Dissatisfied with my science teaching". Next, we set out to determine whether or not we could find any differences between the two groups in goal achievements in science teaching, class size, teacher characteristics, teaching methods, teacher attitude towards science education and how the teacher had experienced the science teaching and the students.

**Goal achievement in science teaching**

We asked the teachers to state the extent to which they felt that they had achieved specific goals for their science teaching. They were asked to score their achievement for each goal on a scale from 1 to 5 (5 being the highest achievement). The results are given in Table 1. This shows that there is a high correspondence between goal achievement and satisfaction with their science teaching. For all of the goals, the mean achievement score is higher in the satisfied group, and a comparison of the mean scores with a t-test shows that all goals are significantly higher (95% level) in favour of the satisfied group. This was not unexpected, but it strengthens the separation between the two groups.

**Table 1.** Teacher response to goal achievement

| Goal | | Mean | St.dev | t-value | d.f. | Sig. |
|---|---|---|---|---|---|---|
| Gave the students exciting experiences in science | Dissatisfied<br>Satisfied | 3,05<br>3,81 | 0,89<br>0,85 | -5,12 | 174 | 0,000 |
| Developed the ability to work independently | Dissatisfie<br>Satisfied | 2,80<br>3,29 | 0,85<br>0,70 | -3,80 | 172 | 0,000 |
| Gave the students knowledge that is useful in their everyday lives | Dissatisfie<br>Satisfied | 2,80<br>3,29 | 0,80<br>0,68 | -3,98 | 171 | 0,000 |
| Gave the students higher self confidence in science | Dissatisfie<br>Satisfied | 2,98<br>3,53 | 0,94<br>0,82 | -3,691 | 172 | 0,000 |
| Gave the students outdoor nature experiences | Dissatisfie<br>Satisfied | 3,50<br>4,17 | 1,07<br>0,95 | -3,95 | 172 | 0,000 |
| Prepared the students for further science education | Dissatisfie<br>Satisfied | 3,02<br>3,70 | 0,76<br>0,75 | -5,17 | 173 | 0,000 |
| Increased the students interest for science | Dissatisfie<br>Satisfied | 2,88<br>3,35 | 0,85<br>0,85 | -3,13 | 172 | 0,002 |
| Increased the interest for science, especially among the girls | Dissatisfie<br>Satisfied | 3,09<br>3,83 | 0,88<br>0,87 | -4,87 | 173 | 0,000 |
| Gave the students as much knowledge in science as possible | Dissatisfie<br>Satisfied | 2,98<br>3,50 | 0,66<br>0,69 | -4,37 | 171 | 0,000 |
| Gave the students practice at following instructions in hands-on activities | Dissatisfie<br>Satisfied | 2,91<br>3,32 | 0,83<br>0,87 | -2,74 | 173 | 0,007 |
| Achieved to teach the students the names of common plants and animals | Dissatisfie<br>Satisfied | 3,47<br>3,86 | 0,96<br>0,82 | -2,66 | 173 | 0,009 |

**Class size**

Teaching science may be influenced by how many students there are in the class. Hands-on activities and outdoor education may be more difficult to carry out in large groups. In addition it is more difficult to give individually differentiated education in large groups. However, we have not found any relationship between how satisfied the the teachers are with their science teaching and class size. Further, there is no difference between classes with a balanced gender ratio and classes where either boys or girls dominate.

The teaching environment in a class varies due to factors such as social background, intellectual capacity and motivation. However, we have not asked the teachers to assess the classes according to these factors, so we have no data as to what extent the teacher's evaluation of his/her own science teaching is influenced by these factors.

**Teacher characteristics**
We asked the teachers for their gender, age, educational background in science and educational experience in science.

Male and female teachers did not differ significantly in their general evaluation of their own teaching. However, when we look at their evaluation of their goal achievement in science teaching, we found one interesting difference. Female teachers reported a significantly higher achievement in the goal "*Developed the interest for science, especially among the girls*" (Score: Female=3.59, Male=3.14, t-test, t= -3.351, df=172, p< 0.001). For the goal "*Gave the students a higher self confidence in science*" there was also a difference in favour of female teachers, but the difference was only significant the second year of data collection(Score: Female=3.50, Male=3.14, t-test, t= -2.752, df=172, p< 0.007).

Among the satisfied group of teachers, 40.6 per cent have studied science for a year or more, while the proportion is 25.6 per cent in the dissatisfied group. Furthermore, the number of teachers without any scientific education is higher in the dissatisfied group (55.8 per cent) compared to the satisfied group (40.6 per cent). However, a chi-square test for equal distribution in the satisfied and dissatisfied groups gave no significant difference (Pearson Chi-square=3.68, df=2, p<0.159) for educational background in science. Comparing teachers with and without education in science with regard to educational goal achievement did not produce any significant differences. One would expect that when almost half of the teachers have no educational background in science, this would be reflected in their assessment of the teaching. When there are no differences, this can mean that educational background is of minor importance for successful science teaching. However, it may also be the case that teachers with little or no background are less ambitious and therefore less critical to their own science teaching.

No significant differences were found between the satisfied and dissatisfied groups in terms of the age of the teacher and the teacher's educational experience in science.

**Teaching methods and types of activities**
We asked the teachers how frequent they used different methods and types of activities in their science teaching. Only the second year data are presented here because we were forced to change the original questionnaire at this point because the original questionnaire gave rise to many misunderstandings among the respondents. The frequency of different teaching practice was registered according to the following scale:

Never = 0
Once a year = 1
More than once a year, but less than once a month = 2
At least once a month, but less than once a week = 3
Once a week = 4
Practically every science lesson = 5

**Table 2.** Methods and activity types used in science teaching

| Methods and activity types | | N | Mean | St.dev | t-value | d.f. | Sig.(2-t) |
|---|---|---|---|---|---|---|---|
| Teacher lectures | Dissatisfied<br>Satisfied | 27<br>60 | 3,58<br>3.50 | 0,86<br>0,87 | 0,32 | 85 | 0,752 |
| Teacher gives practical demonstrations | Dissatisfied<br>Satisfied | 27<br>58 | 2,59<br>2,64 | 0,84<br>0,89 | -0,22 | 83 | 0,825 |
| Students study the textbook | Dissatisfied<br>Satisfied | 28<br>61 | 3,23<br>2,99 | 1,21<br>1,30 | 0,83 | 87 | 0,410 |
| Students working with thetheory in groups | Dissatisfied<br>Satisfied | 27<br>62 | 3,00<br>3,02 | 1,11<br>1,02 | -0,07 | 87 | 0,947 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Repetition of theory | Dissatisfied<br>Satisfied | 27<br>57 | 2,15<br>2,35 | 1,35<br>1,17 | -0,71 | 82 | 0,483 |
| Tests | Dissatisfied<br>Satisfied | 27<br>59 | 1,78<br>1,57 | 1,16<br>1,17 | 0,78 | 84 | 0,440 |
| Students working with hands-on activities | Dissatisfied<br>Satisfied | 28<br>65 | 2,68<br>3,42 | 0,86<br>0,88 | -3,73 | 91 | 0,000 |
| Interdisciplinary work/project work | Dissatisfied<br>Satisfied | 26<br>63 | 1,92<br>2,29 | 1,16<br>1,02 | -1,46 | 87 | 0,148 |
| Outdoor education | Dissatisfied<br>Satisfied | 28<br>65 | 2,41<br>2,73 | 1,08<br>0,75 | -1,65 | 91 | 0,103 |
| Using TV, video, slides, etc. | Dissatisfied<br>Satisfied | 28<br>62 | 1,46<br>1,90 | 0,88<br>0,77 | -2,40 | 88 | 0,019 |
| Visiting museums, factories, public institutions, etc | Dissatisfied<br>Satisfied | 28<br>62 | 0,82<br>0,92 | 0,67<br>0,80 | -0,57 | 88 | 0,572 |
| Using ICT | Dissatisfied<br>Satisfied | 27<br>61 | 0,44<br>1,13 | 0,80<br>1,15 | -2,82 | 86 | 0,006 |

The different methods and activity types and the score for the two groups of teachers are given in Table 2. Comparing the two groups (t-test) shows that there is a significant higher score in the satisfied group with regard to how frequent the students do hands-on activities, how frequent they make use of ICT in science lessons and how frequent they use TV, video, slides or other audio-visual equipment. There is also a difference, but not significant (0.05-level), in how often they have outdoor education.

We interpret the difference we observe between the two groups as a difference between variation in teaching methods and in methods that involve the students actively. The satisfied group of teachers use other methods more frequently than traditional lecturing. This may present science in a more interesting way to the students. Also, teaching with students who are more active makes the teachers more satisfied with their teaching.

**Teachers' attitudes towards science teaching**

Since this study is part of the evaluation of the curriculum reform that re-established science as a separate subject in Norwegian primary schools, it was natural to ask the teachers whether or not they agreed with this or if they wished to go back to the integrated subject. Generally, a majority of the teachers did not agree with putting science back into an interdisciplinary subject. However, there is a significant difference between the satisfied and dissatisfied groups in their views of this question (Scores: Dissatisfied = 1.91, Satisfied =1.26. t-value =4.07, d.f. =176, $p<0.000$). The dissatisfied group is more negative to science as a separate subject and wants to go back to the old integrated subject. Here they were more free to choose subjects and we know (e.g. Lie et al. 1997) that this resulted in less emphasis on science, especially in chemistry and physics.

To the statement "*I teach science only because I am imposed to do so*" the dissatisfied group has a significantly higher score than the satisfied group (Scores: Dissatisfied = 3.02, Satisfied =1.30. t-value =8.30, d.f. =176, $p<0.000$). Therefore we believe that the motivation for science and science teaching is generally lower in the dissatisfied group of teachers. This, of course, can be a major reason for these teachers being dissatisfied with their science teaching.

**Table 4.** Teachers' responses to statements on their experience with science teaching

| Teacher experience with science teaching | | Mean | St.dev | t-value | d.f. | P< |
|---|---|---|---|---|---|---|
| Science demands more work than other subjects I teach | Dissatisfied<br>Satisfied | 3,93<br>3,53 | 1,00<br>1,14 | 2,10 | 176 | 0,037 |
| It is difficult to find good ideas for hands-on activities | Dissatisfied<br>Satisfied | 3,82<br>2,34 | 1,13<br>1,22 | 7,11 | 174 | 0,000 |
| Hands-on activities in science are too time consuming | Dissatisfied<br>Satisfied | 4,00<br>3,16 | 1,10<br>1,27 | 3,91 | 176 | 0,000 |
| I have used material from other sources than the textbook | Dissatisfied<br>Satisfied | 3,02<br>3,37 | 1,42<br>1,08 | -1,72 | 176 | 0,087 |
| The amount of compulsory theory in science is too extensive | Dissatisfied<br>Satisfied | 4,05<br>3,29 | 1,28<br>1,27 | 3,41 | 175 | 0,001 |
| The school is not adequately equipped for science education | Dissatisfied<br>Satisfied | 4,05<br>3,34 | 1,29<br>1,44 | 2,91 | 176 | 0,004 |

**Teacher experience with science teaching**

Table 4 shows how the two groups of teachers have experienced their science teaching. We see that both groups find science teaching demanding, but the dissatisfied group significantly more so than the satisfied group. The dissatisfied group clearly see it as a problem to find good ideas for hands-on activities and find this type of education too time consuming. They also felt that their schools were poorly equipped for science education. Finally, the dissatisfied group find the compulsory theory in science to be too extensive.

These results show that the dissatisfied teachers find the science teaching more rigorous and more demanding than the satisfied teachers. They feel pressured both by a large curriculum and lack of time to do hands-on activities. Together with the problem of finding good plans for hands-on activities, this indicates that the teaching is more focused on the textbook and theory rather than methods that would activate the students. This is also confirmed in the study of teaching methods and activity types in the section above.

**Teacher experience with the students in science**

Both groups find that the students are generally interested in and dedicated to science (Table 5), but the dissatisfied group evaluate the student interest lower than the satisfied group. Both groups agree that practical work is what the students like best, and both groups disagree that it is more difficult to engage girls in practical work. The dissatisfied group agree more to the statement that practical exercises causes disorder and disturbance in the class.

Again, we see that the dissatisfied teachers have more negative experience with hands-on activities in science. In spite of that, they agree that this is what the students like best. And even if both groups have a high score on students interest, the satisfied teachers judge their students as more positive than the dissatisfied teachers.

**Table 5.** Teachers' experience with the students in science

| How teacher experienced the students in science | | Mean | St.dev | t-value | d.f. | P< |
|---|---|---|---|---|---|---|
| The students were positive and dedicated | Dissatisfied<br>Satisfied | 3,81<br>4,35 | 1,01<br>0,78 | -3,65 | 175 | 0,000 |
| The students liked hands-on activities best | Dissatisfied<br>Satisfied | 4,43<br>4,56 | 0,73<br>0,75 | -0,96 | 176 | 0,339 |
| It was more difficult to engage girls in practical exercises than boys | Dissatisfied<br>Satisfied | 1,98<br>1,69 | 1,17<br>1,01 | 1,56 | 176 | 0,122 |
| Hands-on activities causes disturbance in the class | Dissatisfied<br>Satisfied | 3,14<br>2,36 | 1,15<br>1,29 | 3,56 | 176 | 0,000 |

## Conclusion

This study has shown a marked difference between science teachers who are satisfied with their science teaching and those who are dissatisfied. It is plausible to think expect that some of these differences should be related to teacher characteristics such as age, gender and teaching experience. The stereotypic picture of a successful science teacher is often a young, but experienced male. It is therefore interesting that the only significant gender related difference we found was that the female teachers reported that they had increased the interest for science, especially among the girls more than male teachers did. The gender aspect has been a prime focus of science education research for several decades. The female science teacher as a role model for girls has been emphasised (Sjøberg 1998) and it is positive that the female teachers themselves feel that they are successful in getting girls interested in science.

In Norway the present situation is that, about half of the teachers in primary school teach science without any education in science. We know that many teachers feel that they lack competence and knowledge and this makes them insecure as science teachers. One indication of this is a high demand for short courses in science among teachers with no science background (Klepaker et al. 1999). We therefore expected that we would find a difference between the teachers with and without science background. It surprised us that we did not find significant differences related to formal education in science, even though other have found the same (Wenner 1993). This can, of course, mean that education in science is of little importance for teaching success. Another explanation may be the level of ambition between educated and uneducated science teachers. The uneducated teachers have less ambitious goals which are more easily reached (Stevens and Wenner 1996). However, this interesting question needs further research in order to be answered.

A clear conclusion we can draw is that the satisfied teachers are positive towards and more frequently utilize hands-on activities that involve the students actively. The general picture is that they give more varied science teaching with less emphasis on lecturing and textbooks. Further, they use other sources of information such as ICT. They also report that the students like science teaching where they actively participate. The dissatisfied teachers are more negative towards science, have difficulties in finding good plans for hands-on activities, and they regard such activities as too time consuming. Low self-efficacy and negative attitudes are not only a problem for the teacher, but also for the students, since it also influences the students' learning and attitudes (Hewson et al. 1995). We should, however, be careful to conclude that positive teacher evaluation is equivalent to good science education. This is the impression given through the teachers' eyes. We need to ask the students for their opinions, and we need to study what kind of knowledge, skills and attitudes the students have acquired before we can say if the teachers' impressions are correct. This we intend to do in a follow-up study. Here we will go into more detail on teaching practice by comparing both teacher and student answers. Hopefully, we can point out, in more detail, factors that contribute to good and engaging science education.

## References

HEWSON, P. W., KERBY, H. W., & COOK, P. A. (1995) Determining the conseptions of teaching science held by experience high school teachers. *Journal of Research in Science Teaching*. 32. 503-520

KLEPAKER, T., TVEITA, J., & NERGÅRD, T. (2000). Fra orienteringsfag til naturfag i norsk grunnskole. Hvilke konsekvenser har overgangen fått for naturfaget i klasserommet? In Aho, L., &Viiri, J (ed.) Undervisning i Naturvetenskap ur Kultur-, Teknologi- och Miljøperspektiv, 341-350.

KUF (1999) The Curriculum for the 10-year compulsory school in Norway

LIE, S., KJÆRNSLI, M., & BREKKE, G. (1997). Hva i all verden skjer i realfagene? TIMMS, ILS, Universitetet i Oslo

SJØBERG, S. (1994). Naturfagutredningen, del 1. Kirke-, utdannings- og forskningsdepartementet.

SJØBERG, S. (1998). Naturfag som allmenndannelse – en kritisk fagdidaktikk. ad Notam Gyldendal. Oslo

STEVENS, C. & WENNER, G. (1996). Elementary preservice teachers' knowledge and beliefs regarding science and mathematics. *School Science and Mathematics*, 96, 2-9.

WENNER, G. (1993). Relationship between science knowledge levels and beliefs towards science instruction held by preservice elementary teachers. *Journal of Science Education and Technology,* 2. 461-468.

**Keywords:** science teaching, teacher attitudes, curriculum reform, primary school, teacher's selfevaluation

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# METHODS OF USING STUDENT ASSESSMENT TO IMPROVE A CONCEPTUAL PHYSICS COURSE.

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**Abstract**

"It is important to evaluate the effectiveness of any new course against the original objectives for creating it. This presentation describes how subjective responses and objective evaluations are used to assess how well the students assimilate the contents of a course designed to teach conceptual physics to non-science college students. Based on these evaluations changes continue to be made to the course format and materials to improve the students' appreciation of the role that technology has in their everyday life. Judged by registration growth, improvements in student performance, and subjective responses the course is contributing to the goal of graduating scientifically literate students."

## Introduction

This course was one of the Virginia Commonwealth University (VCU) new general education courses designed to improve students' scientific literacy by studying the process, concepts and details of modern experimental science. A scientifically literate student was described as someone able to think scientifically, understanding some of the relationships of science to other non-scientific disciplines, able to read and critique articles in the popular media, and aware of how technology is intrinsically linked to everyday life. The general education requirements at VCU were expanded to require an experimental course in both biology and the physical sciences. In conjunction with these changes one of us wrote a text (Niculescu, 2000) and developed a conceptual physics course titled "Wonders of Technology". Support for this work also came from the NSF supported[1] Virginia Coalition for Excellence in Preparation of Teachers (VCEPT) whose goal is to educate teachers to provide high quality instruction in science. It also anticipates the student will become familiar with the methods of scientific enquiry, will be able to relate technology to everyday experience, historical development and contemporary issues, and will have investigated some aspects of physical phenomena using technology. The course meets many of both groups' needs and this paper describes how the course has evolved and how its effectiveness has been quantified.

It is difficult to measure progress towards these goals by just looking at final grades since students differ in abilities, grading can vary with professors and with a new course there are always changes to be made. Evaluation of course success can be made after several semesters by looking at enrollment, student subjective responses and objectively evaluating how well students have assimilated the course material.

## The Course and the Student Population

The course is designed to appeal to non-scientists, to show them that exploring the world of technology can be fun and that the conclusions from a science course can be applied to the students' everyday experiences. In the course title, "technology" was used in preference to "physics", to emphasize the connections of general scientific thinking with everyday life, rather than to relate it to a very specialized scientific topic. Physics is typically perceived as very difficult, understood only by elite academics and having little relation to everyday experiences. There is also the preconceived idea of many non-science majors that physics is dull and beyond their comprehension. A National Task force found that physics is "...increasingly disconnected from societal needs and federal priorities" (Hilborn, 2000). Seymour also reported (Seymour, 1995) that many students switching

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away from mathematics and science cited " turned off science" as one of their reasons for changing studies. As described at the 2001 International Organization for Science and Technology Education (IOSTE) symposium (Za'rour, 2001), this problem is not restricted to the United States. A survey of pre-college students in China (Luo, 2000) also reported that approximately 20% of the students either feared or disliked physics. When understanding physics is described as "...harder than climbing the staircase to heaven", and physicists are characterized as "..a kind of computer machine with extraordinary powers of thinking, special wisdom and insight, that are far beyond the power of ordinary people" it is clear that average college students will not be attracted to physics nor relate it to their everyday life.

Initially the course was two two-hours sessions per week, each session providing a lecture component and an experimental component. However as enrollment grew, the number of sections increased and it was found that a lot of instructor time was spent presenting an identical set of lecture slides. This led to a restructuring where the lecture component became a weekly one hour session given to rather large classes, typically over 100 students. The experimental component, now called the "studio" session, is a single 3-hour session each week and is given in classes of no more than 28 students. This still provides strong student-instructor interaction and makes more effective use of the instructors' time. Within each studio the projects are conducted with groups of 2-4 students.

The course is open to all students with no pre-requisites. Many of the incoming college students, especially non-scientists, have been intimidated by mathematics and science during their prior educational experience and seem to believe that physics is an abstruse and difficult study where the prime goal is obtaining the "right" answer. Enjoyment and understanding have little value and success has been strongly correlated with mathematical aptitude. To try to counter these attitudes the course only uses mathematical rigor where essential, and the students are required to make their own experimental measurements. With few exceptions the "right" answer is that derived from their own measurements. In subsequent class discussions, if they find that their "right" answer is inconsistent with the "right" answers found by much of the class, much is gained from the subsequent discussion. They can be asked what could have gone wrong in the measurement process, or with the equipment, or whether there is more than one possible result. Rather than see their work resulting in failure to obtain an expected result, they are encouraged to examine how they obtained the results and what future improvements can be made. Typical conclusions are the need to replicate measurements and the accuracy that can be expected from the equipment. An example is a project where the refractive index of a transparent material is measured. Some groups are given plastic and some glass. When results are discussed it is apparent that results fall into two groups both of which have variability and both of which are correct.

## Subjective Assessments

### A. Course Evaluation Questionnaire

Initial course assessment was made with two questionnaires that were completed by the students at the end of the semester. The first was a standard questionnaire that is used by the VCU College of Humanities and Sciences to evaluate courses and instruction. It gathered some demographic information on the student (class, grade point average), their expectations of the class and the instruction, whether these were met, how they found the classroom environment and what demands the class placed on them. They were then asked to evaluate the course, the instructor, and the learning they achieved. The questionnaire results have not varied much with time. The environment was always judged adequate (the highest rating on the scale), the students always thought they deserved a higher grade than they expected to get, and the learning was rated somewhere between good and very good

This type of questionnaire has not helped course development much and it is likely that ratings are correlated with the students' expected grade. The questionnaire would probably identify major shortcoming with the class environment, or the demands put on the student, but hopefully the instructors would have identified and remedied these problems well before the questionnaire results were evaluated at the end of the semester.

### B. VCEPT Questionnaire

A second questionnaire, designed by VCEPT, was also given at the end of the semester. This questionnaire was designed to determine how well the course met the needs of future science teachers. Since only four questions were specific to teaching intentions, the answers were able to provide general directions for course improvement. Among the questions asked are how the course increases the students' science understanding and motivation for science, how the course science concepts are related to "real world" applications, and evaluations of the textbook, class participation and class effectiveness. Most answers fall into the "Agree" and "Strongly Agree" categories but a review of the ratio of the numbers of these responses suggests this type of course enables the students to relate science concepts to "real world' applications, that the majority are actively involved in learning the course content, and that they felt participatory activities were an effective learning tool. There is also a very positive response to the small group activities.

The questionnaire also asked students to provide open-ended responses to the most important things they learnt from the course, which aspects were most difficult, which most beneficial, and any changes they felt should make. Although the students are more likely to recall recently taught topics, these responses provide a view of their recall at the end of the semester. When many students voluntarily provide similar responses on some aspect of the course it is worth careful attention.

The topics that were consistently identified as "new skills learnt" were electricity, light and color and the various forms of energy. The former two topics are presented in the middle of the course and energy transformation is a theme throughout the course. These responses suggest a lack of exposure to these topics in their high school education, a conclusion later supported by more objective evaluations.

The topics identified as most difficult were mathematics and the use of formulae. These would also seem to reflect a weakness in their prior education, although since the students were not pursuing mathematics, science or engineering this result was not unexpected. In working with the students the instructors found many had very poor mathematical skills and seemed much more concerned with getting the "right" answer than in following the correct steps that would get the answers. During the studio sessions emphasis is placed on reaching reasonable deductions from the experimental data. The data gathered by the student is the "right" data and they are asked to use it in the "design" aspect of each studio. This aspect requires the student to use the equipment, and measurements they have just made, to redesign the experiment for a different result. After doing the theoretical design they test it experimentally and demonstrate the results to the instructor. As examples, in a cooling experiment they are told to set up conditions so that a cup of hot water reaches a given temperature in a given time, and in mechanics they are asked to set up distances on a racetrack so that an accelerating car and a constant velocity car cross the finishing line simultaneously.

The close instructor-student interaction is invaluable when a piece of equipment is faulty or when major errors are made in the measurement process. If there are no obvious answers to the questions posed in a studio instruction sheet, the student is told to discuss it with the instructor. Once the anxiety of "right" versus "wrong" answer is diminished, the students are able to concentrate on drawing reasonable conclusions from the results they have measured, and most seem to enjoy the experience of scientific investigation. Of the scientific topics covered in the course they reported having difficulty with concepts of electricity, with conversion of units and the commonplace problem of understanding speed and acceleration. The latter often causes problems to science majors, so its presence here is understandable. Electricity may present more of a problem for non-scientists than science majors since typically they will be taking readings from meters. They never see an electron in motion, so the study is rather abstract and they rely a lot on "black-box" type measurements where they are asked to accept a value without much understanding of the measurement process. Optics is more understandable since there are light beams, objects and images, and the whole spectrum of colors; tangible results that they can observe and manipulate.

Over 50% of the students voluntarily reported that they found the experimental hands-on aspect of the course to be most beneficial in their learning. The other aspects seen by many as beneficial to learning were the elegant Powerpoint presentations used in the lecture component relating technology to historical and cultural developments, and the small group interactions that were necessary to carry out the projects. Experimental demonstrations, one-on-one interactions with the instructor and the emphasis towards "real-world" applications were also mentioned a significant number of times.

**C. Course Improvements derived from Subjective Evaluations**

The use of subjective evaluation by students at the end of a semester to assess the effectiveness of a course and to guide course improvements is somewhat problematic. Students with good grades are likely to view the course positively, while those with poor grades, often a consequence of their own poor study habits, are likely to be generally critical of the course and the instructors. Course changes should only be considered when there are many similar responses.

When the students were asked how this specific course might be improved, the principal responses were: to clarify the experimental explanations, to use less mathematics, to simplify the text and to identify more precisely the topics in the text for which they were responsible. These suggestions stimulated a second edition of the text, separation of the lecture and studio sessions, and a very careful review of how formulae and mathematical concepts were presented. Even though these latter are only used where necessary, a review is now given at the start of every studio of the formulae that will be used that day, together with some examples of how the measurements are inserted into the formulae. Although this change is most beneficial to the weaker students, it has reduced the number of times work is handed in with mathematical errors that completely obscure the physical concepts covered in the experiment. Ideally they should be able to extract information from the text, or to ask the instructors for detailed guidance. However most texts contains considerably more material than can be covered in the course, and college students are often reluctant to demonstrate to their peers that they could not, or did not, follow what has just been explained in class.

During the four years the course has been offered, the students have rated it positively in most characteristics and the number of registered students has grown dramatically as shown in Figure 1. A cynical observer could correctly comment that the same results could be obtained by not requiring the students to attend class, and by giving a very high proportion of "A" grades. A review of the course attendance numbers, the course completion percentages, and an analysis of the grade distributions show that these possible explanations are not valid.

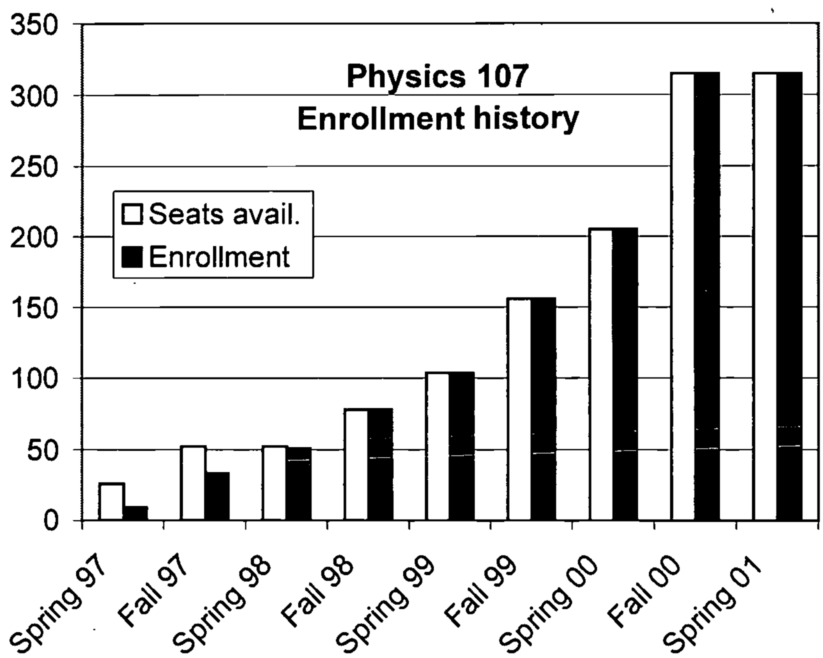


**Figure 1.** Growth of "Wonders of Technology" Course Enrollment

## Objective Course Assessment

### A. Pre- and Post-Course Quizzes

So far all the discussion has centered on subjective student evaluations. Such evaluations are highly correlated to how well students are doing in the course, and also how much they are enjoying the material. General trends can be identified and used if there are enough responses. However the concern remains as to how effectively the students are absorbing the material and what they are actually learning. This is not just an academic concern, but is a measure of both the effectiveness of the material and the presentation method. Introducing non-scientists to Measurements, Properties of Materials, Light and Optics, Electricity and Magnetism, Motion and Flotation, within one semester is already an aggressive objective. It is eased somewhat because the goal is to teach the scientific process rather than to memorize facts.

An objective measure of how well students were absorbing the material was obtained in the Spring semester of 2000 by giving a short quiz to the students before the course began, and then repeating these identical questions in the final written examination. Fourteen open-ended (O-E) questions were selected from the previous semester's final written examination covering the range of topics in the course. Students were clearly told that this initial quiz would not count towards their grade and was an evaluation of their incoming knowledge of the course topics. These same questions were re-administered the next semester only using a multiple-choice (M-C) format. This was tried since increased enrollment, from 200 to 300 students, led to manpower limitations on hand-grading open-ended responses. Table I shows the number of correct responses under each format. One question was omitted since it did not translate well to a multiple-choice format. Figure 2 shows a graph of the increases in percentage correct answers from pre- to post- for each format. As was hoped, both formats clearly demonstrate an improvement in the students' performance after taking the course, and this is confirmed by a students t-test. However the correlation coefficient for results by the two methods is only 0.4, so the results of one test format are not good predictors of the numerical results of the other test format. The Spearman Rank Correlation Coefficient is significant at the P=10% level so there is a stronger correlation between the ranking of the answers than between the percentages of correct answers. A factor contributing to this low a correlation factor is the issue of translating from an open-ended question to a multiple-choice question. An open-ended question is a good way of encouraging non-scientists to express their knowledge, without too much concern on using correct technical expressions, but the interpretation of the answers by an instructor is rather subjective. Since answers to multiple-choice questions are more objective and easier to process, the quizzes are now being given in this format. It is felt that this improves the consistency of the results.

**Table I.** Number of correct responses under different questionnaire formats.

| | | | **Correct Open Ended** | | **Correct Multiple Choice** | |
|---|---|---|---|---|---|---|
| | | | pre- | post- | pre- | post- |
| | Total # responses | | 188 | 175 | 274 | 259 |
| Question | Topic | Type | | | | |
| 1 | Energy | Concept | 32 | 124 | 163 | 221 |
| 2 | Materials | Concept | 23 | 112 | 193 | 235 |
| 3 | Measurement | Concept | 39 | 136 | 150 | 214 |
| 4 | Materials | Application | 92 | 114 | 158 | 202 |
| 5 | Motion | Recall | 47 | 62 | 158 | 167 |
| 6 | Motion | Recall | 30 | 40 | 58 | 122 |
| 7 | Motion | Application | 12 | 66 | 77 | 124 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8 | General | Concept | 131 | 169 | 252 | 255 |
| 9 | Measurement | Concept | 33 | 165 | 240 | 247 |
| 10 | Optics | Concept | 81 | 72 | 183 | 189 |
| 11 | Optics | Concept | 12 | 98 | 57 | 164 |
| 12 | E&M | Concept | 18 | 144 | 23 | 86 |
| 13 | E&M | Concept | 8 | 116 | 57 | 132 |

**B. Differences between students dropping the class and late registrations**
As shown in Table I the number of students taking the pre-quiz and post-quiz was different. Some students decide to drop the course after attending the first session, other missed the first session for a variety of reasons, and there is usually a waiting list of students wanting to take the course if spaces become available. A evaluation was made on whether the students dropping the course were less well prepared than those completing it, and whether the students who took their places in the course were either more motivated or better prepared to do well in the post-quiz. Using a single-tailed student t-test with unequal variances on the pre-test results, the performance of students dropping the course was nor significantly different than those completing it (t=0.43, P=0.34). Using the same statistical test on the post-course quiz results, those joining the course after it had started did not perform significantly better than those who were there throughout the course (t=0.41, P=0.34).

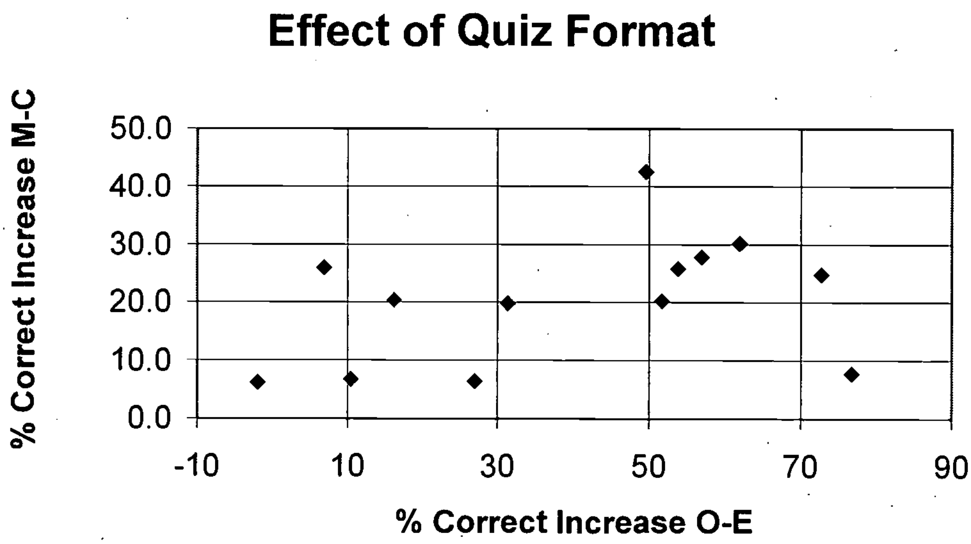


**Figure 2.** Increases in Percentage Correct Answers using Different Formats.

**C. Hake Factor**

If the course is effective there should be a dramatic increase in the percentage of correct answers to each question. This increase is dependent on how well the incoming students are prepared. If the incoming students are already familiar with the course material the percentage improvement of correct answers from pre- to post- is likely to be lower than if they were unfamiliar with the material. An example of this was a question asking the purpose of forming a scientific hypothesis, 88% of the students identified the preferred answer in the pre-course quiz, so the maximum possible percentage improvement was only 12%. In contrast only 10% of the students identified the expected answer to a question on Electricity and Magnetism in the pre-course quiz. This allowed a maximum improvement of 90%, and even if the course was only partially effective in teaching this topic, the increase in correct answers will certainly exceed the 12% possible in the other example. Based on this information the hypothesis question was removed and less time spent describing why forming a hypothesis was important.

Because the percentage of correct answers is dependent upon the students' initial knowledge, and there is a low correlation between alternative formats, a better metric than percent correct answers is needed to evaluate the course effectiveness. A value that has been used extensively to measure this improvement is the Hake Factor (Hake, 1998). The Hake Factor H is defined as

$$H = \frac{\text{\% correct post - course} - \text{\% correct pre - course}}{100 - \text{\% correct pre - course}} x100$$

and represents the percentage of the maximum possible improvement that is achieved. From an evaluation of 62 high school and college physics mechanics courses Hake originally found that traditional courses typically had a low value (H<30%), and that most Interactive Engagement type courses (courses where considerable effort is made on interacting with the student) fell in the medium value region (30%<H<70%). H>70% was judged to be a strong improvement.

**D. Comparison of Hake Factors for Multiple-choice and Open-ended Results**

The Hake factors were evaluated for the data shown in Table III and the results are shown in Figure 3. The topic of each question is also identified. The average Hake Factors were 51% for O-E format and 46% for M-C format. Both of these fall within the mid-range of Hake's analysis for Interactive Engagement type courses. A comparison of the results for the two quiz formats for each question is shown in Figure 4 and demonstrates a better correlation between the two sets of data (correlation coefficient is 0.71) than is seen for the percentage improvements shown in Figure 2. The Hake Factors shown in Figure 3 range from 16% to 80% for the M-C format, and from –3% to 93% for the O-E format. The negative and the 93% improvement are good examples of the potential problems of identifying acceptable answers when grading O-E responses. One of the large benefits of using multiple-choice responses is that subjective decisions on correctness are not necessary. All quizzes are now done in this format. O-E responses continue to be used in the studio sessions, where a prime objective is to have the student interpret and draw conclusions from the data they have gathered, rather than to select from a series of given answers.

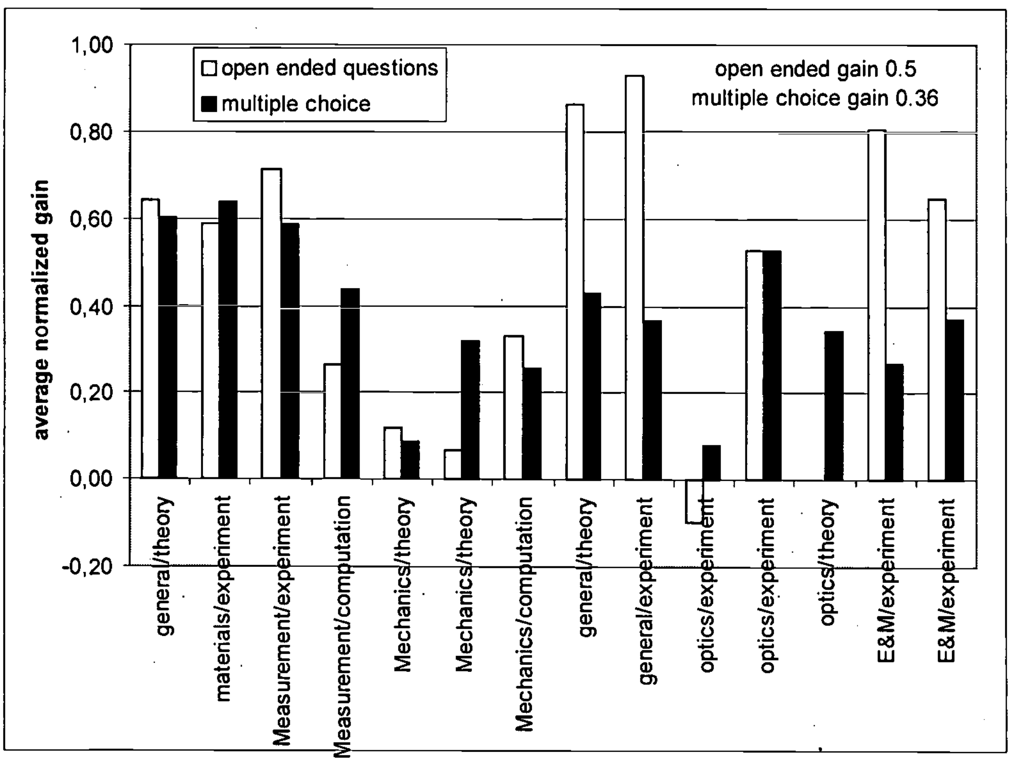


**Figure 3.** Hake Factors for Tests given in the Spring and Fall 2000 in Wonders of Technology

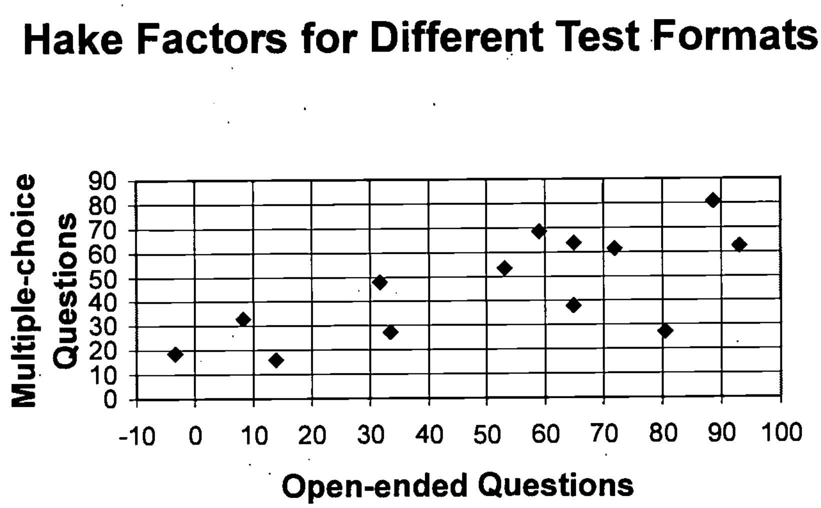


**Figure 4.** Hake Factors for Different Test Formats

**E. Time Consistency of the Data**

It is valuable to determine whether there is any consistency of the responses over time since each semester the student population changes completely and improvements are made to the course format. From Spring 2000 to Fall 2000 the format of the questions was changed from O-E responses to M-C and this has already been discussed. From Fall 2000 to Spring 2001 the format did not change and seven of the questions were identical. Figure 5 shows how much the responses to these questions in the pre-quiz changed between these two semesters. It can be seen that the responses fall quite close to the line corresponding to identical responses. The small deviations seen could easily represent incoming class differences. The intent is to retain these same questions in future evaluations so that there is a monitor of the knowledge of the incoming students.

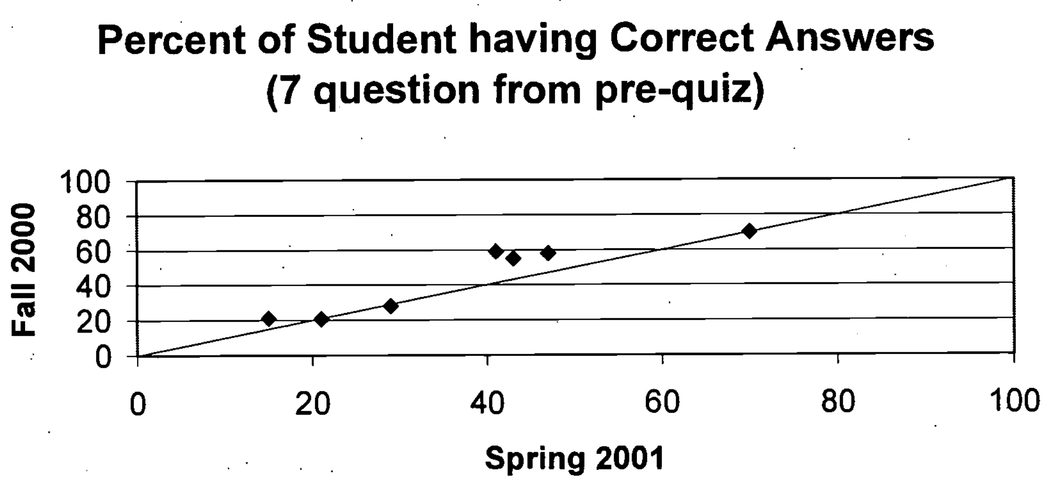


**Figure 5.** Variability of Student Responses to Control Questions in Pre-Course Quiz

**F. How well prepared are the incoming students?**

The results of the pre-course quizzes can also identify topics where the incoming students are either well, or poorly, prepared. There are a limited number of questions that can be asked in the quiz, but classifying them by course topic and type (Aubrecht, 1983), allows identification of areas that are consistently high or low in the ratings. The type of question is classified as recall, concept, interpretation or application. Recall is memorization, concept is non-numerical application of course material, interpretation is drawing conclusions from provided data (usually graphical), and application is a numerical problem, either single or multiple steps. The ranking of the responses can be based on the pre-course results, the change from pre- to post-course, or the Hake factors.

The first version of the quiz showed that the majority of the incoming students did poorly on questions involving optics or E&M. This was confirmed in the second version when all the questions involving optical concepts (vision, objects and color) were ranked at the bottom end of the scale (less than 20% of the students selected the preferred answer). E&M fared a little better, but it seemed that incoming students were not very knowledgeable in either of these fields. The students were also relatively poor at doing calculations, but this was expected since the course was designed for non-scientists who typically were mathematically weak.

In Table I, question 9 involves reasons for making multiple measurements in experiments. The O-E responses show a very large improvement from pre-course to post-course, while the M-C responses changed very little and had a high percentage correct. The majority of the students were able to respond correctly when presented with a choice of answers. However in the studio sessions they only made multiple measurements when specifically directed. Choosing a preferred answer from a list is much simpler than changing an established form of behavior! M-C responses can be misleading especially when relating best practice with everyday experiences.

The percentages answering questions correctly on the post-course quiz varied from 40% to 90%. The one response below this range was poorly worded and will be replaced in future quizzes. A question concerning the modern uses of gold was well answered after the course material had explicitly addressed how the use of gold had developed historically, and then later described the properties of materials used in modern computers. Both pieces of information easily relate to the students' everyday experiences.

## Summary

Assessment of how well the students are absorbing the course material can be done with both subjective student responses, and with objective evaluations. In both cases it is important to evaluate effects that introduce bias, and to measure results against controls. Subjective responses need to be examined very carefully if there are a small number of responses. Strong instructor student interaction is important to identify problems as they occur, rather than relying on memories at the end of the semester when many other concerns take the students' attention. Many examples are given where asking identical questions at both the beginning and the end of the semester serves as a tool to identify shortcomings in the students' preparation, or possibly issues of material presentation.

One of the major objectives of effective assessment is course improvement and for this both subjective and objective evaluations are valuable. The objective evaluation provides information on the effectiveness of the course material and presentation, whereas subjective evaluations provide information on the attitude of the students to the course. Students with a positive attitude towards the course are much more likely to learn effectively

These studies were based on a science course for non-scientists and we found that de-emphasizing getting "right" answers and stressing class involvement has certainly contributed to a very large growth in registration numbers, and positive lecture and studio learning environments , that are enjoyable for both students and instructors.

## References

Niculescu V.A. (2000), Wonders of Technology, *John Wiley &Sons, ISBN#0-471-39862-4,* second edition

Hilborn R.C. (2000), The National Task force on Undergraduate Physics: Some FAQs, *Forum on Education, American Physical Society, Spring/Summer 2000, p4*

Seymour E. (1995), Revisiting the "problem iceberg", *Journal of College Science Teachers, May 1995, p392*

Luo X., Liu X., Fang X., Huang S., Liu B. and Han C. (2000*), The "third eye" demonstration show, American Association of Physics Teachers summer conference 2000*, University of Guelph, Canada

Hake R.R. (1998), Interactive-engagement versus traditional methods, *Am. J. Phys. 66, 1, 64-74*

Aubrecht G.J. and Aubrecht J.D. (1983), Constructing Objective Tests, *Am. J. Phys. 51, 7, 613-620*

Za'rour G.I. (2001), Relevant Teaching, *Proceedings of 2001 IOSTE symposium in Paralimni, Cyprus, p3*

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# AN APPLIED METHODOLOGY FOR A NEW FORM OF TECHNOLOGY EDUCATION: ELECTRONIC COMMERCE

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## Abstract

The e-commerce and e-business concepts are changing the business environment, not only in terms of the creation of networks of firms abilitated by information technologies or the improved efficiency for rutinary business transactions, these concepts are also affecting the labor force and changing their work. In order to effectively integrate the technology with the human knowledge about business process, employees require to develop new capabilities, both attitudinal and technical. Since many of these employees have completed formal education, the acquisition of the new capabilities must come from training programs that need to be carefully designed by taking in account the labor market needs. In this work, a five step process is used to develop an e-commerce labor training program, which will be operated by the Mexican Association for E-commerce (AMECE), the main objective of the program is the development of the required capabilities to use the technological standards and tools involved in the best e-commerce practices. The program contents are derived by considering the labor market needs, the AMECE strategy and mission, and the profile of the participants. This activity ends with a technology educational model for e-commerce that considers capabilities along three dimensions: operational, technical and strategic. From this basic structure, specific syllabus, courses' formats and required infrastructure are derived. These syllabus were the basis for the development of the National Standards for electronic commerce labor capabilities.

## Introduction

The adoption and understanding of e-commerce practices demands a favorable attitude, which derives from the users' interest in learning how to effectively integrate these practices to their work and live. The factors that determine the users' attitude to the technology are of differente types (technical, economic, availability, competitiveness, etc.), but one of the most important is the cultural one, which is determinant since the first interaction of the person with the technology. Therefore, it is relevant to consider that the introduction of information technology into the business processes demands a fit between the organizational culture with the new technology, with successful implementation being dependent not only on the individual's work capabilities and knowledge, but also on his (her) attitudes, abilities and feelings toward the information technology (Harper and Utley, 2001). In the last two years, with the accelerated difussion of e-commerce activities, a new culture has raised, whose values are identified as openess, flexibility, adaptability, transparency, and risk taking; while its relevant attituteds are frustration resistance, obstacle elimination and proactiveness.

The development of business applications mediated by electronic means can be facilitated if the organization supports their workers with a Technology Education program that will allow employees to acquire new capabilities and to take advantage of the information technology. Under globalization, one of the challenges for organizations and countries is the development of these technology education programs that will contribute to the creation of the supporting culture for the new business context. This work describes the process followed by the AMECE (Mexican Association for Electronic Commerce) for the development of the Working Capabilities Program for E-Commerce (Erosa, 2001), which became the base for the National Norm for Laboral Competence in E-Commerce.

Since the basic interest for this program is the development of e-commerce capabilities into specific working contexts, it was critical to take in account the expected benefits for the e-commerce adopting firms and relate them with the required human resources abilities. From the point of view of a selected group of high executives, whose organizationes are affiliated to AMECE, e-commerce cabilities should derive in higher productivity, process simplification and human capital reduction. In consequence, the main objective for this "E-Commerce Labor Training and Certification Program" that AMECE will offer, is stated as follows:

"To develop the required capabilities to use the technological standards and tools involved in the best e-commerce practices, and to improve the decision process in order to support the organization strategy under the new business environment derived from the e-economy."

### Methodology

A five steps methodology was used, designed to incorporate the market needs (organizations requirments for an e-commerce training and certification program) with the vision and 2001 operation objectives of the organization that will offer the program (AMECE). The translation of the market needs into the program will assure the acceptation of this new product, while the revision of the program contents from the point of view of the AMECE strategy will assure its operation and benefits for AMECE. This methodology that looks for the integration between market needs and educational provider objectives is adapted from Mexican experiences in developing education programs (Erosa, 1989; Erosa & Arroyo, 1996), and uses relevant information from three sources: the market (entities that demand training and education), the strategic plan of the educational organization (AMECE) and the opinions from experts that will be involved in the implementation of the new education program. The process is described in Figure 1, the first step is the collection of data from the relevant information sources. In this case, the third data source, the *experts' panel*, is integrated by persons from different AMECE functional areas, with all of them connected in some manner with AMECE Associates Services area, and whose promotion and support activities are closely related with the program operation and results. The second stage is the information analysis that will result in the identification of the required training capabilities for e-commerce and e-business. Since education and training are critical components to the service that AMECE provides to its associates in order to improve their e-business practices, the design of any training course requires to develop a profile for the participants and to known the activities that are going to be supported by information technologies. Once this initial inventory of needs is elaborated, it must be revised by the several AMECE areas that will be involved with the operation of the program, such that it can actually be implemented. The third step involves the identification of courses and their contents, by considering the needs expressed by the participants, the heterogeneity of the participants' base (segments), and again the AMECE experts opinion. Once the course basic themes are developed, the fourth stage is the definition of the most convenient intructional strategy (Theoretical course, Workshop, Seminar, etc.), as well as its duration, required materials, instructor's profile and infrastructure for operation. Elements for the evaluation of each course from the point of view of participants are also designed, in order to have information that will allow AMECE to continously improve the training service.

The AMECE mission and strategy is the basic framework for the design of the E-commerce Labor Training and Certification Program. The proper alignment between the program contents and the objectives in the AMECE strategic plan is relevant to guarantee the program operation. But of course, the program must also satisfy the needs of all the AMECE associates (12, 500 firms) that are distributed all around the country (Erosa & Arroyo, 2001) and have different profiles (size and economic activity or sector).

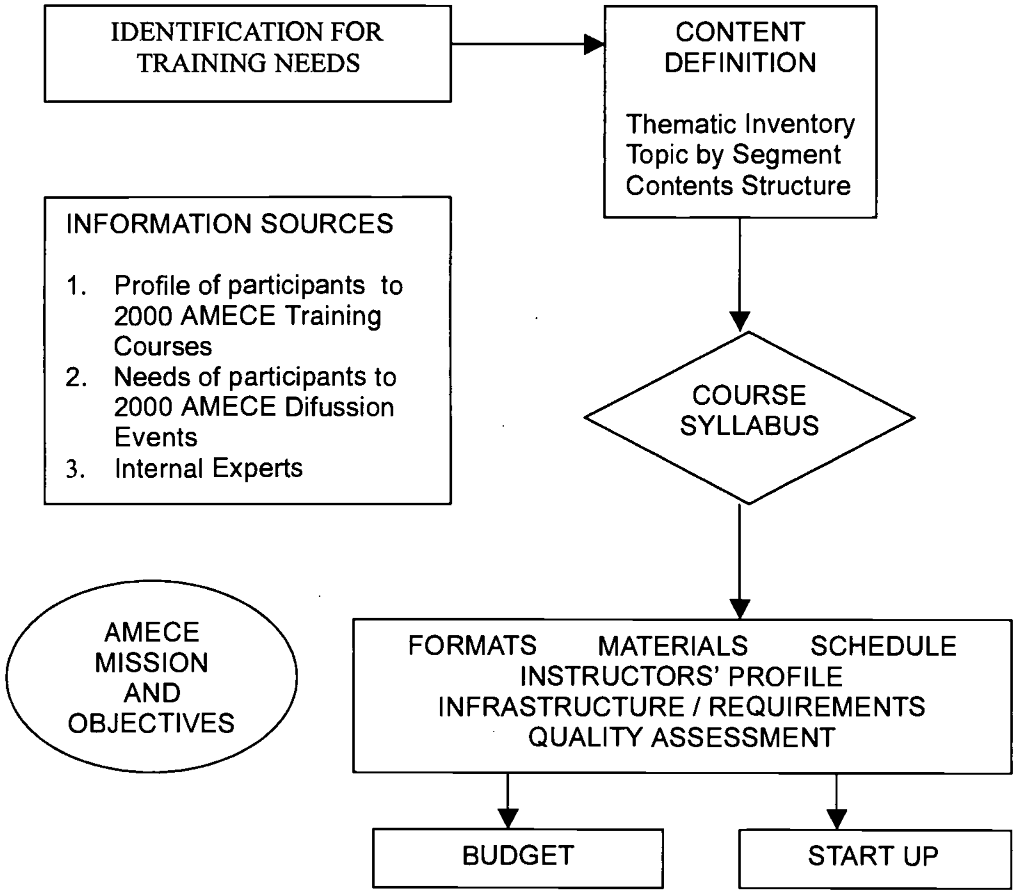



**FIGURE 1.** Methodology for the Design of the Program "Basic Laboral Capabilities in E-Commerce Use"

The process for the design of the E-Commerce Labor Training and Certification Program that AMECE offered during 2001, is a unique model in the sense it takes in account the global business environment, the firms that demand training and certification for their employees, and the AMECE objectives for growth and sustainability under a perspective of high service quality in education. In the following sections, each of the main steps for the program development will be described in detail.

**Training Needs Diagnostic**

In order to support the e-commerce activities among the Mexican organizations, the AMECE mission states the importance of providing valuable and high quality educational servicies for its associates. In the education program, a basic course is related to the use of the product identification technology known as bar codes. This particular program is offered to new associates and its main objective is the development of the required abilities to handle the AMECE Electronic Catalog, which is an important product that AMECE offers to enhance their associates' competitiveness. These two courses -bar code and electronic catalog- were the main training offer during 2000. Table 1 shows some relevant statistics related to interest in these two courses; the data reflect the compromise and effort deployed by AMECE in order to create a e-business culture in Mexico. The training strategy during year 2000 involved the use of "motivation sessions" for bar code use (2 hrs.), these sessions were realized from January to October, at AMECE locations, and were conducted by the Associates Services staff.. Meanwhile the courses for the use of the AMECE Electronic Catalog (6 hrs.) were outsourced and realized during July. Since October 2000, the electronic catalog course was compulsory for new AMECE associates. This decision was taken in order to combine the efforts of bar code diffusion and the integration of a complete supplier catalog. All the courses had a local coverage (only Mexico City area, which includes the Federal District and limiting states), with a total number of 922 individual participants at the end of October, which are representatives of 559 different firms. Given this composition, the collection of participant firms is judged a representative sample of the total number of firms in the Mexico City interested in e-business. Therefore, the information provided by these participants is appropriate for the identification of segment profiles and their specific training needs.

**Table 1.** AMECE. Total Number of Participants in Training Courses. January-October, 2000

| MONTH | COURSES PER MONTH | NUMBER OF PARTICIPANTS | NUMBER OF ORGANIZATIONS |
|---|---|---|---|
| January | 8 | 70 | 54 |
| February | 8 | 89 | 60 |
| March | 8 | 67 | 46 |
| April | 7 | 90 | 31 |
| May | 9 | 91 | 52 |
| June | 9 | 84 | 43 |
| July | 8 | 97 | 57 |
| August | 9 | 71 | 44 |
| September | 9 | 83 | 50 |
| October | 2 | 8 | 7 |
| Bar Code Training (2 hrs. each) | 87 | 756 | 444 |
| Electronic Catalog Training (6hrs. each) | 34 | 166 | 115 |
| Internal (Oct.) | 4 | 31 | 25 |
| External (July-Oct.) | 30 | 135 | 90 |
| **Total Training: January- October** | **117** | **922** | **559** |
| Persons per course | | **7.9** | |
| Firms per course | | | **4.8** |
| Hours/Person | | **2 517** | |
| Hours/Firm | | | **1 578** |

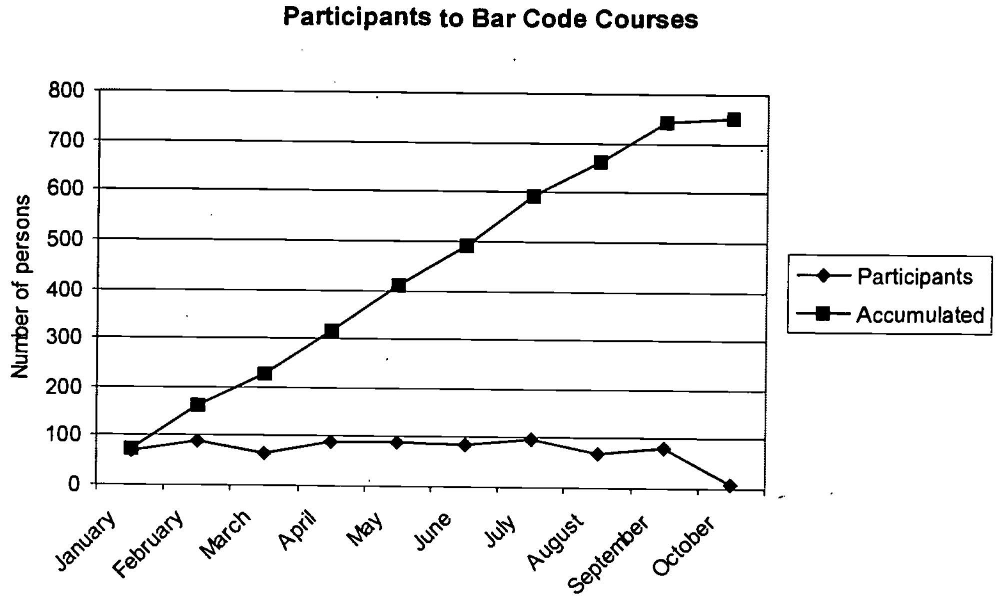
During the period of analysis (January to October, 2000), the policy for participation in the training courses was the following:

(1) Introductory courses for Bar Code Use. These course are scheduled in advance, participation is optional for each firm and instructors are provided by AMECE. In consequence, total number of assistants is unknown in advance, participants are heterogeneous in terms of firm size, economic activity (sector), participant's work position and his (her) responsabilities within the firm. These conditions make difficult to plan for physical infrastructure and to select specific material that will attend particular needs.

(2) Training courses for Electronic Supplier Catalog Management. This kind of courses began as training courses for AMECE instructors (Associates Services Area), and evolve to specific courses under firm requests, participation is also optional and they are outsourced (external instructors).

(3) A combined course that includes basic topics on Bar Code Use (1 hour) and Supplier Catalog Management (5 hours), this new course is the one that was made compulsory to new AMECE associates since October 2000.

Figure 1 shows graphically the assistance to the introductory bar code courses. The data exhibit moderate variability in the number of participants per month, with a minimum of 68 participants and a maximum of 98. This time series reflects the interest in the acquisition of the bar code technology by the firms located around Mexico City, with the accumulated number of firms leading to a linear diffusion pattern for the technology, consistent with the observed pattern since the first year for AMECE operations, year 1986 (Erosa and Arroyo, 2001a).

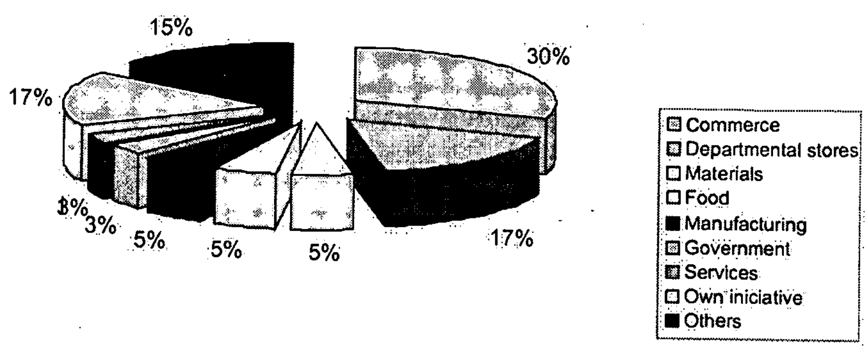



Source: Elaborated with base to courses records Jan- Oct, 2000. Technical Direction and Associates Services.

**FIGURE 2.** AMECE. Assistance to Introductory Courses for Bar Code Use. January - October, 2000. Total number of participants during the year = 756

In order to identify the basic market for AMECE training programs, represented by those firms that selected the bar codes as the product identification technology, the information about the main economic activity of 96.5% of the new bar code adopters was analyzed. This information allows to identify the sector that generates the highest demand for bar codes and which will be the principal customer for the program.

The graph in Figure 3 shows the decomposition of participants by sector, and allows to identify the Commerce sector as the principal adopter of bar codes, and whithin this sector, the suppliers for the big Mexican retailing chains are the greatest fraction of the AMECE associates base. Fifty percent of these new associates were reffered to AMECE by Wal-Mart (includes as particular brands Wal-Mart, Aurrera, Superama y Sams), Gigante (only two firms that stands for 14% and were referred by Soriana), and Comercial Mexicana (11.6%), with the remaining participants being referred by others big retailing stores such as Price Club, Garis, Carrefour, Chedraui, Nutrisa and Auchan.



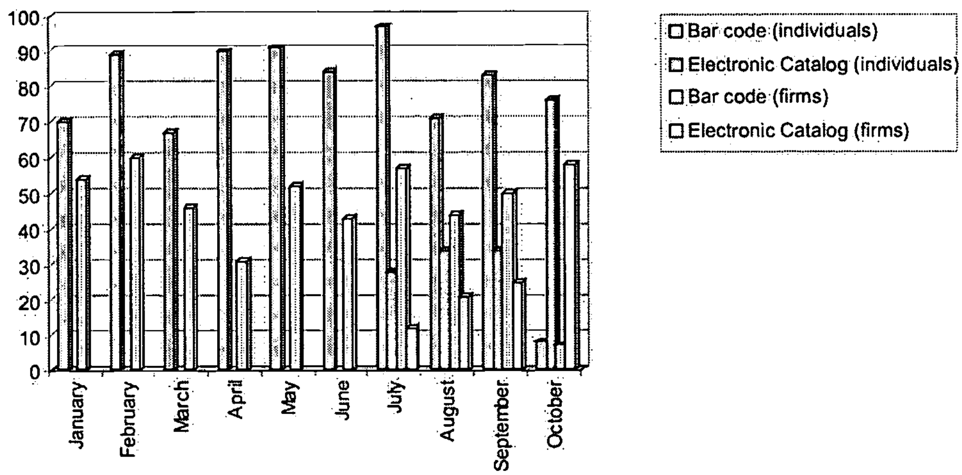

Source: Elaborated with base to courses's records Jan- Oct, 2000. Technical Direction and Associates Services. AMECE

**FIGURE 3.** AMECE. Assistance to Introductory Courses for Bar Code Use by Sector. January - October, 2000.Number of firms, N = 541

Besides the participation of firms that become AMECE associates due to the intervention of powerful stakeholders, there is the case of non-influentied firms that become associates because of their market's pressure and/or because they are convinced of the benefits of the bar code technology. Seventeen percent of the new associates base are firms in this category, with another 17% of these voluntary associates also related to the big department stores (50% of the participants in this subgroup of N=92 firms are suppliers of SEARS). In this voluntary segment, under the category "others" (15%) are included firms with diverse economic activities such as consulting, education, design, or antrophology.

In alignment with AMECE policy, the training courses were modified after the introduction of the Supplier Electronic Catalog, this action was taken because the organization considers that the introduction of this technology innovation demands new abilities to complete its adoption and to integrate it with the business processes. Therefore, in July 2000, Electronic Catalog Training courses, provided by an external agent, were introduced in parallel to the introductory courses for bar code use, resulting in an important increment in the total number of participants, specially for the new offer about electronic catalog use. The total number of participants, divided by number of individuals or firms, to each course (bar code use and electronic catalog), are depicted graphically in Figure 4. The two separate courses were offered only during four months (July-October), in October, AMECE took the decision to combine the two courses contents, and to assign the instruction and logistics to the are of Associates Services. This action resulted in an important increment in the number of participants. The graphs evidences higher variability in the number of participants (1 to 9 per course) than in the number of firms, with the lowest individual participation for January, May and August, and with an important increment once the decision of merging the bar code and electronic catalog courses was taken (October). In order to increase the courses' productivity, the number of participants was related with the average number of courses given during a month (11.1), suggesting the convinience to establish a minimum number of participants (7.6) to open a course, this requirement will allow to improve the resource assignments, which is part of the AMECE productivity objectives. The coverage efforts resulted in an average participation of 7.9 persons and 4.8 organizations per course after October, which reflects the interest of the Mexican firms to acquire new abilities related to e-commerce.

The content analysis for the participants' comments to the courses allowed to identify the response times of the technology infrastructure as the most relevant operation problem. The impact of the merge of the two original courses in a single course was also discussed with the instructors, that figure out as the "experts". They reported an important number of unresolved questions about bar code use, probably as a result of the reduction in time and materials. With respect to the Electronic Catalog courses, the participants' evaluations indicate as additional areas to improve –besides technology infrastructure response time- the quality of materials for presentation, the design of better examples, the use of innovative didactic techniques. All these comments should guide the design of the program for instructor training, with particular emphasis in the use of didactic techniques beyond oral presentation.

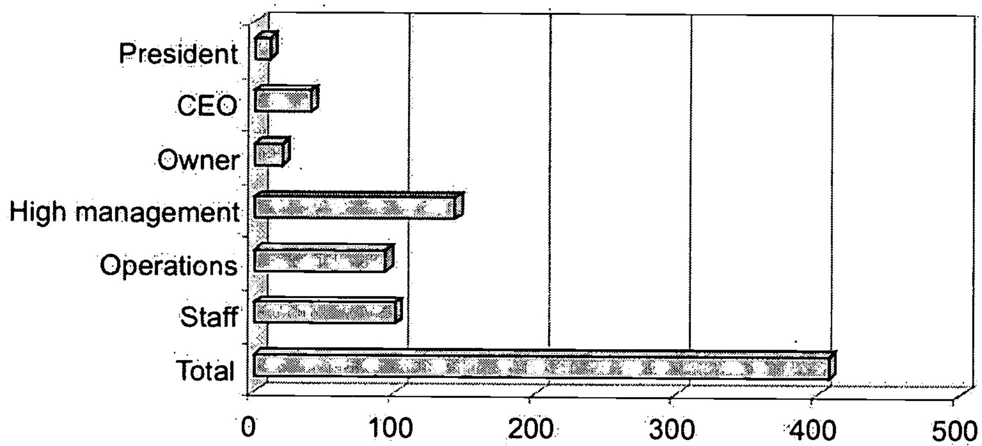



Source: Elaborated with base to course records Jan- Oct, 2000. Technical Direction and Associates Services. AMECE

**FIGURE 4.** AMECE. Assistance to Introductory Courses in Bar Code Use and Electronic Catalog. January - October, 2000. Number of individual participants = 922. Number of Companies. N = 559

The analysis of the participants profiles is the second relevant point for the design of AMECE training programs, because it allows to identify segments of users with different needs. The variable selected for the segmentation is the participant's functional area, because it not only provides information about the activities that will be influenced by the technology but also about the level and type of decisions.

The graph at Figure 5 shows that the majority of participants are at the highest organization level, this fact evidences the strategic importance assigned to the basic technology for product identification. The staff and operative segments are also represented but in a lower extent, identification of these two groups suggests the convinience of training programs at two levels: High Direction and Operation Management. This segmentation will allow to increase the AMECE training coverage, because each firm that participates in the training programs will send a representative from each level and from each functional area, situation that will assure the high management support and the integration of the information technologies into the business processes.




Source: Elaborated with base to course records Jan- Oct, 2000. Technical Direction and Associates Services. AMECE.

**FIGURE 5.** AMECE. Profiles for participants to Introductory Bar Code Use by Functional Area. January - October, 2000. Number of individuals = 408

From the graph in Figure 5, an important segment at the High Direction level is identified, this segment is formed by the owners of small companies (21 participants). The potential customers in this group demand a customized service, and have particular e-business needs and expectations. A customized service will not also contribute to retain this customer segment, but also be a relevant contribution for the development of the micro and small organizations (PYMES) that conform the majority of the economic units in Mexico. The highest percent of participants at the High Direction level are Chief Executive Officers (CEO's) or the equivalente position in Mexico known as General Director, situation that confirms the high priority assigned to the e-commerce. The other important positions at this high organizational level are Director for Operations and Director for Marketing, leading to the proposition that e-commerce has a marketing strategic role for the Mexican firms.

The composition of the Operation Management segment in terms of functional areas indicates that e-commerce and e-business activities are concentrated at three areas: Sales and marketing, Production and manufacturing, and Administrative support activities (Finance, Accounting and Information Systems), with the specific number of participants from each area reported at Table 2.

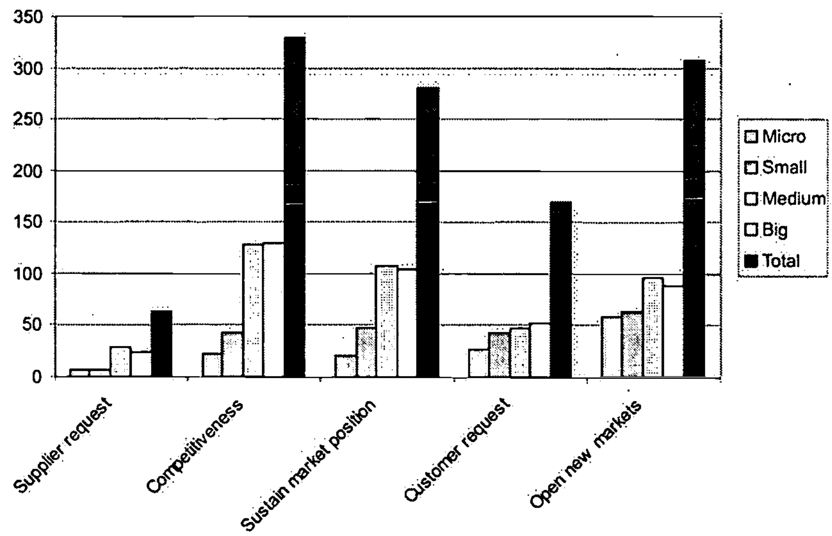
**Table 2.** Participants at the Operational Level

| Position/Area | Sales | Operation | Administration | Other |
|---|---|---|---|---|
| Sales ( + Marketing) | 41 | | | |
| Production ( + Manufacturing) | | 30 | | |
| Administrative support (+ Systems) | | | 72 | |
| | | | | 36 |
| TOTAL = 179 | | | | |

All of the participants in each of the courses and diffusion events conducted by AMECE responded to a survey about the actual use for e-business within his (her) organization. The total number of firms interviewed was 649, with 632 responding to the questions about firm's size and economic sector. This information is relevant for the design of the AMECE training programs, because it permits to known the current status for electronic business and the future applications demanded by each firm considering its particular profile (Erosa & Arroyo, 2001b).

One of the first questions in these surveys was the reason for e-business adoption. Except by the least frequent reason "suppliers request", there were statistical differences (ji-square test) in the adoption reasons by firm profile, these differences by firm size are shown graphically at Figure 6, and can be summarized in the following points:
(1) The majority of micro and small firms uses or will adopt the e-business due to their "most important customer request" or to "open new markets." This last adoption reason was the most popular among small firms (70%).
(2) Medium and big size firms use or will adopt the e-business because they consider e-business an important element to "enhance competitiveness", to "sustain competitive position within their sector" or in the last case "to open new markets".

The general conclusion is that medium to big size firms (45-60%) adopt the e-business to sustain or improve their competitive position, meanwhile micro to small firms adopt the e-business in a reactive manner, as a response to the pressure of important customers. In consequence, medium to big firms will expect to derive strategic benefits from e-business and look for higher integration within internal functional areas and with key stakeholders, meanwhile small firms pursue higher efficiency in their regular transactions with their principal consumers. This situation derives in a educational offer for each firm size.




Source: Elaborated with base to 2000 survey. Technical Direction and Associates Services. AMECE.

**FIGURE 6.** Reasons to use Electronic Business by Firm Size

The presented information was analyzed by the panel of AMECE experts, and after open discussion, the following results were derived:

(1) There is a major segment of users for AMECE training programs at the highest organizational level, and in charge of strategic decisions. For this group of individuals, a course relating strategic issues with e-business becomes attractive and useful to justify the investment in supporting information technologies.

(2) The other important segment (35%) that demands e-commerce and e-business training is conformed by individuals in charge of the firm operations. Within this segment, one of the principal functions is to provide administrative support to internal firm's processes (Acounting, Systems, Costing, Purchasing and Finance Administration). For this segment, the identified needs correspond to information technology integration into the regular internal processes.

(3) The high percentage of participant firms from the Commerce sector and in particular related to department stores, suggests the inclusion of a course about value chain managament enabled by information technologies, such that information flows properly between the firm functional areas.

(4) Medium and big size firms have a proactive attitude to e-business, as confirmed by their principal reasons for adoption: to enhace competitiveness, to maintain competitive position and to open new markets. In consequence, the training offer for this segment should be centered around Supply Chain (Logistics) and Value Chain Management, that are two of the present relevant strategies to compite in the market place (Stal, Evans y Shulman, 1992).

(5) Based on the information of the 2000 AMECE survey, related to e-business adoption barriers (Erosa and Arroyo, 2000b), the security and legal aspects of electronic transactions as well as the organizational culture, are identified as important additional topics to include in future courses. The organizational culture is of particular interest, because it was considered as the principal barrier to e-business adoption among surveyed firms, and it has been recognized as an important moderator in the integration of the information technologies with the human resources, which is critical to derive sustainable advantages from the technology adoption (Powell and Dent-Micallef, 1997).

(6) The longitudinal analysis for AMECE associates (Erosa and Arroyo, 2000 a) and the segmentation by firm size, supports the proposal for specific courses for micro and small firms, which are "followers" of the bigger firms and require additional support to effectively use a technology that may be incompatible with their actual systems, business processes and culture.

(7) The distribution of AMECE associates in the several federal entities in Mexico provides the base for a descentralization strategy, which implies that courses should be offered sequentially at different country regions, where the cities that register the highest number of associates by region becoming the associates services centers where the courses be offered.

The above results sustain the proposal for the E-Commerce Labor Training and Certification Program, with user's needs summarized in Table 3.

**Table3.** Training Needs Matrix

| **Training Requirements** | **Level I Training in bar code use and AMECE Electronic Catalog** | **Level II Technical Training** | **Level III Productivity and Competitiveness** |
|---|---|---|---|
| By Organizational Level | | | |
| • High Direction | | | X |
| • Operations | | X | X |
| • Special Staff | | | |
| • General | • Applications for Electronic Catalog focused to particular business characteristics<br>• Basic supporting abilities (PC and Internet use) | | X |
| By Firm Size | | | |
| • General | X | X | X |
| • Micro and small firms | Commerce sector | | X |
| Thematic contents | | | |
| • Business strategy | | | X |
| • Logistics | | | |
| • Security | | | X |
| • Legal Aspects | | | X |
| • Internal administrative electronic | | | X |
| • EDI-XML | | X | X |
| • EDI Mapping | | X | X |
| By geographical region | | | |
| • Mexico City area | X | X | X |
| • Nuevo León | X | X | X |
| • Jalisco | X | X | X |

The final step is to match the thematic contents with the segmentation structure as follows:

I. Identification needs by segmentation on organizational level
   1) High level demands courses that link information technologies with and a) Firm Strategy; b) Integrated Logistics; and c) Security and Legal Aspects; besides the supporting courses
   2) Operation level needs are related to a) Integration of Information Technology with Internal Processes; b) Logistics Strategy and Systems

II. Small and micro firms needs are traslated into specific training courses that link the information technologies with a) Firm Strategy, b) Supply Chain Management and Buyer-Supplier Relationships, c) Security and Legal Aspects; and d) Human Resources (Cultural) Management in the electronic era. The employees in these small firms have less technical knowledge with respect to the employees of big firms, therefore they also have needs at a basic level, namely PC and Internet basic use and applications.

III. The firms located in all target regions outside Mexico City metropolitan area are less advanced in the adoption of the e-business (Erosa and Arroyo, 2000 a), in consequence their needs go from the introductory course in bar code use to all the particular courses relating information technologies with business administration and internal operations. The target regions defined by the expert panel include Nuevo León, Mexico State, and Jalisco, that correspond to the most industrialized regions in Mexico and also Veracruz and Guanajuato as pilot regions with particular geographical advantages (a Gulf of Mexico port and a state with high demographic and industrial potential).

This diagnosis completes the second stage of the design processess for the the E-commerce, at the next stage, the definition of contents for each general need is developed.

**Content Definition**

The content inventory began with the specification of general topics that will cover all the identified needs. These topics include:

- Basic Elements for Business Strategy
- Competitiveness and Electronic Business
- The E-economy
- Introduction to Bar Code Use
- New Codes
- Uses and Applications of the Electronic Catalog
- Code Applications in Several Process Business
- Value Chain Integration via Bar Codes
- Warehouse Management with Electronic Catalog
- Applications of Bar Codes in the Exportation Business
- Basic EDI for Associates and Instructors
- Using a Personal Computer
- Introductory Course for INTERNET Use

The program will have a sequential structure for the courses in order to assure continuous participation, and particular seminars will be customized to specific segments. The results of the logic structuring process of the previous content inventory resulted in the model graphically described in Figure 7. This model for the E-commerce Labor Training and Certification Program includes three dimensions:

1. The first one is centered in operations and involves three critical elements to do e-business: (1) the administration of electronic purchases and relations with suppliers, (2) the supply chain management, and (3) the management of internal processes. These three topics attend the needs for the Operations Management segment.
2. The second level is intendeed to cover technical needs, and therefore it is oriented to provide the basic elements to use Electronic Data Interchange (EDI), electronic invoices and XML lenguage.
3. The third dimension has as main objective the development of strategic abilities, and is specific to the High Organizational Level segment.

All three dimensions require as basic supporting abilities the PC use and Internet navigation. Not a particular individual or area will demand training and/or certification in all dimensions, but a firm that wants to use and derive benefits from e-business must assure that its human resource possess all the described capabilities.

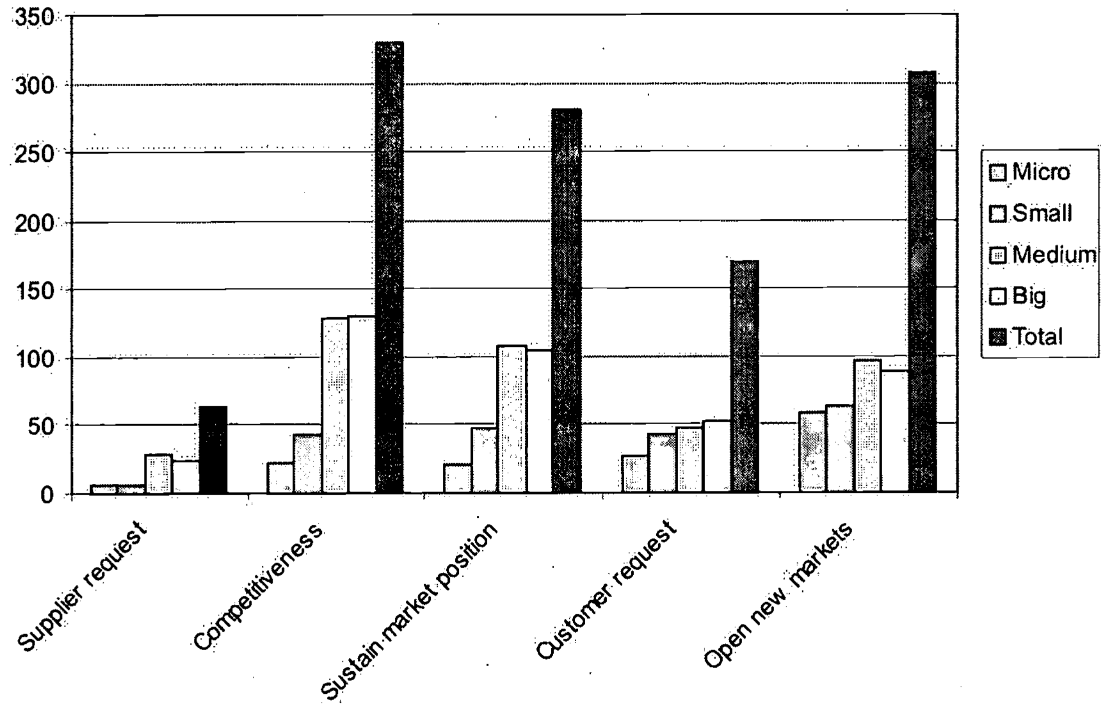



**FIGURE 7.** A Mutidimensional Education Model for E-commerce Labor Training and Certification

**The Syllabus**

Once general topics are structured and related to particular segment needs, the full content inventory was elaborated and used to design syllabus for particular courses. To elaborate the complete thematic inventory, all the basic elements for each general topic were identified, resulting in 42 themes that were classified by their knowledge domain, as shown in Table 3. From this material, three basic knowledge areas emerge: e-purchasing, e-supply chain and e-internal processes. Each area is closely related with one of the dimensions of the technology educational model described in Figure 1, but the additional information about knowledge domain was required to develop the specific syllabus for the courses that will need to be customized for each of the identified segments.

**Table 3.** Content Inventory for Basic Education in E-Commerce

| CONTENT | DISCIPLINE |
|---|---|
| 1. Bar Codes | 1. Standards |
| 2. Concept of business strategy and different types of strategy | 2. Strategic administration |
| 3. Marketing Research (how to identify the characteristics of competition, clients and suppliers) | 3. MKT |
| 4. Value chain (MRP y ECR) | 4. Logistics |
| 5. Supply chain (MRP y ECR) | 5. Logistics |
| 6. The marketing concept | 6. MKT |
| 7. Inventory management | 7. Logistics |
| 8. Sales forecasting | 8. Statistics/MKT |
| 9. Report elaboration | 9. Statistics/bd |
| 10. Basic statistics | 10. Statistics |
| 11. Administration by category | 11. Buys/Sales |
| 12. Costs and profitability | 12. Finance |
| 13. Material resources management | 13. Administration |
| 14. Quantitative analysis of the demand | 14. Statistics/MKT |
| 15. Methodology of description of the product (id attributes) | 15. Standards |
| 16. Marketing mix (the 4 P's) | 16. Standards |
| 17. Planning | 17. MKT |
| 18. Information databases (data mining, handling, diffusion, management and revision) | 18. BD |
| 19. The purchasing function | 19. Buys |
| 20. Optimization | 20. Administration |
| 21. Structured offers and special cases | 21. Buys/Sales/MKT |
| 22. Order administration | 22. Logistics |
| 23. Standardization and policies for procedures | 23. Standards |
| 24. Negotiation | 24. Buys/Sales |
| 25. Concept of planogramation, volumetry, administration of shelves | 25. Logistics |
| 26. Invoicing and collection | 26. Finance |
| 27. Concept and managing of tools associated with the quality control | 27. Logistics/Production |
| 28. Concept of logistics, definition and management of the components, transportation, packing and crate | 28. Logistics |
| 29. Plan of professional development | 29. Administration |
| 30. Introductory course to use the PC | 30. Outfitter |
| 31. Introductory course to use the INTERNET | 31. Outfitter |
| 32. Report elaboration | 32. Statistics |
| 33. Decision making | 33. Managerial |
| 34. Leadership styles and direction | 34. Managerial |
| 35. Development of communication skills | 35. Managerial |
| 36. Managing conflict | 36. Managerial |
| 37. Handling the information policy | 37. Managerial |
| 38. Statistical analysis | 38. Statistics |
| 39. Formation and integration of distance-work teams | 39. Managerial |
| 40. Managerial efficiency | 40. Managerial |
| 41. Better practices for costs administration, purchases and collections | 41. Finance/Buys/Collection |
| 42. Use and operation of the catalogue | 42. Standards(outfitter of the catalogue) |

The specific syllabus for the courses that will cover the needs of the Operation Management segment are shown as illustration of the results for the fourth stage of the process (Figure 1) for the design of the E-commerce Labor Training and Certification Program. The courses are grouped by knowledge area and offered as a complete seminar, with each course closing with a workshop about Electronic Catalog use that will summarize the course themes and will be the evaluation mechanism to verify the acquisition of the desired capabilities.

**SEMINAR 1**
**PURCHASING MANAGEMENT AND RELATIONS WITH SUPPLIERS**

1. Business strategy
The strategy concept and strategy types

2. E-purchasing
The purchase function
Negotiation
Invoice and accounting

3. The marketing strategy
Marketing research
Basic statistics
Quantitative analysis for the demand
Statistical analysis and reports
Sales forecasting
Management by categories and segmentation
Structured offers

4. Standards
Standardization norms and policies
Standard code for product and assignation
Methodology and product description
Database management
Electronic catalog and its alignment with databases
Basic tools for quality control

5. Workshop for Electronic catalog use and operation

**SEMINAR 2**
**INVENTORY AND SUPPLY CHAIN MANAGEMENT**
1. Business strategy
The strategy concept and strategy types

2. Standards
Standardization norms and policies
Standard code for product and assignation
Methodology and product description
Database management
Electronic catalog and its alignment with databases
Basic tools for quality control

3. Supply chain management
The integrated logistics concept
MRP system

Inventory management
Transportation and handling materials
Planogramation, volumetrics and rack design
ECR system
Logistics strategy

4. Workshop for Electronic catalog use and operation

**SEMINAR 3**
**COSTING AND INTERNAL PROCESSES**

1. Business strategy
The strategy concept and strategy types

2. The marketing strategy
Marketing research
Basic statistics
Quantitative analysis for the demand
Statistical analysis and reports
Sales forecasting

3. E-purchasing and selling
Best practices for costing, purchasing and cobranzas?
Costs and profitability
Invoice and cobranza?

2. Standards
Standardization norms and policies
Standard code for product and assignation
Methodology and product description
Database management
Electronic catalog and its alignment with databases
Basic tools for quality control

4. Workshop for Electronic catalog use and operation

**Program Infrastructure**
The final step for the program development process was to define the program format and the required infrastructure, both physical and human (including nstructor's profile). With respect to program format, the AMECE expert panel suggested a weekly basis for the courses in a particular seminar, with the option to continue to the next seminar if the participant shows proper competences. Since this kind of program is oriented to particular business application, the last course has a workshop format (Electronic catalog use and operation). Under this format, the participants will be able to practice the acquired concepts and to begin the development of applications into their functional area. The PC and Internet courses, are necessary to each participan that wishes to follow the seminars, because they provide supporting basic abilities, in consequence they will be offer on a continuous basis (one per week). Since bar code is the key technology for e-business in the case of products, the introductory course for bar code use will also be a continuous offer.

With respect to didactic materials, they include the basic material for presentations, student's manuals and the use of a CD/e-card with exercises and material for self-study. This last interactive material was designed as a result of the instructors and participants comments (2000 courses) in relation with the frequent remaining questions about particular applications. Even though internal and external instructors have didactic experience and professional background in the disciplines that conform the courses' knowledge domain, additional training in novel didactic techniques and/or EDI use, business strategy, integral logistic, etc. will also be provided by the AMECE R&D Direction, in order to assure excelence in the instructor's profile as specified for AMECE standards.

The syllabus that conform the whole E-commerce Labor Training Program were the basis for the development of the National Standards for Electronic Commerce Labor Capabilities (NSECC: Diario Oficial, January 2002), that is why the "Certification" part was added to the program denomination. Using as illustration the second syllabus, the structure of the NSECC, is as follows (CONOCER, 1997):

1. Strategic level.
   Logistics derives value to the firm through "the capability to integrate product, information and cash flows for decision-making purposes that link both internal and external processes" (Novack et al., 1995). The elaboration of the logistic strategy demands a long-term focus, knowledge about the market and strategic planning, negotiation abilities, individual relationships and abilities for the creation of strategic alliences.
2. Operational level
   Databases and software facilitate operations necessary to manage and process customer orders, via proper operation of distribution facilities, warehouses, transportation scheduling, production and procurement activities. The tactical decisions at this level require an evaluative focus over a set of alternatives, therefore quantitative tools for decision making are required. Planning and coordination of activities such as scheduling, production, and inventory deployment require information about past activity levels and current status, in consequence additional capabilities related to forecasting, effective communication and database management are necessary.
3. Technical level
   Interorganizational systems such as EDI are essential to integrated logistics because the need to share information about sales, forecasts, inventory, and orders on a timely basis among the firms involved in the supply chain. Abilities to handle this kind of software as well as to mantain and use databases are the basic cabilities at this level.

Since the labor market is in total agreement with the required capabilities at each level, the designed program technically professionalize the worker, keeping the qualificational differences at each level. The application of the established norms allows to determine if a worker has the technical knowledge and abilities demanded to perform a job at a particular level, if not, additional training until certification will be required. The e-com is not only influenting the business environment but also the education programs. E-commerce and e-business courses are now part of the curriculum of several engineering and business programs, but professionals or technical workers cannot attend to educative institutions to acquire the knowledge and abilities that are demanded in the new business environment. In consequence, continuous education programs need to be designed to attain and retain the skill level required, the content and structure of the programs must be carefully designed in order to guarantee inmediate applicability and increased efficiency in the business process in charge of the certified workers, such that the organization enhace its competitiveness. The most probable situation is that these continuous education programs be sponsored by the government, worker's unions, or the affiliated firm, with the collaboration of educative institutions or qualified organizations such as AMECE. The design of these programs must be centered around the job characteristics in the e-com and e-business context, as expressed by the organizations that are demanding qualified work force.

## Conclusions

The information technologies and the new models for electronic transactions are affecting the business in the sense that human resources should develop in the short term the required capabilities to integrate technologies with the firm's processes. A diagnostic methodology applied in Mexico has allowed the identification of the contents for a program that will provide the required abilities as expressed by the firms that are using the electronic business, assuring at the same time the operativity of the program by the institution in charge of the educational offer. The labor market demands the design of technical educational programs of high quality and applicability that no longer can be developed by formal educative organizations, requiring the participation of other type of organizations that contribute to continuous education and special training. The curricula design methodology applied in this case contributes to the development of a well structured program that will satisfy the direct (employees) and indirect (firms) users. Each of the proposed seminars covers operational, technical and strategic dimensions and closes with a workshop because it is necessary that the trainees develop how-to-do abilities in the short term. Another special feature of the applied methodology is the recognition of educational segments that will receive a customized seminar that will increase interest and performance.

**References**

CONOCER. Guía de elaboración de Normas de Competencia Laboral, 1997. Mexico.

EROSA, V. E. ( 1989). "Un Taller de Diseño Curricular". UNESCO, IV Comité Regional. México.

EROSA, V. E. and Arroyo, P. E. (1997). "Creación de Pequeñas Empresas Exportadoras: Una Experiencia en Centroamérica." Comercio Exterior, Vol. 47, No. 1, pag. 73-79.

EROSA, V. E. , Arroyo, P. E. (2001a). "Adopción en México de Tecnologías Llave para el Comercio Electrónico: Un Análisis Longitudinal 1986-2000." Boletín de Política Informática del INEGI. Año XXIV, No. 4. pag. 27-54.

EROSA, V. E. , Arroyo, P. E. (2001b). "Encuesta Sobre Usos y Percepciones del Comercio Electrónico en México." Reporte técnico. Dirección de Investigación y Desarrollo de AMECE.

HARPER, G. R. and Utley, D. R. (2001). "Organizational Culture and Successful Information Technology Implementation." Engineering Managament Journal, Vol. 13, No. 2, pag. 11-15.

NOVACK, R. A. et al. (1995). "Creating Logistics Value: Themes for the Future. Oak-Brook, IL: Council of Logistics Management.

POWELL, T. C. and Dent-Micallef, A. (1997). "Information Technology as Competitive Advantage: The Role of Human Business and Technology Resources." Strategic Management Journal, Vol. 18, No. 5, pag. 375-405.

STALK, G., Evans, P., and Shulman, L. (1992). "Competing on Capabilities: The New Rules of Corporate Strategy." Harvard Business Review, Vol. 70, No.2, pag. 57-69.

**Keywords:** e-commerce, e-business, technical educational, training needs, labor capabilities, organizational culture

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# TWENTY YEARS OF CHEMICAL EDUCATION IN PETNICA SCIENCE CENTER - YUGOSLAVIA

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## Abstract

Petnica Science Center (PSC) is operating twenty years in Yugoslavia. It is a unique non-governmental, non-profit and independent educational institution working with young people who demonstrate an inclination and interest in science beyond regular school curricula. Most of PSC's educational activities are designed for high school students (age 15-19), but there are also a variety of programs for elementary school children and college undergraduates. Training of teacher was intensified during last three years. PSC is consisted of Library (with 13000 books, 2000 international scientific journals, several databases on CD-ROM, open and free of charge access to Internet and Intranet), Computer centre (over 30 Pentiums) and several departments with equipment suitable for the research and teaching/learning: Anthropology, Archaeology, Astronomy, Biology, Chemistry, Computer science, Geology, Geography, Electronics, Ethnology, Linguistics, Mathematics, Psychology and Physics.

Chemistry was among the first disciplines, which started in 1982. Beside various lectures, workshops and courses, student project was the main teaching/learning method in PSC. During the first seven years (1982-1989) projects were usually realized in a form of summer schools. They included field studies and lasted 2-4 weeks. The teams very relatively large: 20 to 30 participants, mostly secondary school students. The individual student projects started in 1990. In spite of their interest for chemistry, many secondary school students did not have enough knowledge and practical experience to define and perform their projects. The annual cycle of seminars was designed in order to solve these problems. The share of environmental projects was usually very high. In average, it was 64% of all projects realized in Chemistry department of PSC (the total number of projects was 206 in the period 1990-2001). During the last few years, projects became more complex and their quality was considerably improved. International co-operation was permanently the important feature of chemical and science education in PSC.

## Introduction

Petnica Science Center (PSC) was founded in 1982 by a group of young teachers, scientists and university students (Vajgand *et al.*, 1987, Majic, 2000). It is a unique non-governmental, non-profit and independent educational institution working with young people who demonstrate an inclination and interest in science beyond regular school curricula. Contrary to traditional and rigid system, which was dominating in the schools twenty years ago, new styles and teaching/learning methods were introduced in Petnica Science Center. The emphasis was on experimental work; problem solving and students research projects. The equipment and instruments in laboratories of PSC were considerably better than those in the schools (often similar like in the university laboratories for undergraduate students). Teaching staff was also better qualified and more capable than school teachers. Most of PSC's educational activities are designed for high school students (age 15-19), but there are also a variety of programs for elementary school children and college undergraduates.

PSC is consisted of several departments with equipment suitable for the research and teaching/learning in various sciences: Anthropology, Archaeology, Astronomy, Biology, Chemistry, Computer science, Geology, Geography, Electronics, Ethnology, Linguistics, Mathematics, Psychology and Physics. It also has Computer centre (over 30 Pentiums) and the Library with 13000 books, 2000 international scientific journals, several databases on CD-ROM. Free access to Intranet and Internet was also provided for all participants in PSC. Accommodation and meals could be provided for about 100 persons. Participation in educational programmes (including accommodation and meals) is practically free of charge for students. The gender ratio was usually well balanced. Up to 1995 there was a tiny majority of boys (never over 52%). In 1996 the girls prevailed (51.1%).

The importance of PSC could be envisaged from the data for the year 2000. There were over 120 science camps, workshops and courses for over 2000 students from nearly 350 schools. Beside permanently employed staff from PSC, more than 700 scientists and lecturers from about 150 institutions (faculties, research institutes, medical institutions, industrial companies) were also engaged. Furthermore, about 200 young assistants (Petnica alumni and usually university students) were also helping their younger colleagues.

Petnica Science Center was working permanently twenty years. PSC was closed only during NATO bombardment of Yugoslavia in March-June 1999 (like all other schools). Tragic events in former Yugoslavia in the period 1990-2000, including political problems and economic isolation made the activities of PSC more difficult. The number of participants from foreign countries was temporary diminished. However, the links with colleagues were maintained and overall educational activities were increased. In spite of economic problems new building of teaching centre and dormitory was partially finished (foundation and the ground floor). The building and corresponding equipment will be probably completed in near future in order to fulfil great interest of young people and teachers.

**Chemical education in Petnica Science Center**

Department of chemistry in PSC has two large laboratories suitable for qualitative and quantitative analyses (gravimetric and volumetric) as well as several smaller rooms for instrumental analyses (gas chromatograph, spectrophotometer), laboratory balances and storage. Three persons are permanently employed: graduated chemist, engineer of chemical technology and a technician. Beside educational activities they occasionally participated in some research (for example, chemical analyses for water supply organization, interlaboratory studies, etc.). They also participated in scientific/professional meetings and wrote papers. During the year 2000, the total of 29 papers were published by staff from PSC, three of them originated from the Department of chemistry (Majic et *al.*, 2000).

From the beginning, beside various lectures, workshops and courses, student project was the main teaching/learning method in PSC (Jevtic *et al.*, 1995 Vajgand *et al.*, 1987). The importance of this method was increasing, as it is suitable for achieving the scientific and technological literacy of students. During the first seven years (1982-1989), projects were usually realized in a form of summer schools. They included field studies and lasted 2-4 weeks. The teams very relatively large: 20 to 30 participants, mostly secondary school students. Typical example of the project was the study of water resources in the region of river Jadar. The aim was to make evidence of all wells and springs, to take samples and finally to estimate the quality of water on the basis of physical, chemical and microbiological investigation (Peric *et al.*, 1995). Before the field and laboratory work students were informed about the project, their tasks and analytical methods. The training was usually organized in some school or at the university. Volunteers from universities or research institutes provided a good professional guidance.

The individual student projects started in 1990 after the completion of two chemical laboratories in PSC. In spite of their interest for science and environment, many secondary school students did not have enough knowledge and practical experience to define and perform their projects. There are also similar findings in the literature. Gardner (1984) found that the relationship between affective measures (interests, attitudes) and cognitive ones (ability, achievement) had been very weak (the correlation coefficients fallen in the range 0 to 0.4). Therefore, the annual cycle of seminars was designed in order to provide students with theoretical and practical knowledge necessary for research project. Students apply for PSC in September-October each year. Those who passed the screening procedure were invited to winter and spring seminars (4-7 days each) where they could acquire theoretical and practical knowledge on analytical techniques (gravimetric, volumetric, optical and electrochemical methods), methodology of scientific research, data handling and statistics, use of chemical literature, etc. Beside the staff from PSC, volunteers mostly from faculties and research institutes gave lectures and provided training for students. Young assistants (Petnica alumni and usually university students of chemistry, technology, medicine, etc.) were also engaged. Usually, about 6-10 volunteers and 2-4 young assistants were engaged for each seminar. At the end of spring seminar students alone or together with older colleagues had to design their project. After individual preparation (2-3 months) students realized practical parts of their projects in Petnica Science Center during the summer seminars (12-15 days). At the end of seminar students had to present the results of their projects to others and to write the draft version of the report. In consultation with mentors, the reports were later improved and published in PSC publications in different form. Earlier, abstracts of papers in English and Serbian were published (Brankovic, 1991). Later complete versions of papers were published in Serbian with English abstract. Short versions of selected papers were also published each year in Petnica Science Center Almanac (Majic et *al.*, 2000).

### Environmental projects in Department of Chemistry of PSC

The total of 206 student projects were realized in Chemistry department of PSC during 1990-2001. Student projects in chemistry and the environment continuously represented the major portion with average share of 64% (Table 1.).

There were no projects on air analysis. Most projects in the period 1990-1993 were concerned with water analysis (Peric *et al.*, 1995). Most of projects realized at the beginning of that period was relatively simple, e.g. they included determination of only one parameter in few samples.

Later the quality and complexity of student projects on water analysis were considerably increased. More parameters were determined as well as their changes with location and time (daily and during summer seminars). For example, during 1990-1993, a gradual increase in number of parameter studied (in each paper) was observed, from 1-4 to 6-9.

In most projects students analyzed water samples collected near PSC: different sites of Petnica Lake, river Banja and Pocibrava spring. Only two students brought water samples from their home towns (Belgrade and Sabac). Within water analysis 15 parameters were determined. The diversity of parameters determined by students mostly did not change in the period 1990-1994. Chemical oxygen demand, the content of calcium, magnesium and nitrate as well as pH were measured most often (Peric *et al.* , 1995).

**Table 1.** Student projects in chemistry and environmental chemistry during 1990-2001.

| YEAR | CHEMISTRY | ENVIRONM. | WATER | SOIL | FOOD |
|---|---|---|---|---|---|
| 1990 | 24 | 22 | 13 | 8 | 1 |
| 1991 | 27 | 21 | 9 | 5 | 7 |
| 1992 | 17 | 9 | 2 | 1 | 6 |
| 1993 | 16 | 9 | 6 | 0 | 3 |
| 1994 | 17 | 5 | 0 | 2 | 3 |
| 1995 | 10 | 7 | 2 | 1 | 4 |
| 1996 | 12 | 9 | 1 | 2 | 6 |
| 1997 | 17 | 11 | 0 | 2 | 9 |
| 1998 | 20 | 7 | 1 | 1 | 5 |
| 1999 | 9 | 9 | 1 | 1 | 7 |
| 2000 | 17 | 11 | 1 | 1 | 9 |
| 2001 | 20 | 12 | 0 | 0 | 12 |
| TOTAL | 206 | 132 | 36 | 24 | 72 |

During the last eight years, food analyses were the dominating themes of projects (Krsmanovic *et al.*, 2001). The trend of the increase of the complexity of projects was continued. Project usually involved several substrates (two or three), for example food and soil, or water and soil. So, it was difficult to assign projects from this period with one (main) substrate. One of the best projects had the title "The influence of acid rains on the quality of soil and wheat".

Environmental projects were also realized in other departments of PSC (Biology, Geology and Geography). There were also several interdepartmental projects.

## International activities and co-operation

International activities were always important in Petnica Science center. They included participation of the best students from PSC (and their projects) at various international youth events (science fairs, exhibitions, competitions), short study visits to foreign research institutes (usually on the occasion of some international summer course), hosting of visitors from foreign countries in PSC (students and/or educators/researchers).

Students from Petnica Science Center participated successfully several times at various international events such as London International Youth Science Fortnight. Students from Chemistry and Biology departments of PSC also got several awards for their environmental projects presented at "Bios-Olympiad". Scientist from Greece, Dr. Agni Vlavianos-Aravanitis, initiated this important international event which was organised annually near Sankt-Petersburg (Russian Federation) by professor Shishkin and Ladoga environmental club. Miss Danica Galonic (as the secondary school student, age 18) got the first prize in 1996 for the project "The influence of acid rains on the quality of soil and wheat". She later finished with excellent marks her studies at the Faculty of Chemistry of Belgrade University and continued Ph.D studies in USA. Students from Yugoslavia also participated several times at other international events such as International Competition "Young Europeans' Environmental Research". Some of their papers were published in Young Researcher - The European Journal of Science and Technology (paper of Miss Marta Kamenjicki).

Foreign visitors (students and/or educators/researchers) were coming each year to Petnica Science Center even in the period of international sanctions. Usually they were coming mostly from neighbouring country but also from Australia, Canada, Japan or USA. The purposes of these visits were the realization of projects (for students), the exchange of views or sharing the experience (for researchers/educators). Sometimes it turned to a successful co-operation. Recently professor Maciejowska from Jagellonian University in Krakow (Poland) gave in PSC a lecture on the use of problem solving in environmental education. She also organised the workshop with Yugoslav students. Although she used educational material previously developed and tested in Poland, interesting new results were obtained and published (MACIEJOWSKA *et al.*, 2001).

## Teacher training in Petnica Science Center

Teacher training was envisaged as the important activity from the beginning of Petnica Science Center and some courses were occasionally made. However, during the last three years additional and systematic efforts were undertaken in this direction. Teacher Resource Center (TRC) was founded in PSC with collection of carefully selected books, textbooks, manuals, software, videotapes, etc. This is the first such resource center for school teachers in Serbia. Some centres with smaller scope and more traditional concept were also operating earlier, but they were all closed in 1990 (Majic *et al.*, 2000). TRC will help teachers to improve their knowledge and teaching practice. At the same time, the number of courses for various teachers was considerably increased. For example, five courses were organized for chemistry teachers during the last three years. Each course lasted about one week. The emphasis was on active teaching methods, problem solving, project method, role-playing, how to achieve scientific and technological literacy of students, organization of out-of-school activity, etc. Teachers were encouraged to use computers, multimedia and Internet. Examples of software suitable for use in schools were demonstrated. Attention was also given for teaching about chemistry and environment (global warming, ozone layer, new formulations for detergents, etc.) as well as chemistry and health/medicine.

## Educational implications of Petnica Science Center on science and technology education

From the founding of Petnica Science Center, it was always an opened and continual educational experiment. It was the crosspoint of excellence, offering many possibilities for gifted students and gifted teachers/professors. Sometimes it was described as "Science supermarket" - a place were students can find all necessary components for their science projects: ideas, equipment, chemicals, literature and mentors (Frazer, 1984, Krsmanovic, 1988). Emphasis on project as teaching/learning method was was a long time the speciallity of PSC. It is an important method for improving the scientific literacy of students.

For students PSC is a possibility to learn more and to make their own experiments and research with equipment which can not be found easily. For teacher it is the opportunity to work with best students and to test some new teaching units such as bioremediation (Krsmanovic, 2000).

Former attendees of Petnica Science Center usually got best marks at entrance examinations for all faculties.

In another research it was found that typical participant of PSC's programs is 17 years old. She (there are more girls than boys) is among top 1% students in her school and comes from middle class family with moderate family income that cannot cover the basic cost of the program (science camp, course, workshop). This is the main reason why all programs are completely free of charge for participants.

Each year students are asked to fill out anonymous questionnaires about their impressions and estimation of educational programs and their personal experience in Petnica Science Center. They had to estimate several elements of the program with the marks 1-5 (5 being best). In 2000, the program, teaching methods and individual student activities got the average marks 4.27, 4.33 and 4.34, respectively. The quality of lecturers was marked with somewhat higher score (4.61) as well as for the program leaders (4.58). The living facilities got average score of 4.00, while the value for food was the lowest (3.12). The total number of participants was 801 and they gave the average mark 4.43 for the entire program including boarding accommodation and extracurricular activities.

In evaluation of the impact of activities in Petnica Science Center on science and technology education it must be considered that during the last ten year Yugoslavia an people living in it were exposed to the consequences of "International sanctions" (sanctions imposed by the Security Council of United Nations). The economy of Yugoslavia was gepardaized, the public health system was destroyed (after the first two or three years of "Sanctions" reports made by officials of World Health Organization indicated clearly the increased mortality rates for entire population, especially for babies and elderly people). Education system also suffered from shortage of financial support, there were a number of strikes with changeable percentage of participants (sometimes they lasted for several months). There were no strikes in Petnica Science Center, but it was extremely difficult to keep all educational programs running. Petnica Science Center was always more than a hope for Yugoslav future - clever, educated and ambitious young people.

Although it is not easy to transfer educational programs and activities from one country to another, at least some of successful experiences of Petnica Science Center could inspire other chemists and science educators.

## Conclusions

During the twenty years period, 1982-2001, Petnica Science Center (PSC) gave significant contribution to science education, chemical education and environmental education. Many students realized successfully their projects in PSC.

The share of environmental projects was usually very high. It was 64% of all projects realized in Chemistry department of PSC. During the last few years, environmental projects became gradually more complex and their quality was considerably improved.

Methodology for preparation of students and realization of projects was continuously improved, from large team projects to individual student projects of high quality. The best student projects produced in PSC are on a level with similar achievements in other European countries.

Teacher training courses and international activities were always important for Petnica Science Center.

## References

BRANKOVIC, B. (Ed.) (1991). Petnica's Paper No. 23, *Student's Projects 91: Book of Abstracts*, Petnica Science Center, Valjevo, Yugoslavia.

FRAZER, M. (1984). Plenary lecture on the International Seminar on Chemical Education *"The Role of Project Work in Teaching Chemistry"*, School of Chemical Sciences, University of East

Anglia, Norwich, Great Britain, July 18-19.

GARDNER, P.L. (1984). Students' interest in science and technology: An international overview. 12th Symposium of the Institute for Science Education, University of Kiel, Federal Republic of Germany, April 2-6, 1984.

JEVTIC, N., PERIC, LJ., TODOROVIC, M. AND KRSMANOVIC, V.D. (1995). Yugoslav experience from Petnica Science Center: Student projects in chemistry and the environment. Proceedings of the I Regional Symposium: *Chemistry and Environment*, pp. 1031-1034, Vrnjacka Banja, Yugoslavia.

KAMENJICKI, M. (1993). Oxygen content and biological oxygen demand of water samples from different sites of Petnica Lake. *Young Researcher*, 8 (30): 30-32.

KRSMANOVIC, V.D. (1988). Project work as an example of low cost chemistry teaching. In: THULSTRUP, E.W. (Ed.) Teaching Chemistry at Low Cost - A UNESCO Workshop Proceedings, pp. 37-42, UNESCO, International Network on Chemical Education and Royal Danish School of Chemical education, Copenhagen.

KRSMANOVIC, V.D. (2000). Bioremediation - Interdisciplinary approach to scientific and technological literacy. *TEMPUS Seminar: Interdisciplinary Education - Challenge of XXI Century*, Faculty of Chemistry, Jagiellonian University, Krakow, December 14-17.

KRSMANOVIC, V.D., JEVTIC, N., PERIC, LJ., AND TODOROVIC, M. (2000). Environmental projects in Petnica Science Center - Yugoslavia, *Environmental Education and Sustainable Development in S.E. Europe*. Chalkidiki, Greece, June 25-28.

MACIEIJOWSKA, I., JEVTIC, N., PERIC, LJ., TODOROVIC, M. AND KRSMANOVIC, V.D. (2001). Problem solving in environmental education: Polish – Yugoslav experience. Proceedings of the 4th Yugoslav symposium with international participation *Chemistry and Environment*, pp. 452-454.

MACIEIJOWSKA, I., JEVTIC, N., PERIC, LJ., TODOROVIC, M. AND KRSMANOVIC, V.D. (2001). Problem solving in environmental education: The opinion of students. Book of Abstracts, 4th International Conference of the Balkan Environmental Association B.EN.A., October 18-21, 2001, Edirne, Turkey.

MAJIC, V. *et al.* (Eds.) (2000). Petnica Science Center Almanac No. 18, Petnica, Yugoslavia.

MAJIC, V. (2000). The Petnica Science Centre, Serbia – An introduction. *Science Education Newsletter*, No. 152 : 1-2.

PERIC, LJ., SUMAR, M., JEVTIC, N., KRSMANOVIC, V.D. AND TODOROVIC, M., (1995). Student projects on water analysis in Petnica Science Center during 1990 - 1994. Proceedings of the I Regional Symposium: *Chemistry and Environment*, pp. 1027-1030, Vrnjacka Banja, Yugoslavia.

VAJGAND, V., MAJIC, V. AND KRSMANOVIC, V.D., (1987). Yugoslav experience with project work in chemistry at secondary school level. In: RIQUARTS, K., (Ed.), Science and Technology Education and the Quality of Life, Vol. 1., Science Education, pp. 192-199, Institute for Science Education, Kiel, Germany.

**Keywords:** chemical education, environmental education, gifted students, student projects, Petnica Science Center

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# THE INTERACTION UNIVERSITY SECUNDARY SCHOOL: A PROPOSAL TO OVERCOME THE GAP BETWEEN TEACHING AND LEARNING OF CHEMISTRY

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## Abstract

Brazilian educational politics have gone through several cycles of remodeling of the laws and/or guidelines for teaching. Those have tried to define clearly the objectives of the teaching and to reformulate the programs of disciplines part of Chemistry curriculum. The National Curriculum Parameters for the Secondary Teaching (PCNEM), published in 1998, have discussed in a well-established way the problems related to Chemistry teaching. However, what has been observed is that, once again, the Chemistry teaching seems to follow an own road, indifferent to the official proposals, and that the historical problems concerning teaching, still resist to any governmental action. In spite of the historical progresses noticed in several governmental proposals, again is observed a long gap between the proposal and the practice.

The active participation of the university, mainly the public university, is fundamental to change the actual situation on behalf of improvements in the teaching of Chemistry. A special attention should be given to courses for teachers and also to their continuous formation. Events sponsored by public universities have shown the need of university intervention in subjects such as Chemistry teaching for secondary school, is urgent. This was noticed through the participants' comments, that also indicated that the university is very often perceived as an option for help to their needs, but it is usually considered as unattainable. The interaction between the academic and secondary teachers represents a perspective to furnish additional information necessary to overcome their main difficulties, mostly of conceptual order. The proposals described in this work, represents modest but well succeed actions, that could be used to identify some problems of secondary teachers. As result, it allowed the elaboration of alternative actions that have contributed to the improvement of their basic formation. Certainly, the problems concerning Chemistry teaching didn't vanished by the accomplished works, but should stimulate the elaboration of new proposals with potential positive results.

The university can really contribute to improve the quality of secondary chemistry teaching if it acts in partnership with secondary teachers. Several aspects can be minimize by it action such as: difficulties of conceptual order; difficulties to visualize the relationship among the main areas of knowledge, which is a consequence of fractional structure in Chemistry courses for teachers. As well the difficulties of association the theory to chemical phenomena, applications and new insights and difficulties in the application of the experimentation in the classes due to poor undergraduate formation.

## Introduction

Constantly, the problems regarding Chemistry teaching are an important subject of discussion among teachers, researchers and professionals dealing with teaching, who are committed with a public school of quality. Brazilian educational politics have gone through several cycles of remodeling of the laws and proposals of guidelines for teaching, Those have tried to define clearly the objectives of the teaching and to reformulate the programs of the disciplines that are part of Chemistry curriculum. This was the focal point of the Brazilian educational changes over the XX century.

In 1931, the Francisco Campos proposal suggested that Chemistry teaching should be guided by the precepts of the experimental method, indicating clearly the importance of experimental activity of pedagogic character in the acquirement of the knowledge. This proposal was re-written later on and reinforced in 1942, by the Capanema proposal that emphasized the need of the student's constant and active engagement in the development of experimental activities.

In spite of the formal changes in the objectives for the secondary teaching, proposed by the Law of Guidelines and Bases of 1971 (Law n°. 5.692/71), the teaching of the sciences should also be orientated by the "development of the logical reasoning and existence of the scientific method." In this time, the conception of scientific method presupposed the planning, step-to-step, of an investigation of which the experimentation occupied prominent place. In order to implement this proposal, great projects for Chemistry teaching were imported from other countries, mostly the ones developed in the United States. The main goal of those projects was the formation of a great number of scientists. At that time, this it was the only way known as capable to face the challenges imposed by the cold war and the needs for development.

The 70 and 80 decades were marked by the deception in relation to this proposal. At this time, besides the experimentation, the historical aspects of science and day to day dealing related with teaching of science became very important. This approach .was expressed by the "Curriculum Proposal for Teaching of Chemistry of 2° Degree", elaborated from a rich discussion among teachers from public secondary school, S. Paulo Public Universities (UFSCar, Unesp, Unicamp and USP) and from Center of Teaching of Sciences of S. Paulo (CECISP). In 1986, the first edition of this proposal arrived to the teachers of the public secondary school system, including a rich argument on the bases for teaching Chemistry, as well as a methodological proposal and the program content to be worked with.

Finally, the Law of Guidelines and Bases of 1996 (Law 9.394/96, Art. 35; section II), established that the secondary teaching will have as main purpose (among others): "to provide basic preparation for work and the student's citizenship, the continuos learning, in such way that the individuals should be capable to adapt to new occupation conditions or subsequent improvement of society." In order to accomplished the defined purposes in the law, was published in 1998, the National Curriculum Parameters for the Secondary Teaching (PCNEM). It has a well-discussed approach to the problems of Chemistry teaching and the possible methodologies to aid the teacher to implement the proposal.

However, what has been observed, once again, Chemistry teaching seems to follow its own road, indifferent to the official proposals, and that the historical problems concerning teaching, still resist to any governmental action. In spite of the historical progresses noticed in the several proposals for the teaching of Chemistry, again is observed the estrangement between the proposal and the practice

PCNEMs don't present the program for contents to teach Chemistry, as clearly was states in the "Curriculum Proposal for Teaching of Chemistry of 2° Degree". PCNEMs don't also indicate a sequence of what should be approached in the day by day work in the classroom. However, PCNEMs give the true value to the same relevant goals from other proposals (experimentation, history of the Chemistry and day to day dealing) that, in reality, were never present in a significant way in our schools. It doesn't seem clear enough to most of the teachers from secondary school that its discussion emphasizes more educational fundaments, by removing the program content as main focus of the action. In this way, PCNEMs started to represent more doubt than orientation for the teachers whom should be the agents for its implement.

Once again, it could be verified that the problems of Chemistry teaching don't have origin in the effective educational proposal. The implementation of the proposal seems to be being made unfeasible by the lack of orientation for the teachers. The secondary teachers, in enormous majority, have received the proposal in an impersonal way of a printed paper of PCNEMs, as a spelling book that should be followed without any further instructions whew are not found solutions for the school failure. The Government accomplished a formal role that will not have practical repercussion as long as no effective engagement of all the segments involved in the educational process become factual, with great emphasis to the teachers and the material conditions for the schools.

It is urgent to engage efforts of the society to solve such serious problem. The commitment of the university, mainly the public university, is fundamental to change the actual situation on behalf of improvements in the teaching of Chemistry. A special attention should be given to courses for teachers and also to their continuous formation. It is necessary to take action close to secondary teachers and not to let to deceive for the speeches and statistical data that indicate the growth of the number of registrations in the basic education. While it prioritizes the quantitative aspect of the teaching, the history will certainly be able to be written by anticipation, with the report of the failure of more one proposal for the teaching of Chemistry.

Keeping in mind, the secondary teachers' current situation which are dealing with the teaching of Chemistry, we intend to describe in this work, alternative actions of the university already tested and the results achieved, in order to encourage the new and necessary actions. The performance in the secondary teaching is the enormous importance and the university needs an interaction to better elaborate and address new educational proposals.

It is already a common sense that there are certain lacks in the teacher formation in the area of Chemistry, that represent serious problems reflected in the atmosphere scholar in a very negative way. The teachers' isolation in the class rooms, the distancing from scientific atmosphere, the lack of interaction with other professionals from the same area and the lack of conceptual updating are very harmful aspects. These aspects were detected among 78 secondary teachers, during the I SIMPEQ (I Symposium of Professionals Chemistry Teaching), realized at the Chemistry Institute of UNICAMP, in November 2001. As well, among 70 teachers, from 16 cities of S. Paulo State, which have participated in the Pró-Ciências Projects of Chemistry Department of UFSCar, from March to November of 2000 and March to September of 2001.

Each professional of the Teaching of Chemistry knows about the difficulties of your own career, but not always they are able find forms of overcoming them. Certainly, the contact with other professionals can favor the productive exchange of experiences, to bring new perspectives for the work. The SIMPEQ was an event specially promoted to professionals that are acting in the teaching of Chemistry [1]. This event had the participation of members of UNICAMP (9 faculty members and 6 students from the Chemistry Institute and 1 faculty member from the Education Faculty) and supported by the Municipal Teaching Administration of Campinas – SP, seeking to create a new channel for community's interaction with the university. The program consisted in lectures since basic conceptual aspects of Chemistry, experimental activities and debates in order to integrate the Chemistry Institute of UNICAMP with the other professionals of the Chemistry teaching. The registrations were free, and the activities were programmed during one weekend, at first, for limitations of physical space, reserved for 80 teachers only from the secondary public system. In the total of participants 30% of teachers were from private secondary schools, with representatives from 12 cities of the state of S. Paulo. The number of participants from another cities was much larger than the expected. It was surprising, concerning the interest manifested by the secondary teachers' interest, but it also indicated the lack of this kind of activity in the state. The activities for the event intended to contemplate the participants' solicitations at I Regional Encounter for Teachers of Chemistry, Municipal Teaching Administration - Area of Campinas -oeste", accomplished in IQ-UNICAMP, in 25/03/2000, which involved mainly conceptual updating, experimental activities and a discussion among the participants.

This event has allowed verifying the urgent need for university intervention in the subjects such as Chemistry teaching in secondary school. It doesn't necessarily implicate in very complex actions. In certain cases, the action can be immediate, because it simply involves the teachers' reception in the academic atmosphere to use available public goods, as the libraries. This was noticed through participants' comments that also indicated that the university is very often seeing as an option for help to their needs, but it is usually considered as unattainable. The interaction between the faculty members and secondary teachers represents a perspective to furnish additional information necessary to overcome their main difficulties, mostly of conceptual order. Certainly, the desire for formal training programs, organized by university it is part of the expectations of the secondary teachers which have complained about the lack of official activities from the public teaching system of S. Paulo State, mostly to the area of Chemistry. It suits to mention here that a very significant portion of secondary Chemistry teachers doesn't have formation in the Chemistry area.

Another aspect of great relevance it was the difficulty, declared by the teachers, to implement the innovations of the educational politics. The teachers are be annoyed at the lack of dialogue during the elaboration of those politics and, mainly, for the absence of explanation and effective orientation to implement these proposals. Minimize these problems is an incipient task that dashes in the organizational structure of secondary public system which has the difficulties intensified by the higher rotation of Chemistry teachers in secondary public schools of S. Paulo.

The activities were realized during the weekend and the participation was voluntary. The participants were characterized by their intense interest in the event and they were stimulated to interact. This collaborated for the establishment of a very friendly and cordial atmosphere that certainly favored the integration of all involved them.

Teachers with deficient formation in Chemistry ended up detecting their own deficiency from the theoretical activities and they started to look out for solutions to overcome such problem, in an immediate association with a desirable partnership with the university. The experimental activities provided more insights about their difficulties, since the problem to apply the experimentation in the classes to the lack of infrastructure and limitations in the hour class. Again, when the teachers were engaged in a task, with intense elaboration of fundamental chemical concepts, they came across some formation their deficiencies. It reinforced the need of support from the university in the form of programs of continuous formation.

Other subjects, not specific of the area of Chemistry they appeared, during the event, pointing out problems as class disorder, violence, criminality, drugs and indifference to the school atmosphere. The secondary teachers' greatest concern, expresses a lot of times in relief tone, reflects the gravity of the situation that affects those professionals' vitality indicating the great need of programs that contemplates psychological support.

Another initiative developed with positive repercussion it is a result of the work. During last two years, of a group of teachers from Chemistry Department of UFSCar. This group has been investing in an effective interaction with the teachers from secondary schools, through courses of improvement in the Pró-Ciências Program /FAPESP.

During the planning of the methodology for these courses, the option it was to apply a constructive-collaborative model, where the teacher-student participates in the planning of activities and, starting from collective reflections and with teacher-researcher's orientation, it starts indeed to collaborate in the conduction of their own instruction. The activities were programmed with the objective of promoting the teacher-students' effective participation, not only as students attending to an improvement course or updating of contents, but also as agents of their own learning process. Actually, the content of this course was not "supplied" formally, but developed together, allowing that all (students, teachers and monitors) learned much more than just content. There was the intention to develop, from this program, an atmosphere that could propitiate the continuous contact with the participants, besides to motivate them to the continuation of the improvement work.

Several participants have been seeking a more effective interaction with the faculty members, through actions that goes since the presentation of collaboration projects with the secondary Chemistry teaching to possible orientations in graduate program.

The participants, parallel to their updating, developed didactic materials and teaching strategies for contents of difficult assimilation. All acquired material and produced (books, models, films, CD, etc.) constitute a collection and memory of the project to be used by the teachers in their classes.

In the Pró-Ciências–Phase I, was evident the need to share with the participants, a teaching concept sufficiently larger where the daily experiences could be incorporated. The activities had the objective to give subsidies to the group, in the survey of the difficulties in the secondary Chemistry teaching, with the perspective of to innovate and to minimize the problems of the Chemistry teaching. The discussions were accomplished involving PCNEMs, the difficulties to work with the relationship among areas of knowledge and other subjects of the professional exercise. Workshops were accomplished using techniques of conceptual maps and movable visualization [2]. In this way, the difficulties of the teaching and learning of Chemistry were mapped and the topics defined where the teacher-students present deficiencies and those considered of difficult learning for the students of the secondary school.

The government should encourage the Pró-Ciências Program, for instructor-teachers and teacher-students team, because it hardly has been offered improvement courses for teachers of the secondary school. It has been noticed the community's great interest in looking for new alternatives to improve its actions in classroom. As well as in the I SIMPEQ, even with the accomplishment of the activities during the weekends, the participants demonstrated great interest and incentive to participate.

The results of the 2000 course were presented in the Annual Meeting of the Brazilian Society of Chemistry [3] and the compilation of the developed material generated the production of a CD. The results of the 2001 course [4] were presented in six works in 21 EDEQ (Encounter of Debates on Chemistry Teaching) accomplished in October of 2001 at Rio Grande do Sul and, also, during FEALTEC (Fair of High Technology) accomplished in November of 2001 at S. Carlos.

## Conclusion

To furnish to the teachers' of Chemistry needs is essential to overcome the gap that commits the teaching and the learning. The proposals described in this work, represent modest actions but well succeed, that could be used to identify some problems of secondary teachers, allowing the elaboration of alternative actions that have contributed to the improvement of their basic formation. Certainly, the problems concerning the Chemistry teaching didn't vanished by the accomplished of these works, but it should stimulate the elaboration of new proposals with potential positive results.

The most outstanding problems that was identified, can be divided in two very different groups: those whose intervention of the State is made necessary and those in that the interaction between the university and secondary school can result in significant progresses.

In some subjects the action of the university is not enough to overcome the difficulties such problems of structural order (reduced number of classes, lack of institutional support for initiatives and professional improvement and attendance to students with healthy problems) and social problems (class disorder, indifference, violence, criminality and drugs).

On the other hand, the university can contribute acting in partnership with the secondary teachers, seeking to minimize:
1. Difficulties of conceptual order;
2. Difficulties to visualize the relationship among the main areas of knowledge, which is a consequence of fractional structure of the courses for teachers' formation;
3. Difficulties of associating theory to chemical phenomena, applications and new insights;
4. Difficulties in the application of the experimentation in the classes due to incomplete formation and insecurity

The intervention of the university is fundamental to overcome good part of those difficulties and, to provide to the teachers' solicitations, the implementation of programs for continuous formation should be valued and to become executed by the public university.

## References

(1) ROSSI, A. V. (2001) IN: I SIMPÓSIO DE PROFISSIONAIS DO ENSINO DE QUÍMICA, Campinas, SP, Brazil

(1) EDEN, C.; ACKERMANN, F. (1998) IN: MAKING STRATEGY – The Journey of Strategic Management. Sage Publications

(2) Bonfá-Rodrigues, R. M.; Massami, Y.; Gentleman, E. T.; Javaroni, R.C.; (2001) XXIV Reunião Anual da SBQ, Resumo ED-107, Wells of Caldas, MG, Brazil.

(3) Extracted data from final report of the Pró-Ciências Project FAPESP

**Keywords:** chemistry teaching, PCNEM, interaction University–Secondary Scholl, continuous education, educational proposals.

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# MEANINGS OF DEVELOPMENT, TECHNOLOGY AND ENVIRONMENT AMONG SCIENCE EDUCATORS

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**Abstract**

Science educators have a fundamental role in students' constructions of concepts and in their achievement of scientific views. Particularly, when the theme to be studied is related to the environment, where many issues have a high level of subjectivity, teacher's points of views can have a high status. In this paper, we are interested in exploring the meaning of development, technology and environment among high school science (physics, chemistry and biology) teachers. Thirty teachers were asked to write a text expressing their points of view about a fragment of a judicial process related to the environmental impact caused by the construction of the Três Irmãos hydroelectric power plant located in the State of São Paulo, Brazil. As the theme can generate controversial points of view, instead of analyzing the teachers' discourses (texts) by using previously constructed categories, we analyzed them by using a phenomenological approach. In this analysis, we were interested in recognizing "units of meaning" that could express the teacher's beliefs, values, concepts and general ideas about progress, development, technology, costs, environmental impact, application of laws, and environment preservation. The convergences found among several units of meaning allowed us to construct different categories that were found in some literature in environmental education. This enlarged the analysis of the teacher's discourses. The results obtained are considerably relevant because they disclose in-service teacher's ideas that are currently being integrated in science classes. Taking into account that science education should be committed to giving opportunities to the students to see and act in the world in a scientific perspective (in addition to others perspectives) the study of questions like "what is development?", "is technology always beneficial?", "can progress and environment preservation coexist?", and "is it possible to have sustainable development?" are potentially interesting as evidence of social values that are held by different segments of the society. In addition, in the analysis we tried to emphasize the role of environmental education in the emancipation of thinking and in the collective participation of citizens in different segments of decision making.

## Introduction

The theme "environment" became relevant throughout the world since the beginning of the seventies. It was at this time that the process of consolidation of the international capitalism and the limitations of the positivist paradigm in the natural sciences were not successfully responding to the new and complex problems that were emerging in societies (Medina, 1997).

There is a remarkable difference between the conservationist movement, started in the first half of the XX century, and the environmentalist movement just coming into view. It lies in the fact that the first, mainly because of ethical reasons, aimed at protecting the environment against the uncontrolled exploitation of natural resources, while the second, without disregarding that motivation, aimed at considering aspects of the natural environment from the point of view of humanitarian interests, including its collective perspective (Medina, 1997).

In 1972, the United Nations Conference for Human Environment, that took place in Stockholm, expressed its concerns related to the increasing exploitation of natural resources and the future of humankind. As a result of

[1] - Supported by FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo)

this Conference, the UN created an organization called UNPE – the United Nations Program for Environment that was located in Nairobi.

But, it was in Tbilisi, in 1977, that the Intergovernmental Conference on Environmental Education took place. This Conference became an important event for the International Program of Environmental Education. At this meeting, it was stated that Environmental Education is essential in global education. It should be directed to the solution of problems, and it should be concerned with the well being of the human community.

The decade of the 1980s was marked by deeper studies of environmental problems and by a worldwide economical crisis. During this decade there was established a global perspective of ecological phenomena, and also the relationships among the economy, ecology and development. This led to the necessity of adopting new indicators of social and economical well being. By means of a critical analysis of the concept of the National Gross Product, a new indicator was postulated, the Net Social Benefit, which takes into account the issue of quality of life (Medina, 1997).

In the nineties, the globalization process of the world economy was intensified. Local social differences became greater and social-environmental problems became even more visible. But, for many excluded countries, globalization represented a factory of perversities, where unemployment was chronic, and the poverty increases with time and the quality of life of the middle-class decreases. Recent diseases, like AIDS, have been spreading on a large scale. And other diseases that were considered eradicated are worrying and killing thousands of people. Despite the existence of high technology in the medical field and the fast rate by which information is transmitted, the child mortality is growing severely. Quality education is even more inaccessible and selfishness, cynicism, and corruption are growing everywhere (Santos, 2000).

It was also in the nineties that the United Nations Conference for Environment and Development took place, in Rio de Janeiro. The so-called Rio-92 was focused on global environmental problems and on issues related to the central idea of sustainable development. The Treatise of Environmental Education for Sustainable Societies, developed by the Forum of Non-Governmental Organizations (Ngos), committed the civil society to the construction of a fair and humanized model of development.

The Ngos Treatise defines "environmental education for sustainability" as a lifelong learning process that establishes values and actions that contribute to human transformation in the quality of life. It considers that these changes depend on the collective comprehension of the systemic nature of the crisis that threatens the future. It also considers knowledge of the causes in the "dominant civilization model" that are based on high productivity and on a high level of purchase for some, and on a low level of purchase and lack of conditions to produce for the large majority of people.

As a consequence of the Rio-92, a set of proposals for action were expressed in the Agenda 21. In order to follow the recommendations of that Agenda, Brazil created the National Program for Environmental Education. Also, the Ministry of Education created the National Curricular Parameters that include environmental education as a transversal theme. This means that it should be explored in all disciplines of formal education. However, this document did not question whether teachers would be prepared to implement its ideas.

This set of society and governmental actions demands the attention of educators so as to develop a comprehension of the relations between educational and environment issues. This seems to be a basic condition for the construction of a new environmental rationality. In this perspective, it is desirable that the relationships among the society, environment, scientific knowledge and technology contribute the development of socially fair relationships among countries, based on human rights, equality of access and opportunities, and in the utilization of indispensable elements to life; as Milton Santos (2000) would say, "another kind of globalization".

The preparation of future generations to act with responsibility in their social lives is one of the prominent objectives of the general education. However, it seems that it has to be taken more seriously in the case of environmental education.

In the last two decades, the literature in science teaching has demonstrated that science teacher's beliefs can strongly influence student's thinking (Anderson & Mitchener, 1994; Carvalho, 1991; Tobin et al., 1994; Hofer & Pintrich, 1997). As teachers are highly influential in this respect, it becomes evident that they are co-responsible for constructing a social future where the concept of sustainable development is present. In this sense, it is important to develop and understanding of what teachers know, or should know, about important issues of environmental education.

### The objective, justification and the subjects of the research

The main objective of this research is to unveil, analyze and discuss the meanings of the relationships among development, technology and environment expressed by thirty in-service high school science (physics, chemistry, biology) teachers.

The ideas the teachers develop about the relationships between development and environment, as well as the perspectives related to the future that they have, are relevant in the context of the formation of citizens and prospective leaders. Understanding the meanings that teachers attribute to development, technology and environment, and comprehending the social values that might be behind those ideas, and the naïve concepts and fragmented ideas, is an important and useful basis for preparing programs of in-service courses that improve the background of these teachers in this relevant area.

In science classes, at the high school level, it is normal to raise create situations in which teachers and students have discussions about technological devices, and their relationship to the environment and as well about ideas of development. What kind of relationships do science teachers believe exist among these concepts? What are the values manifested in these kinds of discussions? If the technological artifact is a hydroelectric power plant, what are the arguments used favorably or against it?

For our purposes thirty science teachers were invited to write a text that expresses their opinions about a judicial process related to the environmental impact caused by the construction of a hydroelectric power plant (Usina Hidroelétrica de Três Irmãos) located in the Tietê river. We expected that the teachers would focus their attention on aspects related to the role of energy in the development of a society. In this sense, we were interested in knowing the meaning of development that they had, and how this idea was related to others like technology and environment. We intentionally did not ask specific questions so as to avoid inducing unnatural answers. The responses were rich and hard-work discourses that can be analyzed using a qualitative methodology.

### The phenomenological approach

In this study we adopted a phenomenological approach to analyze the discourses of the teachers. In this approach, the researcher is interested in the meanings that somebody gives to something that she or he is experiencing or has experienced. In the present study, for example, we are interested in knowing the meanings by which teachers experience the ideas of development, progress, environment and technology in their everyday lives.

It is not always an easy task to detect the meanings in a written text. Generally, people do not express their ideas in a simple and linear way. Normally, the discourses hide essences or meanings that have to be inferred by the researcher. In the phenomenological approach, the researcher pursued these meanings by dividing the text (discourse) into small portions called units of meaning. A unit of meaning is an assertion about something; it is an attribution of meaning.

When the researcher is dealing with many discourses, the first step is to reveal the units of meaning contained in each individual discourse. This phase of the phenomenological approach is called ideographic. The ideographic analysis refers to the ideology that permeates the naïve descriptions presented by the persons. At the end, the ideographic analysis aims at producing intelligibility that encompasses an articulation of the units of meaning

(Martins & Bicudo, 1989). After doing the analysis of each discourse, the researcher can analyze the convergences and even extreme divergences among the units of meaning expressed by different individuals. The convergences or regularities that can be found among the units of meaning, in different discourses, constitute the nomothetic phase of the phenomenological analysis.

Divergence can also be considered in this kind of research. Sometimes, when people give opposite meanings to the same kinds of experience, it becomes interesting to know as much as possible about what is behind these meanings.

**Results: units of meaning related to the relationships among development, technology and environment**

Due to the restrictions of space in this paper, it is not possible to explore particularities of each individual discourse. Instead, the paper describes the categories that we found to encompass the units of meaning in the discourses, and gives the frequencies with which ideas are found in these categories.

The left column of table 1 presents the categories that were constructed from units of meaning. The right column represents the number of teachers that expressed ideas in that category.

**Table 1** – Categories of relations among development, technology and environment

| Categories | Frequency |
|---|---|
| There is no equity in the application of the law | 8 |
| Progress is opposed to the idea of environmental protection | 7 |
| Environmental management has served political and financial interests | 6 |
| Generation (transformation) of energy is necessary although it causes significant environmental impact | 6 |
| Human beings are a generic entity | 5 |
| Governments do not care about the consequences of progress | 5 |
| Environmental problems may be decreased | 4 |
| Educators can contribute to changes in student's behavior and attitudes. | 4 |
| A minority fight against the environmental impacts | 3 |
| There is a lack of information about environmental issues | 3 |
| Nature is an entity that takes revenge on human actions | 2 |
| Environmental preservation is a warranty to the future | 2 |
| Human intervention is potentially damaging to the environment | 1 |
| Society is indifferent to environmental issues. | 1 |
| The environmental situation is critical | 1 |
| Political activism led to sustainable development | 1 |
| Society promotes environmental protection by means of school education | 1 |
| Nowadays electrical energy is vital | 1 |
| Consciousness can be reached though environmental education | 1 |
| People do not feel themselves to be part of the environment | 1 |

### Analysis and discussion of the categories

**a) The relation human being/nature**

In this study, the discourses of the teachers, in a broad sense, we find that there are dichotomic ideas about the relation human being/nature. The human being is recognized as a generic entity with no historicity and without pertaining to a society. This kind of vision, frequently implicit in the discourses, is opposite to a critical posture in front of the inequalities and differences that coexist in societies that encompass different social classes and cultures. In the same way, when the individuals of this study refer to the term "man" or "woman", excluding the social dimension inherent to human existence, they disregard the perspective of collective engagement, especially in the environmental questions.

Environment is recognized by most of the teachers in this study as something external to society. Frequently, environment and nature appear in a given discourse as synonymous concepts, and the sense that what is natural is preserved prevails in this kind of discourse. This idea of nature is also associated with the idea that "nature is revengeful". This means that a natural catastrophe can be the result of the destructive actions of society. Besides this vision, there is the idea of the destructive potential of human intervention in the environment. This reaffirms the disconnection between individuals and the environment, the feeling of social disengagement, and do not consider the inexorability of this relation. Also, there is the recurrent idea of the environment as a guarantee of human survival in the future, which seems to relate the environment specifically with natural resources. This kind of anthropocentric vision reinforces the already referred dichotomy and obstructs the possibility of a systemic view of environmental relations.

In the efforts to overcome this dichotomy, it is worthy to take into account the effects that this world vision has on the concept of nature: "*nature is not considered a living entity anymore (as it still is for many cultures, so-called primitives) and becomes an assembly of resources (instruments for accomplishing some task). We ourselves became resources (even as human beings) because we are part of this vision of nature.*" (Brügger, 1998, p.63).

Brügger is not convinced of the pertinence of the technical vision of nature and of the instrumental rationalization inside environmental education, which should be, foremost, a political education directed toward the changing of values. For Brügger, in order to revert or lessen the effects of the rupture with that vision, a deeper analysis is needed for realizing how ethically and politically poor it is.

It is important to consider the possibility of going beyond the uniform thinking imposed by the hegemony of the instrumental rationality; to realize the social and historical conditions in which meanings about the environment have been constructed, and also the political relations that help determine them.

**b) The relationship between society and development**

Several discourses of the teachers presented the idea that a generic and abstract "man" is responsible for the growing environmental degradation, whereas society and its institutions fail in acting accordingly in this field.

The idea of society as a homogeneous mass is presented in some discourses. It disputes the idea of a society that includes opposite social forces of groups that defend interests of classes. However, politics is believed by some teachers to be an inferior social practice, a negative practice from the point of view of social values. This pejorative view of politics shows a restrictive perception of the internal and external dynamics of society, and keeps teachers out of the main debates of the organization of social life.

Concerning the nature of environmental problems, there are discourses that defend that the economical elite class, who exert domination through the force of profits that they obtain, is not committed to considering damages that it causes to the environment. This view is opposite to the view of an abstract man, not located historically in space and time, who is responsible for the negative actions toward the environment. But, although this position is a vision that sees different social responsibilities for environmental problems, it does not encourage progress in questioning other possibilities that cause environmental problems.

When dealing with societies, the discourses acquire different views that range from indifference on the part of the society to environmental problems up to its own condition of manager of an agenda of sustainable development.

In the first sense, some ideas arise: only a minority of people act against environmental impacts; indifference related to environmental issues is predominant in society; available environmental information is not enough and the responsible institutions rarely are fair in the application of environment protection laws. These perceptions emphasize a society that is inactive in the face of the paradoxes and challenges of current times, where scientific and technological progress coexist with a situation in which many people lack a basic quality in their living conditions. Besides this, the lack of available information stimulates us to question for whom information can be meaningful if the students are not being prepared to recognize and deal responsibly with them.

The decisions of the social institutions responsible for applying environmental laws are believed by many teachers to be contrary to a sense of justice. It is widely accepted among the teachers that the laws are not equally applied to everyone. They argue that the economically disadvantaged people are severely punished.

Society, as a source of positive attitudes towards environmental issues, is emphasized in the teachers' discourses. For some of them, the schools in society are the most prominent sponsors of environmental protection because that is the main role of education for citizenship. In the same sense, they hold the idea that political involvement brings on sustainable development.

**c) Progress and environment: visions of sustainable development**

A predominant idea in the discourses is that progress and environmental protection are contradictory facts. Though, all the teachers recognize the importance of technological devices for maintaining the ways of life in most of the societies. The contradiction between progress and environment expressed in the discourses keeps hidden discussion concerning the origin and causes of environmental problems. They do not consider the possibility that, for a long time, we have been experiencing a type of development that promotes certain market values that are detrimental to social and environmental values.

The idea of mitigating the environmental damages gives rise to the conflict between benefits generated by the economical and technological development and the environmental costs paid. An expected question arises: What, and for whom, will these benefits serve?

For another side, there are discourses that state that environmental issues are not considered by governments, and that on occasion these issues have served to satisfy political and financial interests of the dominating groups. But, in our view those teachers could go ahead and ask why governments and dominant groups present these behaviors? Then, if sustainable development were taken, even by means of great social pressure, as a model by the governments, we would still have to ask ourselves if it would not be taken as another instrument for the survival of the capitalist model of development. It is not the objective of this paper to propose answers to those questions. Nevertheless, in our view it is necessary to discuss with science teachers their beliefs about development and to show the necessity of discussing ideas that at first sight seem to be ideal and question there real intentions. In the case of sustainable development, it is interesting to note that this concept is not conclusive, and that many different ideas are associated with it.

Many of the teachers' discourses contain the idea that environmental degradation threatens everyone in the same way, the idea that the growing level of consumption is a consequence of societies needs, and the idea that technology is crucial for contemporary life and that it is at the same level even for different social groups.

The political participation of popular segments in the levels of decision, sustained in the discourses, is something that already has official support. Agenda 21 deals widely with the importance of Ngos in actions to promote more social participation. That Ngos can indicate directions for many social propositions, including educative. In this sense, they can prepare the society to view itself as influential in the decision making related to development issues.

Taking into account the discourses of the teachers, it can be observed that efforts should be made in the area of teacher education in order to improve the acquaintance of teachers with the concepts of sustainability and sustainable development. As Leroy and Acseral (2000) say: *"The notions of sustainability and sustainable development can not be defined in an abstract level. They are social constructions that will be accomplished by means of confronts of social interests that will end up privileging one or another conception depending on the relative force of each side".*

Sustainability has to do with the possibility of altering social practices involving the emphatic exercise of citizenship, social justice, and equality between gender and in the political participation of the social actors. However, a sustainability subordinated to capitalist values will not promote the necessary social an environmental changes because it is originated in a view that has the intention to extend the life of the market.

For their side, science and the technological devices cannot be considered neutral, and they have to be situated inside a historical, cultural and social context. Thus, the solution to environmental problems cannot be thought about without considering the political forces that are behind the technological choices (Rattner, 2000).

One of the premises of the concept of sustainable development is the interaction between popular and scientific knowledge (Leroy and Acseral, 2000). This premise opposes itself to the reductionist idea of a privileged knowledge, and reinforce that the environmental debate must take into consideration the plurality of voices and knowledge. This means that the traditional voice of the market economy must give space to the voices of justice, education, health, poverty eradication etc.

**d) Environmental education and the ideal of sustainability**

The discourses of science teachers indicated that environmental education is an important aspect in the debate about technology and development. In theory, environmental education is assumed to be an instrument of consciousness that can promote changes in the behavior and attitudes among students. In a methodological perspective, a disciplinary view emerges in the teachers' discourses as a possibility of having an effective environmental education.

Angotti and Auth (2001) argue that the complexity of environmental issues is much higher than is the comprehension that the majority of science teachers have about it. Thus, schools and teachers, throughout the natural and social sciences, have the challenge emphasizing and explaining the basic issues of the environmental dimension.

Considering the difficulties on defending the idea of a really sustainable development, some authors adopt the notion of "sustainable societies" as a possibility of criticizing the economical primacy present in the concept of development.

For Tristão (2001), the utopia of sustainable development is a paradox since it tries to conciliate arguments from economy with social and political diversity, with those of nature. The equilibrium between environment, and the survival of natural and cultural sources, is something that seems to transcend a model of development, but certainly it has to be based on the articulation of the human dimension.

In environmental education, two visions of sustainability (sustainable development and sustainable society) are influential in the customary pedagogical practices. The discourses analyzed in this study show a tendency of an education oriented to consciousness and changes of behavior, which is in agreement with the first vision.

Crespo (1998) suggests that the idea of sustainable development is based on what is called "*pragmatic environmentalism*", which gathers together trends in the techno-scientific and political ecology. It differs from the idea of the sustainable society that is adopted by "*ideological environmentalism*", "*deepen ecologism*" or "*ethical ecologism*", which believe in changes on peoples sensibilities and in a new subjectivity as a means of avoiding higher environmental catastrophes. According to this author, in pedagogical terms, the first tendency tends to emphasize behavioral instruments by establishing a direct relationship between information and changes in behavior. It can be taken as an "education for results" that is addressed to the citizenship and for the solutions of problems, mainly the local ones.

Brügger (1998) is critical about an emphasis on actions and behavioral changes, and sustains that it fails to consider the motivation that is behind the actions and attitudes changes. This author also considers that changes based on pragmatic reasons are reversible, since they are related to circumstantial contexts.

In the second tendency (ethical ecologism), desirable consciousness is a process that demands the construction of a new sensibility, by inquiring the own values of occidental civilization and of scientific rationalism. In the educational processes based on this tendency, the intuitive reasons and the imaginary are valorized, and ethical-philosophical discourse has the same status as scientific discourse (Crespo, 1998).

In the perspective of sustainable development, that is predicted in the Agenda 21, both of the mentioned tendencies are synthesized in propositions of an education oriented to sustainability. In Chapter 36 of Section IV, the education for sustainable development encompasses two basic and complementary processes. The first one is related to consciousness and emphasizes the comprehension of the relation between society and natural world, between environment and development, and between the local and global levels. The second, is related to behaviors and emphasizes the development of less destructive attitudes and of techno-scientific capacities that are oriented to sustainability (Crespo, 1998).

## Conclusions

Overall, this study shows how big the challenge is that we have at hand. All groups, including science educators, educators of prospective teachers and educators of in-service teachers, and schoolteachers have to face the complexity of issues related to environment.

The distance between the points of views expressed in the "units of meaning" in the teachers' discourses, and the specific literature in the area, shows that it is necessary to expand and explore accurately environmental issues at the basic school level. The diversity of types of categories found in this study, as well as the finding that concepts of sustainable development and sustainable societies are only vaguely present in science teachers perspectives, indicates the seriousness of the problems that we will have to face in environmental education.

## References

ANDERSON, R. D. & MITCHENER, C.P. (1994) Research on science teacher education. In GABEL, D. (Ed) *Handbook of Research on Science Teaching and Learning*, (New York, Macmillan).

ANGOTTI, J. A. P. & AUTH, M. A., (2001). Ciência e Tecnologia: implicações sociais e o papel da educação. Ciência e Educação, 7 (1): 15-28.

BRÜGGER, P., (1998). Visões estreitas na educação ambiental. *Ciência Hoje*, 24 (141): 62-65.

CARVALHO, W. L. P (1991) The Science Teaching under the perspective of creativity: a phenomenological approach, Unpublished *Ph.D. thesis*, Unicamp, Brazil.

CRESPO, S., (1998). Educar para a sustentabilidade: a educação ambiental no programa da Agenda 21. In: NOAL, F. O. et al. (orgs.). Tendências da Educação Ambiental brasileira. Santa Cruz do Sul: EDUSC.

HOFER, B. K. & PINTRICH, P. R. (1997) The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research*, 67, 1, pp. 88-140.

LEROY, J.- P. & ACSELRAD, H. (2000). *Novas premissas para a construção de um Brasil sustentável.* In: RATTNER, H. Brasil no limiar do século XXI: alternativas para a construção de uma sociedade sustentável. São

Paulo: Editora da Universidade de São Paulo, 183-210.

MARTINS, J. & BICUDO, M. A. V., (1989). *A pesquisa qualitativa em psicologia: fundamentos e recursos básicos.* São Paulo: Editora Moraes/EDUC.

MEDINA, N. M., (1997). *Breve histórico da educação ambiental.* In: PÁDUA, S. M. & TABANEZ, M. F. (orgs.). Educação Ambiental: caminhos trilhados no Brasil. Brasília: FNMA/IPE, 257-270.

RATTNER, H., (2000). *Política de Ciência e Tecnologia no limiar do século.* In: Brasil no limiar do século XXI: alternativas para a construção de uma sociedade sustentável. São Paulo: Editora da Universidade de São Paulo, 353-363.

SANTOS, M., (2000). *Por uma outra globalização: do pensamento único à consciência universal.* Rio de Janeiro: Record.

TOBIN, K. et al. (1994) Research on instructional strategies for teaching science, in: GABEL, D. (Ed) *Handbook of Research on Science Teaching and Learning,* (New York, Macmillan).

TRISTÃO, M., (2001). Rede de Relações: os sentidos da Educação Ambiental na formação de professores. Tese de doutorado.Brasil: USP.

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# HUMANISTIC SCIENCE EDUCATION FROM PAULO FREIRE'S 'EDUCATION AS THE PRACTICE OF FREEDOM' PERSPECTIVE

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**Abstract**

The purpose of this article is to outline one perspective for humanistic science education taking into account the contributions of Paulo Freire. From the educational principles on literacy expressed in Paulo Freire's writings and from the conceptions of scientific and technology literacy (STL) movement, arguments will be advanced for characterising a perspective on humanistic science education. The Humanistic Science Education is a slogan that tries to contribute to changing the context of the modern society through educational processes. The modern scientific and technological society is shaped by an ideological technology-system that imposes human exploitation and threatens life in a global scale. The way people select and use technological and scientific resources and information may influence the destiny of society. In this sense, Science Education has a potential to contribute for the transformation of modern society through helping make visible the pitfalls of the system and make people aware of their role as citizen and consumer in this society.

Paulo Freire (1921-1997) is one of the most influential educational thinkers in the world. His classic text, 'Pedagogy of the Oppressed', (1972) has been studied by intellectuals of different areas in many countries over the last three decades. His educational thought is based on human and ethical principles. This article explores the main features of Freire's proposal aiming at constructing an overview of what could be a humanistic science education perspective.

Studies on scientific literacy are another important source for advancing a humanistic science education perspective. Scientific literacy has been studied from different points of view and there is no consensus about its meaning (Laugksch, 2000). These different perspectives on scientific literacy will be compared with Freire's view and taken into account in advancing the principles for a humanistic science education perspective. Conceptions on education for freedom are discussed in the last section and principles and implications for a humanistic science education in schools are examined in the conclusion. As in Freire's thought, the humanistic science education proposal outlined here aims at making the students aware of their role on transforming modern society.

## The context of modern scientific and technological society

The interactions between culture and technology have produced technological changes that engender a domination of social life by technical apparatus. There is an alignment between the internal cultural values of technology and the values of the wider society. The everyday experience of people is inevitably influenced by technological change. The technological systems have the power to shape wider cultural expressions and constructions of meaning. The introduction of new technologies implies the development of new productive practices that transform the rhythms of life, the patterns of traditional social relations of production and traditional sources of collective solidarity and obligation. This results in the acceptance of new cultural assumptions by the society.

The process of penetration of technology into society is also characterised by scientific rationality and by ideological technology-systems domination. According to Marcuse (1964), the industrial society is organised by scientific rationality for increasing the domination of the natural resources. 'The scientific method which led to the ever-more-effective domination of nature thus came to provide the pure concepts as well as the instrumentalities for the ever-more-effective domination of man by man through the domination of nature' (*ibid.*, p. 158).

The rationality of the technological systems has become a political rationality that has in turn determined the human need to improve the productivity and growth of the economic system. It determines the socially needed occupations, skills and attitudes, as well as individual needs and aspirations. Human needs have changed because of the needs created by technology systems.

While technology has improved the quality of life, it has also created threats to human life. The history of the twentieth century is full of disasters that are consequences of the use of new products and technologies, such as the gas leak in Bhopal and in Nantes; the radioactivity leaking in Three Mile Island and Chernobyl; and the birth of children with genetic problems because their mothers used thalidomide. Serious environmental problems were caused by the use of DDT and CFC gases and by the emission of carbon dioxide. In addition, many scientific and ethical questions have been raised in society such as the use of nuclear energy or the new methods in genetic engineering.

The economic and cultural globalisation is another characteristic of contemporary society. The advances in information and telecommunication technologies helped to convert the world in a global village. It became impossible for communities to survive completely isolated from the rest of the world. An economic crisis in a country can affect the entire world. Local conflicts between nations or different ethic groups are seldom resolved locally; and have resulted in interference from other countries. The environmental consequences of the use of new technologies have global implications.

In conclusion, the scientific and technological society is deeply marked by the domination of technological systems in a global scale which improve the quality of life for citizens included in the system but, at the same time, result in risks for life and in the exclusion of billions of people around the world. This context was created by our own society, which by itself selects the manner of its scientific and technological development. As Irwin (1995) suggests, the risks of technology do not imply an inevitable or immutable direction of the destiny of science and technology. In this sense, the future will depend on the ability of the society to construct its trajectory. Here, science education may contribute by assisting citizens to select a better way of using technology in their future.

**Freire's humanistic educational proposal and the transformation of the society**

Education is always a human process; therefore, it is anchored in the transmission, reproduction and creation of values. According to Freire (1974),

> to be human is to engage in relationships with others and with the world. It is to experience that world as an objective reality, independent of oneself, capable of being known. Animals, submerged within reality, cannot relate to it; they are creatures of mere *contacts*. But man's separateness from and openness to the world distinguishes him as a being of *relationships*. Men, unlike animals, are not only *in* the world but *with* the world. (p. 3)

Consequently, education must consider the world in which the men and women exist. Freire (1972, 1974) proposed a revolutionary education for Brazilians according to the context of their society at that time. He supported the idea that education in the Brazilian society, which was characterised by oppression, needed to help people enter the historical process, critically. To accomplish this basic task, it was necessary to have a form of education that enabled people to reflect by themselves on their responsibility and on their role in the new cultural climate (Freire, 1974).

His educational proposal is essentially a humanist pedagogy concerned with the real context of human conditions. Brazilian society at that time had all the characteristics of a 'closed society' in a cultural context of alienation. For this society, it was necessary to create an educational process as a practice of freedom that was supported by a pedagogy of the oppressed. This pedagogy aimed at changing the context of alienation and of oppression.

The basic principle of this pedagogy is the dialogue. Freire (1972) says that is impossible to educate for critical consciousness without the dialectic process that involves dialogue among the persons. It is through dialogue that man and woman are humanised. Word is not a mere expression of thought; it is a transformable praxis, which acts on the world. 'It is in speaking their word that men transform the world by naming it, dialogue imposes itself as the way in which men achieve significance as men' (*ibid.*, p. 61).

According to his dialogic action theory, whereas in the domination process the subject conquers another person and transforms him into a 'thing', the dialogic process has a dialectic feature in that one does not annul another person. In the dialogic process, subjects meet in cooperation to transform the world.

Dialogue does not impose, does not manipulate, does not domesticate. It unveils a reality. Dialogic process in co-operation focuses its attention on the reality that, posed as a problem, challenges the persons. It is opposed to the education made by oppressors, which Freire (1972) called 'banking' education.

> Education thus becomes an act of depositing, in which the students are the depositories and the teacher is the depositor. Instead of communicating, the teacher issues communiqués and 'makes deposits' which the students patiently receive, memorize, and repeat. This is the 'banking' concept of education, in which the scope of action allowed to the students extends only as far as receiving, filing, and storing the deposits. They do, it is true, have the opportunity to become collectors or cataloguers of the things they store. (*ibid.*, p. 45-46)

Likewise, Freire proposes pedagogy for liberation supported by dialogic praxis that allowed the unveiling, by the oppressed, of their oppression situation. For Freire (1972), anybody educates anybody: men and women are educated by each other, mediated by the world.

Freire (1972, 1974) affirms that educating for literacy is more than a mere act of teaching to read and write. Education is a human activity that is inserted in human reality; therefore, its task is to transform the human world. Humanistic education goes beyond teaching contents without social meanings. It focuses on the human condition and in its transformation.

In the Freire's proposal for education for freedom, he had considered the context of oppression of the Brazilian society of his time. In a humanistic perspective for science education, we need to consider the context of the scientific and technological modern society. As it was characterised in the former section, human beings live today under the domination of technological systems, which impose cultural values and offer risk to their life. This is also a context of oppression. In this sense, the aim of humanistic science education is to transform the context of scientific and technological modern society.

The basic principle of humanistic education is to accept and believe in human existence and its capability to change its destiny toward the human values, in contrast with the current situation, in which these values are shaped by the technological systems. This is the target of humanistic science education. Which sense this target has been addressed by the curricula for scientific literacy?

### Scientific literacy for the scientific and technological society

The terms 'scientific and technological literacy' have been associated with studies in public understanding of science; science for all; and science, technology and society (STS) education.

Miller (1983) defines scientific literacy as consisting of three dimensions: (a) an understanding of the norms and methods of science (*the nature of science*); (b) an understanding of key scientific terms and concepts (*science content knowledge*); and (c) an awareness and understanding of the *impact of science and technology on society*.

Millar (1996) groups the arguments that have been used to justify the need of scientific literacy in our society in five categories: (a) the *economic* argument, which connects the level of public understanding of science with the nation's economic wealth; (b) the *utility* argument, which addresses the literacy for practically useful reasons; (c) the *democratic* argument, which helps the citizens to participate in discussions, debate and decision-making on scientific issues; (d) the *social* argument, which maintains a link between science and the wider culture, to promote a more sympathetic view of science and technology amongst the public; and (e) the *cultural* argument, which has the task of giving students scientific knowledge as a cultural product.

DeBoer (2000), discussing the meanings of education for scientific literacy through history, summarizes its proposals in nine statements: (1) teaching and learning about science as a cultural force in the modern world; (2) preparation for the world of work; (3) teaching and learning about science that has direct application to everyday life; (4) teaching students to be informed citizens; (5) learning about science as a particular way of examining the natural world; (6) understanding reports and discussions of science that appear in the popular media; (7) learning about science for its aesthetic appeal; (8) preparing citizens who are sympathetic to science; and (9) understanding the nature and importance of technology and the relationship between technology and science.

Solomon (2001) outlines the aims of scientific literacy in five items: 'the ability to read about and comprehend science; the ability to express an opinion about science; paying attention to contemporary science now and for the future; participation in democratic decision-making; [and] understanding how science, technology and society influence one another' (p. 95).

Science education curriculum for citizenship emphasises the need of preparing students for decision-making. It is a relevant educational target, in the development of critical thinking and in preparing future citizens for living in scientific and technological modern society, to prepare students to take part in the democratic decisions in society.

Fourez (1997) suggests that STL and STS movements may be viewed as revolts against a particular social configuration of scientific and technological practice. Often, in modern society, only experts are consulted by governmental bodies in making decisions on important social issues that affect entire communities. Normal citizens are regarded as having no expertise to participate in these decisions. In this context, science education can contribute to prepare the students not only to understand the opinion of the experts but also to request their right to participate in social decisions that affect their life. Likewise, the scientific and technological decisions related to social issues should be subjected to democratic control.

For Fourez (1997),

> People might thus be considered scientifically and technologically literate when their knowledge and skills give them a certain degree of autonomy (the ability to adjust their decisions to natural or social constraints), a certain ability to communicate (to select the appropriate mode of expression), and a certain degree of control and responsibility in dealing with specific (technical but also emotional, social, ethical and cultural) problems. On this view, STL is not only concerned with scientific and technical knowledge but also with participation in social life in a society bearing the stamp of technoscience. (p. 51)

Some approaches to scientific and technological literacy have also been called science education for social responsibility or responsible action (Santos and Mortimer, 2001). They stress the purpose of developing attitudes and values to engage students in social issues.

In short, studies point out that proposals emphasising education for citizenship, for decision-making and for responsible action, have the common aim of preparing students to take an active role in a scientific and technological society. Many of these proposals have emerged in the context of developed countries, in which most of the population has access to the benefits of the scientific and technological society. In developing and third world countries, the majority of the population is excluded of the benefits of technology. In these countries, to prepare students to take an active role in the technological society can have a different sense, as this can imply, first, to have access to the benefits of this society. The humanistic perspective – to take into account the context of society and human values not only to prepare students to live in it but also to transform it – can have different meanings in different context. Would be possible to have a unique proposal for humanistic science education in a global world?

## Humanistic science education for transformation of modern society

Aikenhead (2000) advises that educational proposals that help enculturate students in western science could privilege inadvertently and tacitly the dominant social, economic and political class in the society, creating implicitly an agenda of the status quo. Jenkins (2000) also points out that 'school science reflects an endeavour that is essentially positivist, heroic, apolitical and more concerned with scientists of the past than with those of the present' (p. 209). Thus, Jenkins (2000) stresses that school science need to be restructured.

> What seems clear is that something more radical than STS programmes or other attempts to "humanise" school science is needed if school science education is to respond adequately to the position that science has come to occupy in the modern world and all that flows from it. (*ibid.*, p. 220)

Irwin (1995) argues emphatically that sustainable development will not be possible without improving the citizen's knowledge. He supports the idea that the social and cultural dimensions of environmental problems are understood only when the citizens become aware of their practical action. In order to attain this awareness, the citizens have to ask fundamental questions about the values structure of their society. Irwin also argues that sustainable development is a challenge that depends as much on social issues as on technical or environmental ones. The way people organise their lives is, therefore, fundamental for this challenge.

Although fundamental, knowledge is not enough. Individuals also need to change their attitudes and values to face the power of the technological systems. This implies political actions and practices in every life directed to construct the new society from human values.

In democratic societies, an effective response to social and environmental problems requires that a critical mass of citizens be politically involved. Science education may contribute to prepare this critical mass of citizens. The STL and STS movements may be regarded as attempts to attain this purpose, when they use democratic arguments and when they stress the aim of decision-making in responsible action. However, to face this challenge, it is necessary to reinforce these proposals with reflection on the particular social configuration of scientific and technological practice and on the context of modern scientific and technological society.

The democratic arguments refer to participation of the citizens in discussions, debate and decision-making on scientific issues. Nevertheless, in which perspective does it intend to carry this debate? Which values are being privileged in the process of making decision about socio-scientific issues? Are the values imposed by technological systems or are they sustainable development values? Whose interests do they serve? Those of the individual or of corporations? If these questions are not considered within the development of the curriculum, instead of contributing to humanising school science, they may in contrast reinforce the status quo.

Some proposals that intend to involve decision-making only prescribe norms and actions that have to be followed in the process of selecting the technological equipment to be used by citizens, without discussing values within the technoscience. These curricula do not reflect on the human values, but prepare students to use the technological apparatus, as if the mere use would improve the life quality. Here, instead of contributing for sustainable knowledge, they transmit a message to spread the consumption of technology, independently of its consequences.

In other words, STS and STL movements have aims that in a first analysis are closed with a humanistic perspective; however, many of these curricula might not contribute to reflect on human values. When it uses the *democratic* argument, this sometimes might be understood as to prepare students to accept the policy of domination of the technology values over the human values. The *utility* argument, might to be faced as to training students to use new equipment, without reflecting upon its consequences. Therefore, we need to explicit for what society we aim to prepare the students: To a society that gives priority to economic values or to a society that give priority to human values?

In short, humanistic science education involves the democratic arguments, but it is necessary to refer explicitly to the project of society we have in mind. For this reason, we support the idea that is important to add another justification for scientific and technological literacy in the list of arguments of Millar (Millar, 1996): the *humanistic* argument. This argument brings to discussion to the need of transforming scientific and technological modern society through human values, preparing the students for a society in which sustainable knowledge and responsible action are the norms. This is not a movement anti-technology, but a movement against a particular model of economic development and technological practice.

Who will decide on what would be a society organised by human values? What are the human values? Who will select them? There is no consensus about these questions; however, if we think in humanistic education the answer is: the human beings will decide about these. In this sense, the challenge of humanistic education is not to give the answer, but to prepare students to reflect and select their own destiny. As Freire (1994) says, education is directive and political in itself, but the educators have to be ethical and although never refusing to express their own dreams and values to the students, they must respect them, showing them their position, but at the same time pointing out that there are other positions that the students can follow, allowing them to select for themselves their own choice..

For the humanistic science education to be implemented in schools, it is very important that science education includes socio-scientific issues (Aikenhead, 1994). In this case, the teacher needs to discuss human values and social implications when introducing socio-scientific issues (Santos and Schnetzler, 1997). Nevertheless, these discussions should not be used only to illustrate the immediate consequences of some technological apparatus such as benefits and damages of the use the mobile telephone, or of the consumption of food genetically altered (Santos and Mortimer, 2000). These discussions have to include, for instance, the understanding of environmental risks; the power of domination that the technological system impinges in culture; the difference between human needs and markets needs; and the developing of attitudes and values consistent with a sustainable development.

At the same time that discusses how a mobile telephone works the teachers might include many other social relevant aspects. For instance, they can debate risks on the use of mobile telephones; less dangerous ways to use it; the need to dispose properly their batteries; the responsibility of telephone companies, of the scientists and of the government toward this issue; and the possible actions of the citizens in society to regulate the use of this technological apparatus. Consequently, further understanding of related scientific concepts, activities such as projects in action and debates on values and environmental, social, political and ethical issues are essentials in humanistic science education.

The emphasis in human values does not mean that science education should only involve social and political discussions. These discussions have to be interwoven with the study of scientific concepts. If we want to transform the scientific and technological society, the first requirement is to provide students with background in science (Miller, 1983).

If the humanistic approaching implies to enlarge the content, including values and reflections on modern society curricula should not be overloaded with scientific concepts. As many of these concepts are not relevant for preparing the students to take part in discussions in the society, the number of concepts should be reduced, because the school timetable does not afford the inclusion of humanistic issues together with so many scientific concepts. Therefore, it is not enough to discuss human values without understanding the related scientific processes; equally, it is not enough to understand these processes without discussing human values.

## Conclusions and implications

We believe that scientific literacy needs to consider aspects related to the conditions of modern society. School science education can have an important role in transforming the dominant values of the technological society into human values.

This is a political agenda, but as Freire always repeated, education cannot be neutral; learning never takes place in a vacuum (1972, 1994). In fact, those that believe that the teacher has to be 'apolitical' are unintentionally and naively supporting the dominant ideology imposed by the technological systems. They reinforce it when they do not discuss it with their students.

The inclusion of socio-scientific issues in the curriculum is a fundamental condition for humanistic scientific education if it wishes to prepare citizens with a critical consciousness of the modern society. Of course, this knowledge has to be interwoven with scientific concepts and with knowledge about epistemology and sociology of science, as this is an inherent condition of scientific literacy.

There is a tension when the function of school science education is considered, between the needs of future specialists and the needs of young people in the workplace and as informed citizens. Those who stress high-level conceptual science education generally do not pay attention to the aspects related to preparation for citizenship. In contrast, those who stress the preparation of future citizens tend to give less importance to the background in scientific concepts than the first. However, the challenge is not to select between two options, but to seek a balanced curriculum that will give the basic conceptual background that is necessary for future specialists without neglecting the introduction of humanistic values. If we do not change this situation, we will not contribute to changing the destiny of the society because uncritical education in high-level science education can prepare uncritical scientists and technologists that will continue to exploit nature and to help building technological systems without taking into account human values.

Another implication is the need of changing the teaching process in the classroom. Humanistic science education has to be carried out by a dialogic process. In this approach, students need to take part directly in the discussions on socio-scientific issues, so they can interact with the world, discuss their life conditions and become committed to social change. The educator in humanistic science education, therefore, needs to promote discussion, involve the students in the debate and explore the values arising from these discussions.

However, the role of the teacher is not to reveal the reality to their students, but to help them to discover the reality for themselves. Likewise, their role is not to impose their values or to give their solutions to socio-scientific issues, but to help the student to understand the different values and alternatives available and to select their own alternatives (Freire, 1994, Santos and Schnetzler, 1997).

These implications for teachers represent dilemmas and challenges for science education. However, the recognition of these dilemmas does not represent an insuperable barrier to change science education, but a challenge that needs to be pursued. Ratcliffe (2001) points out that the future of STS depends on the integration between science teachers and the curriculum. However she says: 'It is the teacher rather than the content that characterises STS education' (*ibid.*, p. 83).

We believe that humanistic science education is a slogan and a challenge in the educational context and that in the modern society all human beings, rich or poor, are oppressed by the paradigm of modernity that enslaves and threatens them. Although the transformation of the modern society is a political project that has to be assumed by different groups in different contexts, science education can have its own contribution to it.

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## References

AIKENHEAD, G. S. (1994) What is STS science teaching? In SOLOMON, J. and AIKENHEAD, G. (eds) *STS education: international perspectives on reform* (New York: Teachers College Press), 47-59.

______. (2000) Renegotiating the culture of school science. In Millar, R., Leach, J., and Osborne, J. (eds) *Improving Science Education: The Contribution of Research* (Buckingham and Philadelphia: Open University Press), 245-264.

DeBOER, G. E. (2000) Scientific literacy: another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching*, 37(6), 582-601.

FOUREZ, G. (1997) Science teaching and the STL movement: a socio-historical view. In JENKINS, E. (ed.) *Innovations in science and technology education*, vol. VI (Paris: Unesco publishing), 43-57.

FREIRE, P. (1972) *Pedagogy of the oppressed* (Harmondsworth: Penguin Books Ltd).

______. (1974) *Education for critical consciousness* (London: Sheed and Ward).

______. (1994) *Pedagogy of hope: reliving pedagogy of the oppressed* (New York: The continuum Publishing Company).

IRWIN, A. (1995) *Citizen science: a study of people, expertise and sustainable development* (London and New York: Routledge).

JENKINS, E. (2000) 'Science for All': Time for a Paradigm Shift? In Millar, R., Leach, J., and Osborne, J. (eds) *Improving Science Education: The Contribution of Research*. (Buckingham and Philadelphia: Open University Press), 207-226.

LAUGKSCH, R. C. (2000) Scientific literacy: a conceptual overview. *Science Education*, 84(1), 71-94.

MARCUSE, H. (1964) *One dimensional man: studies in the ideology of advanced industrial society* (London: Routledge & K. Paul).

MILLAR, R. (1996) Towards a science curriculum for public understanding. *School Science Review*, 77(280), 7-18.

MILLER, J. D. (1983) Scientific literacy: a conceptual and empirical review. *Daedalus: Journal of the American Academy of Arts and Sciences*, 112(2), 29-48.

RATCLIFFE, M. (2001) Science, technology and society in school science education. *School Science Review*, 82(300), 83-92.

SANTOS, W. L. P. dos and MORTIMER, E. F. (2000) Uma análise de pressupostos teóricos da abordagem CTS no contexto da educação brasileira. (An analyse of theoretical presuppositions of the STS approaching in the Brazilian educational context) *Ensaio – pesquisa em educação em ciências*, 2(2), 133-162.

______. (2001) Tomada de decisão para ação social responsável no ensino de ciências. (Decision-making for responsible action in science education) *Revista Ciência & Educação*, 7(1), 95-111.

SANTOS, W. L. P. dos and SCHNETZLER, R. P. (1997) *Educação em química: compromisso com a cidadania* (Education in chemistry: commitment with citizenship) (Ijuí: Editora da Unijuí).

SOLOMON, J. (2001) Teaching for scientific literacy: what could it mean? *School Science Review*, 82(300), 93-96.

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# THE KNOWLEDGE OF TEACHERS, MOTHERS AND STUTTERING SUBJECTS ON THE STUTTER: PEDAGOGICAL AND EDUCATIONAL IMPLICATIONS

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**Abstract**

In this study, in light of scientific, psychological, epistemological and social assumptions, we have characterized mothers' and adult-stuttering subjects' conceptions and compared them with those of schoolteachers (both student teachers and teachers) who we identified in a previous study. The results show that both the subjects and teachers conceive stuttering as being due either to psychological or biological reasons, and that the nature of their conceptions is alternative and common sense. The conceptual dissonances identified in this study show the deficiency of the educational system in preparing these subjects to cope with the problem. In this sense, the need for differentiated, qualification strategies are pointed out, based on a new logic of scientific education, mainly of teachers, centered on methodologies of trans-disciplinary teaching, by taking into account the relationships among science, technology and society. **Key words:** concepts of stuttering; qualification of primary school teachers; science education.

## 1. The social context and its challenges: construction of new teaching skills aimed at dealing with complex human realities.

Society is more and more complex due to several factors, including scientific and technological advancement itself – a process pertinent to culture and to social interaction, which may hinder both individual and collective human development.

Facing this reality imposes the symbolic job of 'giving meaning to' the part of reality that we understand, science education[1] in light of a New Philosophy of Science, which recognizes the importance of teaching for this process (Abimbola, 1983; Hodson, 1988; Cachapuz et al., 2000).

The need for scientific education for understanding human realities and one's own presence in the modern world is based on the collapse of classic science, and on the conquests of natural science, mainly the physical ones.

According to Morin (2000), classic science, based on a path of absolute certainties that is either atomistic, epistemological, elementary, logical or not, no longer explains complex human realities, as revealed in his statement: the order that lacerates and changes itself, the omnipresence of the discorder, the appearance of the organization, the incompletude of the logic, turned out to be an instrument and no longer sovereign of the thought, all that not only brings about huge breaches in the system of classic intelligibility, not only moves the four pillars of that intelligibility, but raises a crisis of foundations (Morin, 2000, p. 132).

Paradigm shifts in the field of Psychology of Learning, accelerated by a crisis of foundations of a positivist nature, open doors for investigations into another perspective, a cognitive one, and through this perspective, analyses of relationships of psycho-physiological (Piaget, 1971b), interpersonal, psycho-pedagogical (Ausubel, 1963), linguistic and social-cultural nature (Vygostsky, 1991; Vygostsky et al.,1991) gain emphasis.

[1] Scientific education: term used to represent significant learning processes through comprehension (of transformation, of conceptions and human practices, of the ways of learning science). In this case, the self-motivating/organizing factor is the political/social context and the restructuring factor/element is the citizen's qualification/scientific education.

Investigations in this epistemological direction, centered on features of human relationships and assumptions of a psychological, epistemological and sociological nature, reveal the influence of human behavior on the learning process and on human knowledge construction. They corroborate the idea of taking the sociological nature of learning into account, mainly in relation to the school learning process (Hurd, 1998, p.412-413). Moreover, they corroborate the idea of having to organize the teaching context by means of organized principles of a cognitive and social-cultural nature.

The challenge of organizing teaching contexts in this direction depends on the teaching and learning conception being a recurrent process of a socio-cultural nature, a task not so easy to cope with at a time of epistemological 'disorder', great diversity of teachers' and students' epistemological ideas concerning the nature of sciences (Harres, 1997), and teaching practices on a *scientific* perspective, based on the teacher's epistemological absolutism (Becker, 1993; Praia e Cachapuz, 1994; Haswheh, 1996).

Cachapuz et al (2000, p. 71), when analyzing the problem of scientific education in contemporary society, and its contributions to human development, also draw attention to ethical questions. They emphasize the need for a different epistemological approach for teaching sciences, the need to abandon an internal (psychological) perspective of investigations into this field, and its progress towards more integrating theoretical guidelines that develop human beings (epistemological, psychological, sociological and ethical). They take into account that these guidelines are necessary for the solution of problems of different natures, but mainly those of an ethical-social nature, a requirement for guiding values and actions that are more conscientious of the ontological and epistemological nature of science and technology.

De Posada (1996, p.307), in search of an integrating theory for the learning process in sciences, refers to the inherent nature of the teaching-learning context, and significant learning through comprehension. He attributes the difficulty of integrating scientific meanings into the student's experimental and episodic memory to alternative, non-scientific ideas, and their origins. Nevertheless, he defends the need for a theory that makes it possible for scientific thought to become more meaningful to the student, since scientific logic results from assumptions and implemented methods in different, specific contexts of daily life.

This researcher's studies have been corroborated by investigations based on benchmarks for analysis of explanatory episodes in the science classroom, drawn from theoretical contributions from various fields of knowledge (Scientific Education, Linguistics, Cognitive Science) and empirical investigations involving observations of science classes, in the conviction that learning science is learning to see the world in other ways, some totally intuitive (Martins et al. 1999, p. 30). In other words, the result is: part of the difficulty in the explanation of scientific concepts results from the fact that learning sciences involves not only enlarging the perception horizons and acquiring new knowledge and information, but mainly, to start conceiving the physical world in a different way and to glimpse other relationship dimensions between man and nature.

In the field of specific learning, an experimental science, Hashweh's (1996, p.232) studies reveal that learning is more than just gathering information; the subjects' interactions in similar contexts or even in identical ones may evoke the use of different 'cognitive structures' as well as of similar ones, since the selection of the physical aspects is dependent on the subjects' internal factors that "mobilize" the structure of concepts reorganized at the moment of the interaction, in other words, for the same context, different representations may be charted for different features and relationships. Many of the links of the students' pre-conceptions may be successively charted for some aspects and relationships in the context with which they are familiar.

In addition to these affirmations, which point to the influence of teaching contexts in learning science, in the last few years, there have been countless studies that show the influence of alternative conceptions, that are characteristic of the common-sense evolution process in the development of scientific knowledge.

These conceptions are hard to transform and may remain throughout the education process, thus hindering both science learning and understanding of complex human realities, such as the teaching and learning process of children with dysfluency problems.

Learned individuals' maintenance of alternative conceptions related to complex problems such as stuttering show the weakness of the educational system in qualifying teaching professionals and of the population in general in common-sense transformation, which hinders the progress of science.

Thus, one of the responsible factors may be traditional science epistemology and its teaching, which because they are centered on a positivist view of production and socialization of scientific knowledge, when hindering an understanding of the world and its processes, also hinder the advancement of science itself and its best social application as well. In this sense, Edgar Morin (2000, p.247), by postulating the paradigm of complexity as being necessary for understanding and intervention in the world, puts forward the idea that desiring the transformation of epistemological directions implies projecting the school, science and its teaching on account of the social needs/difficulties, individual and collective eagerness, and *qualifying* the complex teaching-learning context in a modeling, intelligent way, by considering it, *a priori,* as images of intelligence, active orderly organization (not totally predictable and, therefore, intelligible) through a logic of self-eco-reorganized (computerized, informed, accessed) organization.

Based on these ideas, given the results of the study that we have done regarding teachers' conceptions and attitudes about school-age children's stuttering, in this study we have proposed to identify the way mothers and adult-stuttering subjects, who live with the stuttering problem, conceive and cope with this kind of problem and compare them with the conceptions and attitudes of teaching professionals, in order to identify and understand the nature of their likely dissonances and relationships with the education system itself.

This research approach recognizes the importance of a new epistemological direction for the construction of science by means of strategies of innovative, differentiated-formative intervention. In other words, it is necessary to emphasize the conceptual and methodological dissonances of education, which weaken the education system, thus hindering the learning of science.

**1.1 Stuttering in elementary-school children: a complex human reality with implications for learning, language development and social integration of individuals with this type of problem.**

Stuttering is a speech dysfluency that often appears in early childhood, not when children begin to speak, but when they start communicating with other people (Dinville, 1993). It is likely to think that this kind of problem is related to language requirements typical of school and family contexts such as expression requirements, efforts of attention, selection of words for the construction of phrases, and so forth (Pereira et al., 1995).

Mothers and teachers, among other individuals, are part of the education context, where children in their initial phase of literacy are included and may contribute to the configuration of problems of this nature. When correcting the child's speech, disregarding his or her feelings, mothers and teachers can hinder the communication needed for understanding the reality experienced, taught and learned.

On the other hand, this kind of non-pedagogical attitude may be based upon understanding learning as a process that is independent of both communication and psycho-social human development.

Câmara and Morais (1998), in a study based on the sociological assumptions of Bernstein's pedagogic speech theory on the influence of pedagogic practices in learning and social integration of school-age children during their initial literacy phase, point out the educational-context features that facilitate school learning, including characteristics that allow for the free flow of information in the classroom, communication of ideas, and that neither reveal different classes nor different attitudes among children. Besides this influence, these investigators have pointed out pedagogic features related to a higher degree of conceptual requirement, with systematized knowledge based on scientific principles.

According to the researchers, the highest degree of conceptual requirement is a pedagogic characteristic with great potential to nourish the learning processes, including among working-class children, thus contributing to a balance of the discriminatory effects of socio-cultural conditions regarding access to the education system.

On the other hand, Afonso and Neves (1998), using assumptions of a psychological, epistemological and sociological nature when investigating children's conceptions and their social group, by taking into account that family discourses and practices tend to influence children's conceptions, have pointed out the interference of 'social class' variables and social context gender, among others, in the children's ways of thinking and acting.

These investigators, when comparing conceptions accepted by mothers of different social classes, have found that in general terms, children's ways of answering is much the same as that of their mothers.

They have found, however, that this similarity is greatest between children and mothers of lower social classes. They have concluded, that on the whole, the obtained results support the assumption of the influence of primary socialization context variables (that happen in the family) in the conceptions that the children reveal certain phenomena involving knowledge of a scientific nature, meeting the results obtained in other investigations (p.116).

It seems, therefore, that certain educational-context characteristics of teaching and learning, in and out of school (in the family), influence learning by means of understanding language construction and the child's social integration.

However, although these educational-context influences on learning and the development of concepts and attitudes seem to be evident, the influence question related to the qualification of teachers and other people who participate in the knowledge socialization process have not been the subject of scientific investigation in a more external, sociological direction. Conversely, in the field of Phonoaudiology[2], such problems have received a more *techno-scientific* treatment, aimed at correcting sounds, as if the learning and human communication did not depend on interrelated aspects such as science, technology and society.

The approach of human-communication problems from a strictly *techno-scientific* viewpoint can lead to the development and/or maintenance of less-than-pedagogical beliefs and attitudes, ineffective in understanding and coping with the problem, on the part of people who experienced the problem, as well as on the part of those who live with the subjects. In addition, it may favor the exclusion of individuals who live directly with the problem.

The results of our studies (Villani et al, 2001), and those by Chiquetto (1992), Barbosa and Chiari (1998), regarding conceptions and attitudes of teachers who deal with stuttering children, point in this direction. According to these researchers, the teachers' conceptions are quite varied, similar to the common-sense conceptions, a reality contrary to the one postulated by Câmara and Morais (1998), favoring school-based learning.

This assumption has been corroborated by the results of our studies, which show that 42% of a sample, consisting of 32 student teachers, do not know how to act with children who stutter in reading situations, and that 28% of them defended un-pedagogical intervention, unsuitable to the learning process: asking the stuttering child to take a breath, think and read slowly (Villani et al, 2001).

This way of managing the problem might be due to an erroneous way of conceiving stuttering as a dysfunction, accompanied by an alteration of speech rate.

In addition, the results of this same study show that the reality of teachers' knowledge in a situation of writing lessons has not been any different, since 53% of them have stated that they would not know how to act with children who stutter in a writing situation and also that 16% of them defended interference in non-existent realities[3] ('show the repeated syllables').

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2 In Brazil, there are specific university programs for qualifying professional doctors to deal with speech problem therapy.

3 The literature shows that children who stutter when writing do not reproduce the repeated sounds orally.

This reality of primary-school teachers' knowledge of children who stutter has shown us the necessity of making further investigations into understanding the question of the teacher's qualification and of his/her ability to cope with children's stuttering in their initial phase of literacy. There is also a need for investigation into raising the necessary funds for scientific education for those professionals, per the results of studies such as those by Sebastião (2001).

This researcher has had excellent results when organizing educational activities involving parents, teachers and children with medium otitis problems, by means of interactive dynamics and previous identification of conceptions and attitudes of those involved. She demonstrated that the effectiveness of her intervention through the research has revealed itself to be a relation between the prior, alternative conceptions of the subjects involved and the teaching dynamics used by her in the study with a view at changing those very conceptions.

The epistemological intervention-investigation method through research used by Sebastião (2001), in light of social and cognitive methodological-theoretical scientific assumptions of learning, configures the mediating investigating agent of the transformation process of ideas, beliefs and concepts of those involved and favors them with the necessary awareness to cope with the investigated problem.

The study results by Sebastião (2001) show the importance of an innovative way of constructing and applying science from identification of social-context factors (the conception nature and the attitudes of those involved) and of critical reflection through research, in a cooperative and articulated way, in order to improve understanding of complex human problems and their confrontation.

Studies like this, based upon the assumption of science education's need to deal with complex human problems, in a dynamics of 'systemic modeling', use the solution of human questions such as teaching and learning aimed at the student's physical, mental and social health, dependent on his/her active, conscious and responsible involvement. Or, in other words, on his/her own, learning and experiencing communication problems with teachers and family members among others.

In this same sense, promoting health also involves promoting the necessary awareness related to more effective pedagogical attitudes when facing the problem. In other words, it involves teaching science by means of research programs and interactive dynamics involving the various social structure segments, so that the problem to be managed can be shown.

## 2. Research Methodology

In order to carry out a study of the conceptions and attitudes of 32 student teachers and 29 teaching professionals related to stuttering children (previously presented) (Villani et. al, 2001, Villani and Curriel, 2001), we applied a semi-structured questionnaire in a sample that consisted of 30 mothers of children who stutter and who are in their initial phase of literacy, as well as 31 adult subjects who stutter.

In the designing the instrument, besides the specific aspects of stuttering (etiology, symptomatology and treatment), human-interaction features related with the communication have also been taken into account.

The sample of teachers involved in previous research had secondary education degree, whereas the sample of mothers and adult subjects who stutter involved in this study had primary education degree (1st to 8th grade), and/or incomplete secondary schooling.

Some of the mothers work as housewives; others as store clerks, students, kitchen helpers, supermarket cashiers or saleswomen. The adult subjects who stutter, for their part, either study or work as drivers, carpenters, salesmen or bakers.

For the sample selection, data were obtained from professionals in public schools or health networks, or through information given by people in the local community.

The subjects' answers have been analyzed and classified in light of a cognitive/interactionist vision of learning, that is, learning as a complex phenomenon, dependent on the process of knowledge socialization.

The syntactic and semantic structure analysis of the subjects' answers, carried out based on principles and theoretical-methodological assumptions from both Phonoaudiology and Education, has allowed us to identify and characterize inadequate answers regarding the handling of the stuttering problem (diagnose/guide children with the problem and teach them, mainly in reading and writing situations).

In this line of investigation, learning is conceived as a complex phenomenological process, resulting from the subject's interaction with his/her social context, under the influence of multiple factors, of a biological, psychological and social nature (genetic, linguistic, cultural ones, under the influence of the educational system). Therefore, it is dependent on human communication and human-relation dynamics that privilege the understanding and construction of meanings through both the oral and written language.

The analytical results of both the mothers' and stuttering subjects' responses to the informative questionnaire have been compared with those obtained in a previous study involving primary school teachers and student teachers..

This characterization and comparison have permitted us to better understand the socio-epistemological nature of the subjects' knowledge, their likely dissonances and socio-cultural implications: if the manner of educated subjects, who have primary and secondary education and cope with stuttering, has contributed or not to its minimization, maintenance and/or aggravation.

The hypothesis of this study is that identification of the nature of subject's knowledge, and the way it is used in situations that deal with complex human problems, may reveal new ways teaching and learning and training professionals to handle problems of this nature, in agreement with what is understood and proposed by the current law and fundamental guidelines of the Brazilian education system.

## 3. Results

Analysis of the results allows us to state that, on the whole, the subjects studied, like both student teachers and practicing teaching professionals, (Villani et al, 2001 and Villani and Curriel, 2001), conceive stuttering as a speech dysfunction, accompanied by rate alteration, of a biological, psychological, or emotional nature.

The subjects' answers were shown to have linguistic characteristics (syntactic and semantic ones) typical of common sense, derived from a line of thought based on a logic of attributes and premature certainties, not founded on what is probable or hypothetical, but rather a limited prediction of every day life phenomena, as Santos (1992) has described.

A comparative analysis of the subjects' conceptions and attitudes (teachers, mothers and stuttering subjects) makes it possible for us to affirm the following:

1. In terms of the number of conceptual categories of subjects studied, as shown in Table 1 below, adults who have the problem have the greatest number of categories of answers, in relation to the concept of stuttering (8), the way of identifying it (10), and its etiology (9).

**Table 1.** Number of response categories of teachers, mothers and stuttering adult subjects (ways of identifying stuttering, understanding its etiology and the onset of its appearance).

| Investigated concepts | Number of response categories | | |
|---|---|---|---|
| | Teachers[4] | Mothers | Stuttering adults |
| 1. Stuttering | 2.25 | 5 | 8 |
| 2. Ways of identifying stuttering | 4.50 | 4 | 10 |
| 3. Stuttering etiology | 4.75 | 4 | 9 |
| 4. Onset of stuttering's appearance | 7.5 | 3 | 7 |

2. In terms of the subjects' conceptions of the nature of stuttering, as shown in table 2 below, while the subjects who live with the problem believe that stuttering is either of a psychological (54.80%) or organic (45.10%) nature, teachers (51.00%) and mothers (63.30%) seem to believe more in the psychological nature of the problem.

**Table 2.** Teachers', mothers', and stuttering adults' beliefs regarding the nature of stuttering.

| Beliefs | %Teachers | %Mothers | %Stuttering Adults |
|---|---|---|---|
| Stuttering has a psychological nature | 51.00 | 63.30 | 54.80 |
| Stuttering has an organic nature (hereditary) | 22.00 | 33.30 | 45.10 |
| Stuttering does not have a specific nature | 16.00 | 23.30 | 29.00 |

3. In terms of the subjects' conceptions and attitudes regarding prevention and treatment of stuttering as shown in table 3, while teachers and mothers of children who stutter seem to believe more in a cure than in prevention, stuttering adults seem to believe more in prevention than a cure.

Among teachers who believe in prevention of the problem (10.75%), some state that this assumption is based on the case of stuttering having an emotional cause. Those who believe that the stuttering can be prevented have argued in defense of the following ideas: working on speech and the nervous system; 'allowing the child to believe in his/her good speech' when the child begins stuttering between the ages of 2 or 3, [a time when] one cannot make another speak faster, because the anxiety created by the adult causes the stuttering to appear.

In addition, they have also stated that it is important to investigate the reason of this disorder and believe that stuttering can be prevented, depending on what has caused it. However, 10% of the teachers who stated that they believe in prevention of the problem argued that the way to prevent stuttering is either to get information from the child's parents, or by means of the teacher's attitudes. There are those who believe in prevention through the help of a specialized professional, and others who do not believe that stuttering can be prevented: 'It may be outgrown, but not prevented'; ['cannot be prevented'] (because it is not predictable).

[4] The number of categories of teachers' beliefs shown in the table was the resultof an arithmetical average of the number of categories obtained in every one of the classifications of student teachers and teaching professionals previously studied involving teachers who teach preschool and 1st and 2nd grades of primary school. Refer to VILLANI, V.G; CURRIEL, D.T; OLIVEIRA, C.M.C. What student teachers think about the 'stuttering' *Nuances Magazine*. Paulista State University, v.7, 2001, p.53-61 and VILLANI, V.G and CURRIEL, D.T. Comparative analysis of student teachers' and teaching professionals' conceptions of stuttering among children. *Núcleos de Ensino Magazine*, Paulista State University, v. 1, p. 91-102, 2001.

When asked about ways to minimize stuttering, 78% suggested improper actions, such as 'asking the child' to take a breath: 'to think', 'to slow down', and 9% suggested: 'being patient', 'trying to understand what the child says in a calm way', 'speaking correctly/in a subtle way'.

In terms of the mothers, those who believe in prevention of the problem defended: 'paying special attention to the child's speech and taking him/her to a phonoaudiologist; because if the mother takes him/her for therapy sessions when he/she is in pre-school, it is very likely that the child will stop stuttering'; 'it [the problem] appears and disappears naturally, as long as the child is helped'; 'by following a treatment'.

Among subjects who stutter, only 9.6% stated that they do not believe in prevention and defended the following actions for handling the problem: 'to put thoughts into words before speaking'; 'just slow down, but my habit will not let me'.

An analysis of the teachers' answers about the possibility of outgrowing the stutter shows that 88% of them believe in this assumption and 9% believe in a cure or its 'control', depending on other factors ('only if it is a child'; 'it depends on the stuttering', 'he/she does not outgrow the problem, but one can control it') .

Mothers who believe in outgrowing stuttering (86.60%) or minimizing the problem (26%) defended: 'asking the child to take a breath'; 'correcting the child after he/she finishes speaking'; 'looking for the help of a professional'.

Adult subjects who live with the problem and believe in outgrowing the stutter (61.2%) or minimizing it justified themselves through the following attitudes or argument: 'I think that [outgrowing the problem requires] treatment and a good relationship with family and work colleagues'; 'if [it were not possible to prevent] what would be the use of phonoaudiology?'; ('It can be outgrown if one talks to the phonoaudiologist) and to the psychologist'). 'It's just a question of wanting it' ['It can definitely be outgrown'].

4. In terms of the subjects' conceptions about the relationship of stuttering with a phase in the child's development, they were quite varied.

Teachers who believe that stuttering might be normal in a certain stage of development argued: 'he/she [the child] is developing his/her language skills and is beginning to say sentences'. Those who do not believe in the possibility of a relationship between stuttering and the child's development have explained it the following way: 'when he/she [child] learned to speak, he/she did not learn to speak by stuttering'.

Mothers who believe that it is normal to stutter in a certain phase of language development state the following: '[it is normal] when the child begins to speak', 'there are children who require more attention from their parent, and when they are not given special attention, they feel left out', 'because I have already taken my child to a psychologist and he said that it is normal for children up to seven years old'. Those who do not believe in this relationship argued: 'if it has to occur, it will not be in a development stage ', 'because my child has always stuttered', 'when a child has a real stutter, there is no specific stage', 'all children are normal and in their development that does not occur', 'it may occur even with a grown-up'.

Adult subjects who believe in the relationship of stuttering with a development stage (52%) argued: 'he/she (child) might stutter because he/she does not know how to speak, but then he/she does not stutter anymore'; 'I have lived with it since I was two years old', 'because the child is learning how to speak'. Those who do not believe in this relationship argued: 'if there were [a relationship], all children would go through this stage', 'because as far as I know, the majority of children have never had stuttering problems', 'because parents overcorrect their children, they should let the children speak more freely'.

5. In terms of the belief that stuttering is related to a learning disability, while teachers seem to have different opinions on this issue, the majority of the mothers believe that children who stutter may have difficulty learning. On the other hand, adult stutters do not believe in these assumptions.

Mothers who believe in this relationship argued: '[the child] has trouble asking the teacher something ', 'he/she [the student] feels embarrassed speaking', 'because children have difficulty reading', '[the children] mix up many letters', 'for not being able to pronounce certain words, he/she [the child] ignores [reading] and does not learn'. On the other hand, mothers who do not believe in this relationship argued: 'because my child is successful at learning in school'; 'my child learns fast'.

Stuttering subjects who believe in this relationship argued: 'When a stuttering child has doubts, she/he does not ask the teacher'; 'because when I was a child and studied, if my teachers asked me to read a text, I did not'. Those who do not believe in the relationship between stuttering and learning disabilities argued: 'the stutterer reads better, has a better memory'; 'I used to be a stutter and had good school development'; 'I speak for myself, I have taken several courses, I teach, I am a saleswoman and participate in several meetings'.

**Table 3**: The percentage of answers by teachers, mothers and stuttering adults regarding their beliefs in prevention, outgrowing stuttering, its relationship with the child's stage of development, and learning disabilities.

| Beliefs | % Teachers | | % Mothers | | % Stuttering Adults | |
|---|---|---|---|---|---|---|
| | YES | NO | YES | NO | YES | NO |
| Believe in prevention | 10.75 | 32.75 | 20.00 | 66.60 | 90.40 | 9.60 |
| Believe in a cure (outgrowing) | 91.75 | 0.75 | 86.60 | 13.30 | 6.120 | 35.40 |
| Believe in the relationship between stuttering and stage of development | 52.25 | 18.50 | 40.00 | 50.00 | 52.60 | 48.30 |
| Believe that children who stutter have more difficulty learning | 39.25 | 49.25 | 60.00 | 40.00 | 29.00 | 71.00 |

6. In terms of the relationship between stuttering and the child's social interaction context, when asked if they belief in the existence of children who stutter more frequently when communicating with certain kinds of people and/or situations, 79.63% of the subjects answered affirmatively and quoted as examples the presence of people such as doctors, dentists, teachers, strangers or those who hold high positions or situations that provoke emotional reactions, among others.
7. In terms of etiology of knowledge on stuttering, the majority of the subjects stated that their knowledge comes from every day activities (reading books, magazines and newspapers), and from experiences with other people such as phonoaudiologists, psychologists and doctors.
8. In terms of information on the problem, in spite of not having consensus among the subjects on a cure or prevention of the problem, the majority of subjects (94.26%) believe in the importance of receiving guidance in this sense.

## 4. Discussion and preliminary conclusions

An analysis of the subjects (teachers, mothers of children who stutter and adult subjects who live with the stuttering problem) shows that, on the whole, the subjects who cope with stuttering are more concerned about speech correction than its meanings. Moreover, their conceptions are more often based on intentions or reasons or actions founded on premature certainties, thus characterizing them as "common sense" or unscientific. When favoring observations and verifications related to an explanation of stuttering, confirming "certainties", the subjects revealed that their ability to predict the problem was restricted to the phenomena of every day life.

A comparative analysis of their answers shows that grown-ups who live with the problem present important conceptual differences from mothers and teachers. Among these differences, the most significant were the number of categories of ideas about stuttering, the way of identifying the stutter, and its etiology (table 1). Besides these, differences existed regarding prevention of the problem and its relation to learning disabilities difficulties.

Unlike teachers and mothers, adult stuttering subjects seem to believe more in prevention of the problem than in outgrowing it, due to the fact of having no learning difficulties related to the problem.

This way of understanding the problem may reveal that these subjects, as adults who have lived with the problem, no longer hope to face it and/or solve it. Furthermore, in spite of being stutterers, they do not feel they have been harmed in their personal lives.

Dissonances among the subjects' conceptions reflect a lack of consensus on stuttering and its likely relationship to learning and human development. This relationship might be related to conceptions of human communication, as independent of learning, or otherwise, with a concept of learning as a process that results from memorization and not from understanding[5]. Our studies, on university students' studying behavior, point in this direction.

We identified university students' conceptions and attitudes towards studying and analyzed their likely relationships with aspects of the teachers' pedagogical practices, which are said to result from a positivist view of human knowledge (Harres, 1997). The students' conceptions were shown to be deficient in logical scientific thinking [6] ('I study in accordance with the teacher's evaluation'), 'first I study by reading, and then by making a summary', 'I study every day', 'I always follow the teacher's instructions', 'I do exercises', 'I read in aloud', 'I read the text by trying to memorize it topic by topic' (and so on), and probably results from experiences relating to teaching situations and mechanical learning (learning based on the memorization of concepts).

Among the implications of this kind of conception of learning by memorization, besides the attitudes of mechanical learning, one can also find the construction of fragmented ideas, such as the deficiency in interdependence between human learning and communication, also maintained by the lack of conscience regarding the relationships among scientific development, application of science, and social exclusion.

The responses of subjects who believe in the relationship between stuttering and learning disabilities corroborate this statement, given that arguments were shown to be based on the question either of social exclusion or learning by memorization ('a stuttering child, when he/she has a doubt, does not ask the teacher'; 'because when I was a child and studied, if the teachers asked me to read a text, I didn't', 'stutterers read better, have better memories', 'I used to be a stutterer, but I had good learning development').

Like the stuttering subjects, the majority of student teachers that we interviewed (66%) did not believe in the relationship between stuttering and learning disabilities, versus 31% that believed in this relationship (Villani et al., 2001, p.57). However, those who do not believe in this relationship justified themselves in several ways, either by not separating the speech problem from its cognitive aspect, or by relating stuttering to an emotional aspect. None of them argued that the relationship between stuttering and learning disabilities was based on knowledge regarding teaching or learning. Conversely, their statements revealed that either they do not believe in the relationship between communication and learning how to write, or that only an organic dysfunction may imply learning problems ('stuttering is a speech problem in the sense of communication, and I believe that it does not influence writing'; 'because he/she does not have any mental disorder').

Conceptions of the same kind were found by Chiqueto (1992) Barbosa and Chiari (1998) among teachers, mothers and other family members of the stuttering subjects.

This kind of belief about stuttering can lead everyone, especially teachers, to correct the speech of a child who stutters when reading and/or writing, thus disregarding the sense and meaning of the child's speech, a teaching condition that may hinder meaningful learning through comprehension, and the social integration of a child with dysfluency speech problems.

[5] It is worth pointing out that stuttering is a speech dysfluency that does not appear in situations of memorized speech, but rather in spontaneous speech.

[6] The deficiency in logical scientific thinking in the subjects' conceptions of studying has been characterized based on the lack of the use of scientific methodological-theoretical assumptions (i.e., the material world).

In this sense, Montero (1985) called attention to promoting health in the complex dynamics of human relations, to professional work involving cultural aspects and specialized knowledge that 'conditions' the health of less-favored social classes in terms of subjection, hindering/preventing the promotion of their own health. And given that the very subject who feels and learns lives in the context of the complex network of social factors, admitting him/her into the administration process of his/her own health involves public policies for the recovery of the population's participating spirit, as well as new pedagogical practices aimed at recognizing the subjects' conceptions, which the current education system is not prepared to do, especially given the lack of learning opportunities in science in people's every day life.

Improving this situation will require everybody's involvement in educational processes by means of teaching methodologies capable of favoring the construction of full competences needed for the practice of the scientific and technological autonomy, as well as teaching autonomy.

Based on these ideas, and given what Câmara and Morais (1998) stated about the importance of context features that facilitate school learning, including features that permit the free flow of information in the classroom and the communication of ideas, it is possible to infer that teachers' attitudes of focusing on speech correction rather than the act of recognizing meanings and senses by preventing an understanding of the learning reality experienced by the individual, are un-pedagogical, and hinder both the learning and social integration of subjects with speech dysfluency.

Furthermore, by also taking into consideration what the researchers have stated above regarding the importance of characteristics in the school context that do not promote either distinct classes nor differentiated attitudes among children (pedagogical characteristics related to the highest degree of conceptual requirement, with systematized knowledge from scientific principles), it is possible to infer the importance of scientific education for student teachers in the field of Phonoaudiology, in order to enhance understanding of the relationships between application of science and the social integration above all regarding children with communication problems.

In this sense, by taking as a reference the previously described aspects in this study about the complexity of human nature and the best ways deal with it, as Pillon (1990, p. 14) reminds us, the traditional practice of transferring actions in teaching programs aimed at the health is no longer justified, regardless of the population's previous conceptions regarding health problems. Even though these curricula and programs may produce the desired result, either through a cure or prevention of diseases among the poorer social classes, they should give way to more open projects that add philosophical aspects of contemporary trends of thinking to the dynamics of networks, with 'ecological niches' where the concepts arise.

We have taken the example by Pillon (1990), which states that such aspects are very important in defining the world, culture, knowledge, education, society and science itself, remembering that sciences (from human sciences to exact sciences) depend on the careful analysis of knowledge processes, also affected by the view of the researchers' world (religious, political, philosophical and cultural views implicit in different projects).

In conclusion, we believe that the outcomes of the studies that we have carried out, which show incongruities between scientific theories and assumptions and common citizens' conceptions and practices, and incongruities between values and feelings that underlie the necessary learning approaches for the construction of the scientific knowledge, point to the need for a differentiated type of education. In this sense, teachers need to receive better educational training, 'learning how to learn', which is necessary for development, self-knowledge, and construction of pedagogical knowledge more inherent to specific human realities, regardless of social conditions established through contrary forces and powers.

The teachers' political-scientific background may favor a break from the social and political structure that has benefited the development of alternative knowledge to the detriment of the scientific knowledge, for instance, by disregarding everybody's participation in the process of knowledge construction. In order to be overcome, it will require the adoption of methodologies that are closer and more compatible to the social and democratic process of knowledge development.

Along these lines, Solomon and Thomas (1999), in a broad study of questions of a similar nature, criticize investments in scientific education based solely on formal teaching, and they remind us that different kinds of learning cannot be produced and controlled institutionally (teaching that takes place at school, or at colleges, or in courses in classrooms, or by mail in the case of being offered to grown-ups deprived of formal instruction).

According to these researchers, since the learning process is constant throughout life, and due to the fact that scientific learning is not the main goal of the common individual, implementation of differentiated school curricula, more relevant to the common citizen, is justified, in a teaching condition that may have a considerable influence over the learning process. However, they remind us that this learning process may require several types of educational provisions in different stages of life when there appear to be a lot of problems to be solved.

For that reason, according to these researchers, the way to teach scientifically in order to change social practices is to foment both traditional literacy and scientific literacy, in order to make scientific knowledge public by involving everybody in teaching and learning processes of science, building differentiated social senses, making science relevant to the common citizen. Moreover, they add that in this education perspective, which aims at the public understanding of science and of technology, more than at finding an interrupted way of developing scientific knowledge in specific groups, we must look for means of developing them in the natural and social sciences.

Cachapuz et al., (2000) support this view of science, and the way its taught, when proposing teaching through research and the qualification of teachers in a dynamics centered on the investigation-innovation-qualification relationship (Cachapuz et al., 2001). Furthermore, outcomes from studies that show differentiated ways of developing and spreading scientific knowledge, starting from specific cognitive needs and interests, are not enough to educate youngsters and grown-ups who have difficulty distinguishing science from technology, as well as different roles in the context of life (Zoller et al., 1991).

Based on these ideas, taking into consideration the results of our studies and many others accomplished in light of the same cognitive assumptions of human knowledge, according to Solomon and Thomas' (1999) example, we are convinced that it is necessary to invest in the qualification of primary-school teachers (1st to 4th grade), but that this kind of investment requires believing in the importance of the public's understanding of science and breaking with the traditional practice of formal, institutionalized education as the only path to learning science.

On the other hand, we believe that the tradition of legitimizing learning through the disciplinary logic of titles and diplomas must be broken, and we believe that investing in more trans-disciplinary science education, based on the relationship among science, technology and society is important.

## 5. Bibliographical References

AFONSO, M. e NEVES, I. P. Socialização primária e concepções das crianças em ciências. *Revista de Educação*. Departamento de Educação da F.C. da Universidade de Lisboa. v.VII. n. 1, p 107-119, 1998;

ABIMBOLA, I.C. The Relevance of the 'New' Philosophy of Science for the Science Curriculum. *School Science and Mathematics*, v.83, n.3, p. 181-193, 1983;

AUSUBEL, D.P. *The psychology of meaningful verbal learning*. New York: Holt Grune & Stratton, 1963;

BARBOSA, L. M. G. e CHIARI, B. M. *Gagueira: etiologia, prevenção e tratamento*. Carapicuíba: Profono Departamento Editorial, SP, 1998;

BECKER, F. *Epistemologia do Professor: o cotidiano da escola*. Rio de Janeiro. Vozes. Rio de Janeiro, 1993;

CACHAPUZ, A; PRAIA, J; JORGE, M. Reflexão em torno de perspectiva do ensino das ciências: contributos para uma nova orientação curricular – ensino por pesquisa. *Revista Educação*, v. IX, n.1, 69-79, 2000;

CACHAPUZ, A F.; PRAIA,J.; PAIXÃO, F.; MARTINS, I. Uma visão sobre o ensino das ciências no pós-mudança conceptual: contributos para a formação de professores. *Inovação*, v.13, n 43, p.117-137, 2001;

CÂMARA, M. J. e MORAIS, A, M. O desenvolvimento científico no jardim de infância: influência das práticas pedagógicas. *Revista de Educação*. Departamento de Educação da F.C da Universidade de Lisboa. v.VII. n. 2, p 179-199, 1998;

CHIQUETTO, M. M. Reflexões sobre a gagueira; concepções e atitudes dos professores. Florianópolis. *Mestrado em Fonoaudiologia*. Universidade Federal de Santa Catarina, SC, 1992.;

DE POSADA, J..M. Hacia una teoria sobre las ideas científicas de los alumnos: influencia del contexto. *Enseñanza de Las Ciencias*, v.14, n. 3, 1996. p 303-314;

DINVILLE, C. *A gagueira: sintomatologia e tratamento*. Rio de Janeiro: Enelivros, RJ,1993.;

GUITTAR, B. *Stuttering: an integrated approach to is nature and treatment*. Maryland: Williams & Wilkins, USA, 1998;

HARRES, J.B. *Uma revisão de pesquisas nas concepções de professores sobre a natureza da ciência e suas implicações para* o *ensino*. Ion linel "Investigação em Ensino de Ciências". Porto Alegre: Instituto de Física da Universidade Federal do Rio Grande Do Sul, 1997 [cited 06 fev 2000] Available: http://www.if.ufrgs.br/public/ensino/vol4/n3/harres.htm;

HASHWEH, M. Z. Effects of "science teachers" epistemological beliefs in teaching. *Journal of Research in Science Teaching*, v.33, n.1, p. 47-63, 1996;

HODSON, D., Filosofía da Ciencia y Educación Científica. In: R. PORLÁN, J. GARCIA & CANAÃL (Org.) *Constructivismo y Enseñanza de las Ciencias*,. Sevilha: Diada Editoras, Espanha, p 5-21, 1988;

MARTINS, L, R; RIBEIRO, A. P. O; BERNADELI, F.S.K; NUNES, F., M. Situações do cotidiano que interferem na aprendizagem do aluno na adolescência. *Atas do II Encontro Nacional de Pesquisa em Educação em Ciências* .Valinhos, SP, 1999 (CD ROOM);

MORAIS, A. M. *Socialização primária e prática pedagógica*. V.I Lisboa: Fundação Calouste Gulbenkian, 1992;

MONTERO, P. *Da doença à desordem*. Rio de Janeiro: Graal, 1985;

MORIN, E. *Os sete saberes necessários à educação do futuro*. Cortez: Brasília Editora Unesco, 2000;

PEREIRA, L. D.; SANTOS, A. M. S.; OSBORN, E. Ação preventiva na escola: aspectos relacionados à integração professor e aluno e a comunicação humana. In: VIEIRA, R. M. et al. *Fonoaudiologia e Saúde Pública*. São Paulo: Pró-Fono, SP, p.195,1995;

PIAGET, J. *Psicologia y epistemologia*. Barcelona: Ariel, 1971b (versão original, 1970);

PILLON, A .F. *Saúde, Educação e Projeto de vida*. São Paulo, FSP/USP (mimeo), 1990;

PRAIA, J. y CACHAPUZ, F. Un análisis de las concepciones acerca de la natureza del conhecimiento científico de los profesores portugueses de la enseñanza secundaria. *Enseñanza de las ciencias*, v.12, n.3, p.350 -354, 1994;

SANTOS, E. Natureza e características das concepções alternativas. In: CACHAPUZ, A (coord) *Ensino e Formação de Professores*. Projeto MUTARE, Aveiro: Universidade de Aveiro, Portugal, v.1, p.42-51,1992;

SEBASTIÃO, L. T. Educação Infantil e Fonoaudiologia: ouvindo e falando sobre a audição. *Tese de doutorado em Educação*. Faculdade de Filosofia e Ciências. Unesp, Câmpus de de Marília, 2001;

SOLOMON, J. and THOMAS, J: Science Education for the public understanding of science. Studies in Science Education, n. 33, p. 61-90, 1999;

VILLANI, V. G. A investigação-ação sobre comportamentos de estudo envolvendo atividades de metacognição: estratégia para favorecer a aprendizagem significativa". *Anais do III Encontro Internacional sobre Aprendizagem Significativa*. Peniche, Portugal, p.423-26, 2000;

VILLANI, V. G.; CURRIEL, D.T.; OLIVEIRA, C. M. C. O que pensam os professores em formação inicial sobre a 'gagueira'. *Revista Nuances*. Universidade Estadual Paulista, v.7, p. 53-61, 2001;

VILLANI, V.G. e CURRIEL, T.D.; Análise comparativa de concepções e atitudes de professores em formação inicial e em exercício sobre a gagueira. *Revista dos Núcleos de Ensino*. Universidade Estadual Paulista, v.1, p.91-102, 2001;

VYGOTSKY, L. S. *Pensamento e linguagem*. São Paulo: Martins Fontes, 1991;

VYGOTSKY, L. S.;LURIA,A.R.;LEONTIEV, A.N. *Linguagem, desenvolvimento e aprendizagem*. São Paulo: Ícone, Editora da Universidade de São Paulo, 1991;

ZOLLER, U.; DONN, S.; WILD, R.; BECKETT, P. Teachers' beliefs and views on selected science Technology – society topic: A probe into STS literacy versus indoctrination. *Science Teacher Education*, n.75, v.5, p. 541-56, 1991.

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# TEACHERS' EDUCATION FOR SCIENTIFIC LITERACY

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**Abstract**

The objective of this paper is to show the need to restructure science teachers' education if we wish school science to serve the purpose of scientific literacy. This restructuring is very urgent since there is growing research evidence that the majority of citizens in many countries of the world are scientifically illiterate, even in aspects of science that the school science curricula have insisted on like the factual ones.

It has been claimed that in order this reorientation to be achieved, there must be a shift from the courses focusing mostly on the scientific content (as shown empirically to be the case in Greece) to courses illuminating the dimensions of the scientific method, the institutional constitution of Science and the social impacts of this area.

For this in turn, to happen the philosophical underpinnings of the science teachers' education courses must undergo a shift from the assumption that school science is a mere simplification of the total body of scientific knowledge to the assumption that it is a re-contextualized body of knowledge borrowing meanings from the needs and functions of its context (school context in this particular case). If this notion is made explicit to the science teachers through the revised courses of their education, they will be able to become much more reflective about the nature of science 'in the making'. By doing so, they will be able to incorporate in their lessons aspects of science that will be closer to the kind of science that citizens meet in the public domain and hence fulfill the purpose of scientific literacy.

## Introduction

The objective of this paper is to show that in order to reorient science education towards the objective of scientific literacy for all the future citizens, we have also to restructure the science educators' education.

The first part of this paper attempts to show how Science and Technology have permeated a growing number of domains of public life (e.g. citizenship, market, labor market, culture, etc.) during the last two decades. Then it is argued that school science must come closer to the kind of science appearing in the public domain in order to help students to become scientifically literate citizens. By saying scientific literate citizens we mean people that have a minimum understanding of the scientific content, method, institutional function and social impacts of Science and Technology.

In order though science education to start serving this objective, the kind of science taught in schools must change. The reasons for this required change are explained in the second part of the paper.

In the third part, the basic claim is that such a reorientation in science education is impossible without the prior reorientation of the science teachers' education, which at the moment, gives more emphasis on the factual aspects of science rather than on aspects like the scientific method or the social impacts of science. In order this claim to be further substantiated the present situation as far as the science teachers' education in Greece is presented.

Finally in the last part of the paper an attempt is made to present an alternative to the existing framework, which offers a sound basis for the nature of the required restructuring of the science teachers' education. This alternative framework is based on the assumption that school science is not a simplification of the total body of scientific knowledge as is currently assumed but it is a re-contextualised body of knowledge appropriately adjusted to the way school functions.

### The domains of public life that Science and Technology meet the Public

Science teachers should prepare their students for a multiplicity of roles that will be called to play in the future.

The most basic of these roles concern:
a) Citizenship
b) Consumption
c) Employment and
d) Cultural dimensions

**Citizenship**
The issues of:
- conflicting scientific arguments within the same scientific community,
- conflicting arguments which have to do with specific governmental decisions about science policy issues,
- governmental decisions, related directly or indirectly with science and technology issues (e.g. public funding of scientific research, legislation about technical matters, etc), are becoming increasingly prominent in the public life of many societies.

In all of these cases, what is required is not citizens to judge the accuracy of the positions put forward by each side since the basic characteristic of all the scientific conflicts that are exported from the interior of the scientific community to the public field is that they do not constitute well established but fluid knowledge that divide even the experts.

On the contrary, what is required is the public to develop a set of rational (suitability of the followed method, measurements, repeatability of experiments, power and status of the involved scientists and institutions) and not personal or emotional (personal interests, political preferences, beliefs) criteria so as to formulate the appropriate questions to the experts.

The direct involvement of citizens to public issues that are related to science and technology, especially during the last two decades has already led to the first visible results that reform both the relationship between citizenship and science and the internal functioning of science and technology themselves.

These results are:
1. The formation of well organized pressure groups that demand to play a role in the political decision process for science and technology while at the same time they resist to their negative applications (Greenpeace, Friends of Earth, Ecological groups, Consumer groups, etc).
2. The acceptance of the political position that scientific research should be both 'visible' and socially 'acceptable'.
3. The cancellation or the redirection of large and ambitious research projects due to the public opposition they have raised.

**Consumption**
Modern people are bombarded by thousands of new products, promoted basically through advertisement. The reference to the scientific and technological integrity of these products constitutes a basic feature of their market promotion, since as many studies have shown science and technology are still regarded by a large part of the public as carriers of objectivity, impartiality and validity (e.g. Miller, Pardo, Niwa, 1997).

Consumers, then, in order to be able to comprehend the advertised properties of the products on the one side, and to be able to make rational comparisons between them on the other, they should have a basic understanding of the terms and the corresponding concepts presented (e.g. pH, vitamins, proteins, enzymes, etc).

But if *choice* is the one side of the coin then the *protection* from the various risks, mainly health risks, induced by many products is the other. There has been a large debate recently, sometimes quite fiercely is true, for the risks generated by a series of products the production of which, is related to high levels of scientific and technological sophistication (foods, cosmetics, electronic devices, drugs, etc).

Characteristic examples of persistent and intense such debates are the:
1. Toys made of PVC,
2. Genetically modified foods,
3. Risks for severe damage of vital organs of the human body from the radiation emitted by mobile phones,
4. Consumption of fresh vegetables and diary products after the accident of the nuclear power station in Chernobyl.

Consumers can be very easily manipulated by various elites (industrial managers, government officials, local authorities, technical experts, etc.) unless they develop a system of rational checking and filtration of such kinds of information (e.g. status of sources, alternative views, expert advises etc).

**Employment**
Two seem to be the main dimensions of the involvement of science and technology in the field of labor market, this of the increase of productivity through the diffusion of the scientific and the technological innovations and the safety issue. It is widely agreed today that one of the most significant factors, if not the most significant one, in the increase of productivity process is the adoption and assimilation of the fast changing technological applications.

Many psychologists (e.g. Rosen and Weil 1992) of labor have identified the techno-phobia disease of many employees when new technologies are adopted in their job places. This kind of phobia is mainly rooted in the sense of powerlessness, felt in front of something new and unknown as well as in a series of negative prejudices against science and technology (health risks, loss of job positions, complexity of use, etc).

People who acquire a basic familiarity with technology, its applications and the internal mechanisms of its production, get rid of the fear for the unknown, demythologize technology and its successes, and by this way become much more productive and effective in using it. The truth is though, that some aspects of technology, despite the enormous potentials they offer, they require a delicate and careful handling. Knowing the dangers related to technology's applications contributes to the conscientious and careful use that minimizes the level of its dangerousness.

**Cultural dimensions**
Science and technology are two of the most important areas of the modern human culture. We can say that they form a distinct cultural system characterized by its own values, beliefs and methods, allowing the people possessing them to have a completely unique worldview. It is a commonsense that modern science and technology by evolving rapidly and by becoming over-specialized, have broadened their distance from the layman.

The inclusion of the subjects of the Physical Sciences in the National Syllabuses of almost all the countries of the world is a first step, aiding a layman to come in contact with the internal rationale of science. It is therefore obvious that science and technology are basic ingredients of a personal cultural constitution of each citizen. Their current problematic relationship with most of the laypersons has led to the revitalization of antirational positions like the belief in magic and other pseudoscientific theories (parapsychology, astrology).

### The need for a reorientation of Science Education: The failure to meet societal demands

The analysis above has attempted to show that if science and technology education is meant to have any functional role to play in the future lives of the students, then a holistic reorientation of both its content and the associated with that pedagogical approaches, is required. The term that has been introduced the last two decades and shows the path of this reorientation is that of *scientific literacy*. The reorientation of education for scientific literacy has been a matter of fierce debate among science educators, educational authorities and various governmental bodies for many years (Fensham, 1985). It has taken the form of various initiatives, including the movement of the public understanding of Science (Layton et al., 1993; Cross, 1999), history and philosophy of science in science education (Hodson, 1998; Mathews, 1994) and STS (Science-Technology-Society) curricula (Bybee, 1986; Solomon et al.,1994).

The meaning of the term *scientific literacy* though has been the basis of intense theoretical debates among various academic schools of thought, which have attempted to adjust this meaning within their own paradigmatic framework. The relevant literature reveals that the following four are the basic elements that constitute what is implied by the term scientific literacy:

a) Content of science and technology (facts and concepts) (e.g. Royal Society, 1985)
b) Scientific and technological method (e.g. Collins & Pinch 1993; Wynne & Millar 1988)
c) Institutional constitution of Science and Technology (e.g. Jenkins, 1999) and finally
d) Social impacts (benefits and costs) of Science and Technology (e.g. Miller, 1983).

The first element that of the content of science and technology is the one that has been the main focus of the vast majority of the curricula designed up to now. Formal schooling presents science as a coherent, objective and unproblematic body of final and eternal truths. The scientific and technological facts though that future citizens will face in the public domain, are highly controversial and hence open-ended.

The scientific and technological method is considered as an important component in judging the reliability and the substantiality of a scientific claim. This element of scientific literacy is also very valuable on a personal level as it armours the students with unique to science and technology based problems skills and habits of mind (e.g. cross-checking of results, repeatability, hypothesis testing) which enable them to become very efficient in problem-solving tasks that may even fall outside the narrow boundaries of science and technology.

The third element of the above list is considered as absolutely essential towards the promotion of school reforms that will aim to scientific literacy since the school-science is presented unencumbered by its institutional connections. Questions such as 'From whom?', 'From where?' and 'From what institutional sources?' are integral to judgments about the confidence to be placed upon the scientific knowledge. The public uptake of science is not based upon intellectual capability as much as socio-institutional factors having to do with social access, trust, and negotiation as opposed to imposed authority (Wynne, 1991).

Finally the fourth element (social impacts of science and technology) contributes to the objectives of:

a) making the science and technology more relevant by putting them into a familiar to the students socio-economic context and
b) revealing the strengths and the weaknesses of science and technology.

This latter objective can give a realistic picture of the potentials of these two areas so as the future citizens not to lose their faith and withdraw their support from them every time their over-expectations from these are falsified.

School science currently gives almost exclusively emphasis on the content of science underemphasizing all the other elements of scientific literacy. As a result of this, the school-leavers are in their vast majority scientifically illiterate despite the huge amounts of money and efforts that have been spent, especially during the last two decades, in school science reforms. It is very impressive that according to many public surveys in Europe, USA, Canada and Japan (Miller, Pardo, Niwa,1997) only a small part of the public, not exceeding 20% in any case, can be characterized as scientifically literate, having a minimum understanding of some basic scientific concepts and of the corresponding methodological elements.

### The need for a reorientation of Science Teachers' Education

A reorientation of Science Education that will aim at the objective of scientific literacy is practically impossible without the realization, from the side of the science educators themselves, of the crucial role that the four elements of scientific literacy and especially the last three ones as presented above, can play to the formation of an informed citizen. Research has shown (e.g. Eijkelhof, 2000) that science teachers tend to consider subjects characterised by inter-disciplinarity and by the incorporation of the basic philosophy of the science literacy approach (e.g. integrated forms of science, environmental studies, etc) as subjects of lower status than those that give particular emphasis on the corresponding scientific content. This belief is very clearly reflected in their teaching practices and employed pedagogies.

The reasons though of this widespread reluctance of the science teachers to adopt the scientific literacy approach can be traced to the three influential agents involved in the formation of their professional choices which are:

a) Government bodies, planning the science education policies
b) Science textbooks, reflecting the curricular choices and
c) Science teachers' educational systems.

As far as the first of the above three agents concerns, as Fensham (1997) mentions '*from 1983 to the present day, Science for All, or a variant of it, has been officially espoused as the intention for school Science in country after country*'. The Ministers of Education in the Asia region of UNESCO determined in 1983 that this goal was an urgent priority for their educational systems. In the same year the National Science Foundation (1983) presented a report that called for Science for All Americans. Soon after these initiatives the Royal Society in U.K. (Bodmer, 1985) argued persuasively that Science is for everybody. These worldwide governmental policy bodies' initiatives show that at least in theory this agent is absolutely aligned with the pressing need for science education for scientific literacy.

The science textbooks on the other hand, as a significant body of research has shown (e.g. Wilkinson, 1999; Chiappetta, 1991) contain only a minimal amount of references to issues concerning the relationships of Science and Technology with broader societal themes. On the contrary, more attention has been given to the factual aspects of science and technology. This trend has been reversed during the nineties since a continuously increasing part of the science and technology school textbooks concerns issues that can be confronted also in the public arena (e.g. greenhouse effect, acid rain, radiation fallout, etc). Such issues though, are still the minority even within the most modern science and technology textbooks reflecting that clear priority has been given to the solid foundation of knowledge that prepares for the scientific topics that come in the succeeding years of schooling. The influence of the science school textbooks is so strong that as even the more innovative teachers had reinterpreted the Science-Technology-Society use of contexts into pedagogical procedures that enabled them to teach the traditional concepts more effectively, rather than to see them as opportunities for new content and learning outcomes (Fensham and Corrigan, 1994).

Finally, as far as the science teachers' education concerns, in most of the countries the largest part of the future science teachers' education lies in the hands of academic scientists working into corresponding departments of universities and institutes of technology. The image of a graduate scientist that determines the curricula of such departments is this of 'an applied chemist or a theoretical physicist, or even an academic researcher'. In this way traditionally academic scientists and their acolytes among the science teaching ranks have completely controlled what counts as school science (Layton, 1984).

This reality leads to the conclusion that a prerequisite for the needed reorientation of science education so as to serve the aim of scientific literacy for the majority of students is a decisive reorientation of the science teachers' education. In order then to show the basic position of this paper that one of the determining factors affecting the kind and the objectives of science taught in schools is the science teachers' education we will examine the Greek case on this issue.

**The current situation in teachers' education university courses in Greece**

Primary school teachers have to hold degrees from the departments of education. This development is recent - the first departments of education in the Universities (4 years' course) were established in the middle of '80's. Thus, the majority of practicing primary school teachers has certificates from Teachers Training Colleges (2 years' courses).

In order to analyze the way Science Education is taught in primary teachers' training University courses in Greece we will discuss below the following points:
a. Science education subjects and
b. Science related subjects in teachers' education university departments

For the collection of our data we analyzed the official curricula of all Greek Departments of Education[1]. Below, we are referring only to the science education related subjects that are pedagogical in orientation. These subjects are indicated by titles as "Didactics of Science", or "Didactics of Physics" etc.

A system of classification was used in order to depict the existing situation. Dimensions of this system of classification include the:
(a) Number of related to Science Education subjects which are taught in the University Departments (see Table 1).
(b) Inclusion of these subjects in the group of compulsory or selective subjects and
(c) Credits allocated to the Science Education module in each course

**Table 1:** The Science Education pedagogical subjects, taught in the Greek University Departments

| University | Number of Science Education Courses | Percentage of credits allocated to the Science Education module |
|---|---|---|
| University of Athens | 2 | 3.5 |
| University of Patras | 3 | 5 |
| University of Ioannina | 5 | 10 |
| University of Thrace | 2 | 3.5 |
| University of Thessaly | 3 | 5 |
| University of Thessaloniki (Florina) | 3 | 5 |
| University of Thessaloniki | 3 | 6 |
| University of Crete | 2 | no data |
| University of Aegean | 4 | 8 |
| Average | 3 | 5.75 |

[1] For this purpose we have consulted the prospectuses of the following departments of education of Greek Universities:
University of Athens: academic year 1992-1993
University of Patras: academic year 1995-1996
University of Ioannina: academic year 1995-1996
University of Thrace: academic year 1995-1996
University of Thessaly: academic year 1994-1995
University of Thessaloniki (Florina): academic year 1995-1996
University of Thessaloniki: academic year 1995-1996
University of Crete: academic year 1995-1996
University of the Aegean: academic year 1995-1996

It should be noted that in the science education pedagogical related subjects we have included geography and environmental education. Our data show that science education pedagogical related subjects (i.e. "Didactics") are included in all University courses. Indeed, as evidenced by the official curricula there exist three on average science education pedagogical related subjects. From these subjects, two are compulsory and one is selective on average. Table 1 also depicts the percentage of credits (in relation to the overall credits required for a degree in Education) that are allocated into these subjects.

The main dimensions of the content of these science education subjects, in the Greek Universities are:

a. The development of the students' cognitive structures and conceptual change. The epistemological, as well as the historical side of the issue of the change of the scientific knowledge is examined here..
b. The second dimension is more empirical and concerns the recording of representations of certain/particular scientific concepts.

Primary teachers' education courses contain also pure science related subjects.

These, science related subjects are classified according to the dimensions used earlier for the science education subjects. The number of pure science related subjects taught in the Primary teachers' education University Departments as well as the percentage of credits allocated to them is shown in Table 2 below.

**Table 2:** The pure science related subjects, taught in the Greek Primary teachers' education University Departments

| University | Number of Science Courses | Percentage of credits allocated to the Sciences module |
|---|---|---|
| University of Athens | 5 | 21.9 |
| University of Patras | 7 | 11.6 |
| University of Ioannina | 5 | 10 |
| University of Thrace | 11 | 19.2 |
| University of Thessaly | 4 | 6.7 |
| University of Thessaloniki (Florina) | 2 | 3.3 |
| University of Thessaloniki | 4 | 8 |
| University of Crete | 5 | No data |
| University of Aegean | 3 | 6 |
| Average | 5.1 | 10.8 |

From the five on average pure science related subjects taught in the Greek Primary teachers' education University Departments 1-2 are compulsory and 3 are selective ones.

The content of the pure science related subjects focus mostly on the:

a. Basic scientific facts, concepts and principles and
b. Experimental techniques of the corresponding scientific fields.

The comparison between these two broad categories of subjects (Science education and Pure science related subjects) reveals as shown in Tables 1 and 2 that the pure science related subjects are given more emphasis in the primary teachers' educational courses within the Greek Universities.

The same situation exists among the secondary science teachers since before entering the educational system they study in a relevant University department, e.g. department of physics for physicists, department of chemistry for chemists etc., with scarce if any study in education. When in school they teach subjects of their specialization and they are usually asked to teach subjects close to their specialization, for instance a physicist is usually asked to teach chemistry and/or biology, but never subjects which are considered remote to their studies.

**Dimensions of restructuring science teachers' education courses: From Science to School science**

The emphasis on the pure science related subjects (as opposed to science education) in the teachers' education courses of the Universities is not a unique characteristic of the Greek educational system. Similar situations exist in the vast majority of the European countries (European Commission, 2000). This emphasis, though, reflects the underlying assumption that school science is a mere simplification and condensation of the corresponding scientific field. This assumption leads in its turn to an academic orientation in science teaching and backs up the tendency of the science teachers to.pay attention exclusively to the factual aspects of the science content.

This assumption can be only challenged if the school science is considered as a process of re-contextualisation of the scientific body of knowledge (Bernstein, 1996). The most important characteristic of school science is to borrow meanings from the context of scientific knowledge production and reconfigure or reorder them. This reconfiguration and reordering of knowledge has been referred as re-contextualisation and is responsible for radical changes of the image of science presented in the school context.

The process of re-contextualisation of the scientific knowledge in the school context transforms some of its most critical features, preventing the students in this way from realizing its true nature.

If science teachers become aware of the re-contextualisation process, taking place when the scientific knowledge is exported from the context of its production to the school context then they will abandon their single-sided insistence in teaching only the factual aspects of science and they will broaden the scope of their teaching towards the inclusion of all the other aspects (methodology, history of scientific ideas, institutional functions, social impacts) that constitute science more recognizable in the eyes of the students when it appears in the public domain.

The practical implications of this shifting for the Science educators' education courses is the inclusion in them of subjects that illuminate the open, evolving and socially negotiable nature of scientific knowledge. Such subjects can be: a) Philosophy of Science, b) History of Science, c) Epistemology, d) Sociology of Scientific Knowledge, e) Cultural Studies of Science and f) Public Understanding of Science.

These subjects will provide science educators with the appropriate intellectual tools so as to reflect upon the nature of science both in the context of its production and also in the school context and hence enable them to enrich their teaching repertoires with those aspects of science that are more salient in the public domain.

**References**

BERNSTEIN, B., (1996). *Pedagogy, Symbolic Control and Identity: Theory, research, critique*. London: Taylor and Francis.

BODMER, W., (1985). *The public understanding of science*. London: Royal Society.

BYBEE, R.W., (1986). *Science, technology, society. The 1985 yearbook*. Washington, D.C: National Science Teachers Association.

CHIAPETTA, E.L., SETHNA, G.H., and FILLMAN, D.A., (1991). A quantitative analysis of high school chemistry textbooks form scientific literacy themes and expository learning aids. *Journal of Research in Science Teaching*, 28(10): 939-951.

COLLINS, H.M. and PINCH, T., (1993). *The golem: What everyone should know about science.* Cambridge: Cambridge University Press.

CROSS, R.T., (1999). The public understanding of science: implications for education. *International Journal of Science Education*, 21(7): 699-702.

EIJKELHOF, H., (2000). Algemene natuurwetenschappen (ANW): A new course on Public Understanding of Science for Senior General Secondary Education in the Netherlands, (in press) in *Melbourne Studies in Education*, version 25 February 2000.

EUROPEAN COMMISSION, (2000). *Key Data on Education in Europe.* Luxembourg: Office for Official Publications of the European Communities.

FENSHAM, P.J., (1985). Science for all: a reflective essay. *Journal of Curriculum Studies,* 17: 415-35.

FENSHAM, P.J. and CORRIGAN, D., (1994). The implementation of an STS chemistry course in Australia: a research perspective. In J. Solomon and G. Aikenhead (editors) *STS education: International perspectives on reform.* New York, NY: Teachers College Press.

FENSHAM, P., (1997). School Science and its Problems with Scientific Literacy. In R. Leninson and T. Jeff (editors) *Science Today.* London: Routledge.

HODSON, D., (1988). Towards a philosophically more valid science education. *Science Education* 72(1): 19-40.

Jenkins, E.W., (1999). School science, citizenship and the public understanding of science. *International Journal of Science Education,* 7: 703-710.

LAYTON, D., (1984). *Interpreters of School Science.* London: John Murray.

LAYTON, D., JENKINS, E., MACGILL, S., DAVEY, A., (1993). *Inarticulate Science? Perspectives on the Public Understanding of Science and Some Implications for Science Education.* Driffield: Studies in Education.

MILLER, J.D., (1983). Scientific literacy: conceptual and empirical review. *Daedalus,* 112(2): 29-48.

MILLER, J.D., PARDO, R. & NIWA, F., (1997). *Public Perceptions of Science and Technology.* BBV-Foundation.

ROSEN, L.D. & WEIL, M.M., (1992). *Measuring technophobia.* California State University, June Version.

SOLOMON, J. & AIKENHEAD, G.S., (Eds.) (1994). *STS education: International perspectives on reform.* New York, NY: teachers College Press.

WILKINSON, J., (1999). A Quantitative Analysis of Physics Textbooks for Scientific Literacy Themes. *Research in Science Education*, 29(3): 385-399.

WYNNE, B. and MILLAR, R., (1988). Public understanding of science: From contents to processes. *International Journal of Science Education,* 10: 388-398.

WYNNE, B. (1991). Knowledges in context. *Science, Technology and Human Values*, 16(1): 111-21.

**Key Words:** Scientific Literacy, Science Teachers' Education, Re-contextualisation.

080

# ENVIRONMENT AND INTERDISCIPLINARITY: THE CONSTRUCTION OF ENVIRONMENTAL SCIENCE IN FOUR BRAZILIAN GRADUATE PROGRAMS[1]

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**Abstract**

The institutionalization of university programs on environment is a social process that may be understood not only from the viewpoint of its impact on the structure of departments but as the result of a collaboration among professionals demanding epistemological open-mindedness for the exchange among various fields involved to take place.

The thesis on which this article is based had as its goal to analyze several institutionalization processes in order to understand their respective orientations and contents and thus to contribute to the current debate on interdisciplinarity. Through a dialectical socio-environmental perspective, we checked whether the institutionalization processes brought along alterations in the meaning of the concepts of "nature", "life", "human nature", as well as "complexity", "systemic approach", and "transdisciplinarity". Data were obtained through interviews about the institutionalization of environmental sciences in Brazil, aiming at verifying the occurrence of a paradigmatic change.

## Introducing the subject

Enviromental interdisciplinarity refers here to research, knowledge, surveys, analysis and synthesis of reality by different disciplinary fields in joint work linked together by a unified objective focused in the solution of environmental problems. The environmental question is treated both by the Human and the Natural Sciences through a theoretical-methodological approach oriented toward quality of life and sustainable development.

Although it is not realistic to believe in a general unification or universal unity of the sciences, it is reasonable to expect a disciplinary articulation in the face of diversity. It is our hypothesis that the institutionalization of programs related to environment needs to promote interdisciplinarity and this requires paradigmatic changes, from a mechanic-reductionistic perception of the world to that of a systemic-complex one, resulting in a interdisciplinary environmental paradigm.

The goal of this article is to help in the construction and reformulation of curricula that promote interdisciplinary research, teaching and extension at the university level. It also aspires at presenting an evaluation of the state of the art of Environmental Science in Brazil, for the benefit of development agencies.

We attempt first to analyze the process of incorporating environmental questions through studying the discourse of researchers, which may indicate academic tendencies in the construction of paradigms. Second we try to identify different programs working on this interdisciplinary interaction and distinguish representations of interdisciplinarity as they attempt to institutionalize Environmental Science.

We used a quantitative-qualitative methodology inasmuch as we tried to know both the number of specific answer to each question and the type of answer presented, including also the particular vision of each researcher interviewed.. Semi-structured interviews were applied to four teachers and three students of each program, the questionnaire including 12 questions grouped in four dimensions.

Selection criteria for choosing the *stricto sensu* Master and PhD programs of public universities included: time of

[1] PhD thesis on "Interdisciplinarity and Environment in Brazilian graduate programs" financed by FAPERJ from 1996 to 2000 and by CAPES from 2000 to 2001.

implementation; number of theses; origin; teaching staff; subject-matters; accreditation/evaluation; international recognition; contribution to interdisciplinarity and geographic proximity.

## Toward interdisciplinary debate

In the first chapter "Education, University and Society" we review the history of academic evolution, the problems of education in general and of the university in particular and a brief look at the national higher education institutions. Based on works of authors such as J. Diaz Bordenave, C. Buarque, R. Morais, F. Fernandes, P. Freire, C. Furtado, J. Lins Filho, M. Lisboa, M. A. Nogueira, T. Adorno, A. Gramsci, R. Alves, R. Schewarz, R. S. Schwartzman, B. Sousa Santos and M. Weber, we describe the origins, structure, objectives, crisis and solutions of the university. We then study some of the characteristics of each program researched such as habilitation year, academic structure, subject-matters, scientific production, etc. We present a professional description of the researchers.

In the second chapter "Environmentalism and institutionalization" we look at the historic emergence of the environmental question in Brazi and the world as a background for assessing the compartmentalization of knowledge and the departamentalization of the university. In this chapter we use works by J. Baudrillard, C. Castoriadis, J. Alexandre, A. Giddens, J. Le goff, K. Marx, J. Lenoble, J. Lovelock, E. Odum, P. Acot, D.H.Meadows, E.O. Wilson, E. Hobsbawm. Among the Brazilian auhors: R.J. Moreira, A.C.R. Moraes, J.A. Drummond, A. Phillipi Jr., A. Lago, J. A. Pádua. Congress and seminar reports and official documents were also consulted.

In the following chapter we developed the specific notion of "interdisciplinarity" with reference to the ideas of authors such as G. Bachelard, J. Piaget, D. Antiseri, C. Berger, M. Boisot, A. Briggs, G. Michaud. A. Comte, L. Febvre, G. Gusdorf, H. Heckhausen, E. Jantsch, J. T. Klein, M. Lövy, A. Koyré, F. B. Siebeneichler. Among national authors: A. P. Jantsch, A. Follari, D. Marcondes, N. Etges, I. Fazenda. We perceived trends toward more integrated work, reaching the level of transdisciplinarity. The interviews carried out let us question whether there was some type of disciplinary relativization or there is really some dichotomy between Social and Natural Sciences.

In the fourth and last chapter, on "Paradigm", we dealt with the question of epistemology and the crisis of knowledge. We use authors like: E. Morin, L. von Bertalanffy, R. Blanché, N. Bohr, L. Goldmann, T. S. Kuhn e I. Sachs, among others. This allowed us to discuss concepts permeating their contributions such as: "nature", "life", "human nature", as well as "complexity", "systemic approach", and "transdisciplinarity". The outcome of the discussion on paradigm was its application to the concept of sustainable development, using a specific example.

## Some results

For an initial selection of programs to be researched we used first the CAPES-produced list with more than 70 programs. In this first group the majority involved somehow the environmental question, whether in the particular sense of agriculture or in a more general way of development, regional or general, or dealing with questions of health. Similarly we used the list prepared by J. A. Drummond and A. Schroeder[2] which lists 50 interdisciplinary graduate programs in Brazil. In a first selection, we saw possibilities of working with four large groups: a) Biological Sciences (Ecology); b) Environment and Development; c) Human and Social Sciences and d) Environmental Sciences, of which we preferred to consider only one program of each. Below we describe the programs finally analyzed.

We found borderline professional trajectories, considerable regional and international consulting experience, participation in ONGs and research on participation, cooperation and /or environmental education. The institutionalization of the programs suffered more criticism than praise, he compartmentalization of science is seem as an obstacle and both centralization and diffusion in each university unit are taken as relevant. Similarly, a middle term between specialization and generalization through dialogue is perceived as necessary among persons, departments and institutions to attain a true interdisciplinarity. Also in the clash between positivistic

[2] Drummond J.A. & Schroeder, A. Graduate Programs in Enviromental Science and similar in Brazil – a preliminary list". Ambiente & Sociedade, Campinas, NEPAM, NO. 2, 1998.

science and subjective ad qualitative questions the researchers understand that both must be contemplated. New ideas about "nature", "life", "human nature" are stated, at the same time that concepts such "complexity", "systemic approach", and "transdisciplinarity" are explicatory attempts requiring a larger scope, as part of an innovative paradigm that help reform and transform. The replies on sustainable development maintained an equilibrium between skeptic and utopic stands, referring both to its ideological and its revolutionary character. As a final conclusion, the scientific community represented seems to agree that there is need for breaking paradoxes and relativizing dichotomies, on the basis of convergent notions between nature and society.

**- Ecology**

The program of the Federal University of Minas Gerais, Ecology, Conservation and Wildlife Management – ECMVS, received grade 5 in the last CAPES evaluation and was chosen, despite being explicitly disciplinary in Biological Sciences, for having developed a joint project with CEDEPLAR – Regional Development and Planning Center. Through this sustainable development project, both vectors organized themselves around the Program PACDT (Support to Scientific and Technological Development) - CIAMB (Environmental Sciences) of the Ministry of Science and Technology. The methodological proposal stemmed from a macro-project involving a river basin of the region: "a process of reciprocal conviction and discovery", according to the resulting publication[3]. There was a joint analysis looking for indicators of environmental quality, which often transcends the scientific field. In this sense, the quantitative method was used carefully because the degree of social, economic, physical and environmental globality of the local reality is consensually perceived. However, the need for a sectorial procedure requiring a particularized investigation was taken in account. In this case, on the part of the Ecology program, we perceived that the program still present a biocentric bias, resulting in a research practice under marked by conservationist environmentalism. On the other side, under a socioeconomic bias, environmentalism seems to us more integrated to the program in Economics, together with the question of civilizatory development.

The ECMVS was pointed at as sheltering a necessary interdisciplinarity because it lives with professionals of different backgrounds such as park managers, planners of soil use and conservation, etc. For us, a limited relation with Social and Human Sciences, brought up by the fact that teachers of human and exact areas not incorporated in Ecology, which indicates the absence of disciplinary tensions. However, showing their willingness for social insertion, some interactions with society are mentioned by teachers of Ecology, and extension projects truly interdisciplinary are also desired. On the other side, teachers and students of CEDEPLAR expressed attitude change toward optimism as a result of this experience.

In any case, this experience, making it possible for sectors, departments and institutes to work in partnership brings up the perspective of cooperation between Social and Biological Sciences that for so long a time were discrepant. Nevertheless, the Ecology-Economics rapprochement at this university suffers the risk of remaining only in research, not helping yet to reformulate the disciplinary structure of the programs. On the other hand, the project may have sparked sufficient drive for future alterations. Therefore, the PADCT/CIAMB, bringing up questions like the relation between biodiversity, population and economics, seems to have imposed only up to a certain point questions that in our view are fundamental for the program. Although the project contemplates the creation of a new research and teaching line, new subject-matters internal to the program of Ecology were no mentioned in the interviews.

Therefore, we call attention to the difficult but necessary future partnerships between ECMVS and CEDEPLAR as far as joint development of teaching, research and extension strategies is concerned. This articulation may eventually play an indispensable role in the management and conservation of local and regional wildlife, inasmuch as it is after adapting itself to the interdisciplinary work around environmental sustainability, thus preserving socio-bio-diversity.

**- Environment and Development**

The PhD Program in Environment and Development of the Federal University of Paraná is called multidisciplinarian and obtained grade 3 in the present CAPES evaluation. It got the mark of UNESCO quality and also participated in

[3] See Paula, J. A. de. (coord.) *Biodiversidade, população e economia: uma região de Mata Atlântica.* BH: UFMG; PADCT/CIAMB, 1997.

the PADCT/CIAMB. The program presents a centralizing structural unity that promotes practices in regional researches both rural and urban. Its teaching team participates in the permanent opposition of the Natural and Social Sciences whose methodological confrontation makes it possible to think of the local sustainability. Their personal relationship and ideological coincidence are important characteristic of their participants. Besides that, the university tends to the organization of an institute that makes possible the articulation of the graduated program and the Interdisciplinarian Nucleus of Environment and Development - NIMAD program, the last being more envolved with university extension. Their activity points toward a balance between the social reality and the scientific community, both socializing knowledge and structuring citizenship. Thus the program seems to direct itself to a socio-centric approach can be considered a social-environmentalism.[4]

This program, as it carries out the slogan of "think global and act local", demonstrates the real possibilities of the sustainable development through regional practices that are present in their thesis. However we can point to a basic difference between this program and the one previously described. Its possible that MAD, as it is located in the Agrarian Sector far from the Biological Sector, received lesser attention from the conservationist studies. Although some issues referring to health, geography and mainly the ones derived from the Humans and Social Science may be present in the program, one notices the absence of biological professionals *stricto sensu,* partially indicated by the subject matters that are offered. At the same time, the themes developed in the program reveal certain lack of balance such as: rural issues, territorial management, urbanization, public polices, health, sustainable development, ethics and representation. This opinion of ours seems to point to a social-centric bias privileged by the program organizers, although it may also express a point of tension or distance within the academic community of that university. This indicates a contrast with the UFMG program, a fact already perceived when Belo Horizonte program members evaluated negatively the accreditation of the Curitiba program. Such conflict led the researchers of this university and of others (UFSC, UnB) to require the multidisciplinarian modality at CAPES.

Unwilling to devalue the programme, it is our opinion that its participants have promoted social-environmental interdisciplinarity with seriousness and legitimacy in an unique experiment probably to be copied by other universities of the country. Their ideas seen to have been fundamentally inspired by the social economic and environmental dynamics, coming to a conception that may come to build a social-environmentalism. In the other hand, CAPES low evaluation of this program is surprising and may reveal internal tensions for its legitimation. The above mentioned debate allows us to observe the existence of the space for the interdisciplinarian dialog, although it has only reached the distinction between this program and NIMAD, since there are important interactions with society with extensionist approach of the nucleus.

**- Human and Social Sciences**

The Federal University of Rio de Janeiro, through it Graduate Interdisciplinarian Program of Community PsichoSociology and SocioEcology - EICOS obtained grade 4 in its last evaluation. Although this program tends to interdisciplinarity, it fits in a disciplinarian classification, since it was created within the Psychology field, although showing some traces of multidisciplinarity. With the UNESCO quality reference, its course is centered in Human Science tending to articulate with Natural Science. It researches on cultural development, gender, environment, epistemology, ethics and communities indicate an interventionist emphasis which may have resulted from a pragmatic relevance over the theoretical field.[5] As Social Psychology inserts itself in the environmental question, it brings about innovation not without internal conflicts. Anyway, its program is the result of an expressive creativity and conviction and presents an social-centric approach tending to the construction of social-environmentalism.

Although this program has suffered from institutionalization problems it arises with great potentiality since Psychology undoubtedly gives essence contribution to the communities in the construction of the environmental disciplinarity. Furthemore, the presence of a Psychology professional in the interdisciplinarian team takes us to believe that he may help with the inherent tensions present in the meetings with persons and different scientific knowledge.[6]

[4] Of the five programs indicated by CAPES in this field, only this puts "environment" before "development", a fact that may indicate a lower and more humanistic and even conservationist trend.

[5] There are publications of the series Documenta with this discussion.

[6] See the Cadernos of UFPR/GRID Desenvolvimento e Meio Ambiente published since 1994.

The subject matters which are offered, specially those of the Human Sciences, reveal little interest for the biological area, a fact that should present obstacles to the students of different formation who seek elements of Natural Science in this program. In observing the background of the teaching staff as well as the dissertations presented concerning intellectual production, it is verified the distance of the Natural Sciences, although there are exceptions. The academic interactions with society are carried out mainly in the community programs. The theoretical formulation is not explicit in the table of subject matters which reveals an interactive interventionist and applied emphasis. This could caracterize an interdisciplinarity which is rather fed and legitimated by the interaction with the communities.

We could say that "environmentalism" arising from those relationships tends to the anthropocentric perspective and leaves out at least in preference the questions related to the Biological themes. The EICOS program provides Enviromental Sciences with highly important researches for the sustainable development as to the personal and communitarian relationship. Besides that, its lines of research present the possibilities of articulation of other areas such as Sociology, Anthropology, Social Work and Education.

**- Environmental Sciences**

The Graduate Program in Environmental Sciences - PROCAM at Sao Paulo University is called multidisciplinarian and has obtained grade 4 in the last CAPES evaluation. This program explicitly supports the construction of this area troughs a nucleus which congregate various departments and institutes, resulting in an high level experience with practical results. Its institutionalization seems to remove the internal tensions derived from the specific disciplinarian areas, thus valuing interdisciplinarity concepts among the various groups. This may indicates that the structure inherited from the university, subject matters and departments, places tensions and obstacles to the interdisciplinarian work and that the one way out was to create an innovation entity which would promote interaction among the different unities.

Their research projects refer to wide prospects such as the agrarian, medical, geological, technological, political areas among others.The four obligatory subject matters covering theoretical and practical subjects, social and ecological themes show an attempt to articulate the value areas of knowledge, even though their teachers are specialists. The program is carried out in its own headquarters but it also uses the structures of the participating unites, such as Economics, and Bioscience. This seems to favor the development of dissertations with subjects which are a balance between Natural, Hard and Human-Social Sciences, thus reflecting the wide scope of the program, that is expression of the interdisciplinarian work. However, there are still many questions to be solved, such as the lack of a specific staff as it was previously reported in relation of UFPR.

The interdisciplinarity challenges its participants to deal which the social-environmental elements, although the issue of extension is not necessarily part of the practice of the interdisciplinarian dialogue. The interaction development with society - extension programs - are not frequently part of its research. However, numberless practical results in favor of sustainability may be found in the academic conclusions. This may be called "indirect extensionism" which is highly efficient in certain contexts with political and administrative support with the university coordination.

The teaching staff studies issues in interdisciplinarian methodology environmental contexts and ecology in society, as well as environmental evaluation and control. Those considerations lead us to believe that there is a area of consensus in the sense of an equal exchange from each of the three areas of knowledge. However, the graduate commission at the time of the interviews was represented by researchers in Education, Economics, Geoscience and Architecture, demonstrating the absence of the biological science, although there was a specialist of the biological oceanography. Integration seminars make obligatory the interdisciplinarian reflections and interventions, but they don't seem to be sufficient as they represent only two credits units among 38, besides ten more optional. Anyway, we believe that their social-centric bias occurs in a 'social-environmentalism', seeking a balance among the different areas of the scientific knowledge.

## Conclusions

About environmental interdisciplinarity, from authors consulted and statements collected through interviews, we can make the following statements:

- It has a strong reformulation potential, both internal and academic and an important impulse for team work with various participants;
- The challenges include fundamental philosophical, epistemological and ethical questions and not only theoretical and methodological ones;
- The professionals represented suffer considerable stress in "subverting" the old isolationist departmental structure;
- The separation of teaching, research and extension prevents university activities from meeting the socioenvironmental local and regional responsibilities;
- An innovative interdisciplinary pole that would synthetize áreas unite different tendencies and congregate leaderships. Transcending the difficulties inherent to collective work, such articulation when successful brings up a positive integration of different departments;
- The new university locus, therefore, carries with it the possibility of living with diversity. But the challenge persists for all the university hierarchical levels to congregate experiences, methods and world views.

This institutionalization of Environmental Science passes through the art of interdisciplinarity between Biological and Human Sciences, demanding alterations in the sciences as a whole and in the conception of the practices of civilization in its contact with environmental problems. The mechanic-reductionist conception of nature and life seems to suffer a fracture or basic alteration of its central axis in order to be understood in a more complex and systemic way. In this sense, the debate around this change of paradigm is inevitable, although the question has been fragilized by the lack of total transformation in the attitudes, values and principles of the social actors, academicians, politicians, technicians. The university curricula that limit themselves to teach and research are still active but we want to believe that interdisciplinarity around a socio-environmental ideal will collaborate in promoting a movement toward university extension, also desired by the more committed and active teachers.

The four programs analyzed represent, therefore, an academic innovation oriented to the construction of Enviromental Science. We perceive how the necessity of internal partnerships may be a promising potential for external work with the surrounding community, even if indirectly. Thus we believe that research and teaching may ally themselves with the extension component of academic activity, helping theory and together work together to return to society what is created and debated in the university activity. The disciplinary articulation favors the constitution of an integrative paradigm, searching for an equilibrium between socio-political-economic development and environmental sustainability.

To become reality the ideal of paradigmatic change will suffer strong challenges in the university practice of innovation beyond mere academic execution. Therefore, we perceive as highly relevant the efforts to formulate interdisciplinary pedagogies, research studies and extension activities that may perform the true mission of scholarly knowledge.

## Principal bibliography

ACOT, P. *História da Ecologia.* Rio de Janeiro: Campus, 2ª. ed., 1990.

BACHELARD, G. *A Epistemologia.* Lisboa: Edições 70, 1971.

BAUDRILLARD, J. *A sociedade de consumo.* Rio de Janeiro: Elfos, 1995.

BLANCHÉ, R. *A epistemologia.* Lisboa: Presença, 1983.

BOHR, N. *Física atômica e conhecimento humano.* Rio de Janeiro: Contraponto, 1995.

BUARQUE, C. *A aventura da universidade.* Rio de Janeiro/São Paulo: Paz e Terra/UNESP, 1994.

CASTORIADIS, C. *As encruzilhadas do labirinto I.* Rio de Janeiro: Paz e Terra, 1978.

FAZENDA, I.C.A. *Interdisciplinaridade: história, teoria e pesquisa.* São Paulo: Papirus, 1994.

FEBVRE, L. *Combates pela história.* Lisboa: Presença, 1989.

FERNANDES, F. *Educação e Sociedade no Brasil.* São Paulo: Dominus/USP, 1974.

GIDDENS, A. *As Conseqüências da Modernidade.* São Paulo: UNESP, 1990.

GRAMSCI, A. *Os intelectuais e a organização da cultura.* Rio de Janeiro: Civilização Brasileira, 1989.

GUSFDORF, G. *A interdisciplinaridade.* Ciências Humanas. Rio de Janeiro: 1(2):13-22, jul.set., 1977.

HOBSBAWM, E. *La era del capitalismo* Madrid: Labor, 1984.

JANTSCH, A. P. & BIANCHETTI, L. (orgs.) *Interdisciplinaridade para além da filosofia do sujeito.* Petrópolis: Vozes, p.177-194, 1995.

JANTSCH, E. *Towards interdisciplinarity and transdisciplinarity in education innovation.* In: OCDE. Seminário Internacional sobre Interdisciplinaridade nas Universidades, p.108-9, 1972.

JAPIASSU, H. *Interdisciplinaridade e patologia do saber.* Rio de Janeiro: Imago, 1976.

KLEIN, J. T. *Interdisciplinarity: History, Theory and Practice.* Detroit: Wayne Univ. Press, 1990.

KUHN, T. S. *A estrutura das revoluções científicas.* São Paulo: Perspectiva, 1994.

LENOBLE, J. *História da idéia de natureza.* Rio de Janeiro: Ed. 70, 1969.

LÖVY, M. *Ideologias e Ciência Social: elementos para uma análise marxista.* São Paulo: PUC/Cortez, 11ªed., 1996.

MARCONDES, D. A crise de paradigmas e o surgimento da modernidade. In: BRANDÃO, Z. *A crise dos paradigmas e a educação.* São Paulo: Cortez, p. 14-29, 1995.

MEADOWS, D.H. et al. *The limits to growth: a report for the club of rome's project on the predicament of mankind.* NY: Universe, 1972.

MICHAUD, G. *Conclusions générales.* In: OCDE. Seminário Internacional sobre Interdisciplinaridade nas Universidades, p. 298-9, 1972.

MORAIS, R. de. *A universidade desafiada.* Campinas: UNICAMP, 1995.

MOREIRA, R. J. Sociedade e universidade: cinco teses equivocadas. Rio de Janeiro: UFRRJ/CPDA. *Revista Estudos,* nº. 3, nov., p.124-34, 1994.

MORIN, E. *O problema epistemológico da complexidade.* Lisboa: Biblioteca Universitária, nº 38, 1996.

_______. *De la reforma universitaria.* Revista Trabajo Social. México: UNAM, 1997.

PIAGET, J. *Problemas gerais da investigação interdisciplinar e mecanismos comuns.* Rio de Janeiro: Bertrand. Coleção Ciências Sociais e Humanas, v.VIII, p.17, 1964.

SOUSA SANTOS, B. de. *Pela mão de Alice*: o Social e o político na pós-modernidade. São Paulo: Cortez, 3ª.ed., 1997.

WEBER, M. *Sobre a Universidade*: o poder do Estado e a dignidade da profissão acadêmica. São Paulo: Cortez, 1989.

**Key words:** interdisciplinarity, environment, graduate programs, paradigm, environmental science.

# 081 THE ROLE OF SCIENTIFIC DISCOURSE IN BIOEXHIBITIONS PRODUCTION

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**Abstract:**

This paper is the outcome of a PhD thesis produced at the School of Education of São Paulo University and studies the transformation process of scientific discourse - particularly the biological - into expositive discourse in the construction of science museum exhibitions. The methodological approach was based on the principles of qualitative research. Five exhibits were selected from the following museums: Zoology Museum, Veterinarian Anatomy Museum, Oceanographic Museum, Science Station, all belonging to the University of São Paulo (SP), and the Museum of Life – Biodiscovery Space of the Oswaldo Cruz Foundation (RJ). To understand the construction of the expositive discourse, we used the studies carried out by Basil Bernstein (1996) in the field of educational sociology. Also, others authors, related to museum communication and to the concept of didactic/museographic transposition were used. Based on the articulated study _ of the history of Biology and _ the history of museums, the exhibits were described and their constitutive elements such as texts, objects, the relationship between collection, research and exhibit, the discourses present and the role of the biological discourse in the formation of the expositive discourse were analysed. The results suggest the necessity of going deeper into the question regarding the production of biological knowledge, its history and epistemology. The introduction of biological phenomena in science museums raises questions about the particularities of this type of knowledge and may contribute to the understanding of these particularities in teaching and broadcasting.

## I - Introduction:

This article is the outcome of a PhD thesis produced at the School of Education of São Paulo University and studies the production process of science museums exhibitions, i.e., the transformation process of scientific discourse - particularly the biological - into expositive discourse. The characteristics of the various discourses and areas of knowledge that participate in that process were described as we identified what happens to scientific knowledge when is to be expressed in bioexhibitions.

References from the areas of education, scientific divulgation, communication and language, in addition to the works on museology as well as on the history of biology and science museums provide theoretical basis for the study. As such, it focuses on understanding what happens to scientific knowledge when it is presented in museum exhibitions treated as pedagogical entities.

The methodological approach was based on the principles of qualitative research. Five exhibits were selected from the following museums: Zoology Museum, Veterinarian Anatomy Museum, Oceanographic Museum, Science Station, all belonging to the University of São Paulo (SP), besides the Museum of Life – Biodiscovery Space of the Oswaldo Cruz Foundation (RJ).

In this work, we present part of the data from the research related to the role of the biological discourse in the construction of bioexhibitions.

## II – The Studies on Transposition and on Recontextualization of Scientific Knowledge: A Brief Synthesis

The transposition of scientific knowledge to other social arenas has increasingly been the theme of studies in educational and scientific broadcasting areas. Researches in Education have been defending the idea that "scientific knowledge and the knowledge acquired in school lies on different learning spaces and school disciplines hold a different epistemological and sociohistorical background than scientific disciplines" (Lopes, 2000:150). Among other implications, this idea recognizes the existence of a "school culture", with the school as "also being a true producer or creator of cognitive configurations and original habits" (Forquin, 1993:34).

Chevallard (1991), for instance, introduces the concept of didactic transposition stating that "Knowledge-as-it-is-taught, the taught knowledge, is necessarily distinct from the knowledge-initially-designated-as-being-the-knowledge-that-must-be-taught, the knowledge to be taught." (Ibid., p.17). According to Chevallard, the knowledge contents designated as those to be taught are true didactic creations, caused by the educational needs and go through a collection of adaptive transformations. The work involved in transforming a subject of knowledge to be taught into a teaching subject is what he calls "didactic transposition".

Other authors have been working with the concept of didactic transposition and there are indications that other elements than the wise knowledge - as, for instance, the social practices, are references for the construction of school knowledge (Astolfi and Develay, 1990; Caillot, 1996).

Regarding the subject of didactic transposition in museums, the work by Simonneaux and Jacobi (1997) stands out, since they propose the notion of museographic transposition based on Chevallard's work, to describe the transposition of the acquired knowledge into a knowledge to be displayed in exhibitions. Also, we used works about museum communication from Davallon (1999).

Another important reference for the comprehension of the process of translating scientific knowledge are the studies carried out by Basil Bernstein (1996), in the field of educational sociology. This author goes further into the subject of the construction of pedagogic discourse, stating that "pedagogic discourse is a starting point for seizing other discourses and putting them in a special mutual relation, aiming at its conveyance and selective acquisition". As such, to Bernstein (1996:259) "pedagogic discourse is thus a principle that removes a discourse from both its practice and context and relocates that discourse in accordance with its own focusing and selective reordering principles". Thus, the constitution of the pedagogic discourse implies a *recontextualising* principle that selectively appropriates, relocates, refocuses and relates other discourses in order to make up its own order and orderings. Bernstein's work helps us to better understand the process of creating the pedagogic discourse. If we regard museum exhibitions as pedagogical entities and the expositive discourse as a kind of pedagogic discourse then it is essential to consider that this discourse *recontextualised* other ones, including the scientific.

## III – From Natural History to Biology: Walking through the History of Science Museums

The knowledge stemming from the field of biology has long been the subject of science museums exhibitions. Natural History Museums began serving the purpose of collecting, preserving and studying specimens that allowed the systematic investigation and research of nature (Gil, 1988:72). The so-called "Curiosity Cabinets", originated in the 16th Century, gathered heterogeneous collections with samples from nature, historical items and antiques and had their role slowly changed, in an attempt to "replace their old displays by catalogued exhibitions which became a way to introduce 'an order of the same character established among the alive' in the world's conceptual definition and, thus, offering another way of making history" (Lopes 1997:13).

Some milestones were essential in the development of these museums throughout their history. The modern origin of Natural History Museums can be represented with the French example of the *Museum National d'Histoire Naturelle* (1793), the first modern museum of this kind, (Gil, 1988:75), although it has a long history. In the end of the 19th Century, Darwin's work was another milestone in the history of these museums, since: "(...) it produced a decisive evolution in the Natural History Museum's concept and objectives which developed from mere galleries for admiring curiosities into institutions that, apart from broadcasting natural knowledge, play the role of research institutes with the aim of promoting the methodical exploration and systematic study of nature." (Ibid.).

Influenced by Moebius' theory a new transformation takes place in these museums. This theory "is based on the principle of a clear separation between a scientific collection (for research purposes, therefore as comprehensive as possible) and the one which is put to public display, based on the latter but carefully organised and displayed with its most representative items, or their accurate replicas, for a convenient and fruitful approach of the treated subjects by non-specialists" (Idem.).

Natural History Museums have developed throughout the years and are still constituted of collections that highlight scientific research. However exhibitions are becoming more and more important, increasing the use of the resources of modern museology.

On the other hand, Science and Technology Museums have also developed in the history of museums, also with important milestones that help understand contemporary science museums. The origin and aims of these museums are different from those of Natural History, since they were from the beginning "created with essentially utilitarian objectives" (Gil, 1988:77). One may, however, state that this utilitarian aspect depicted a gradual concern with showing scientific and technical evolution to the public and this has become one essential element of these museums.

The 20th Century thus inaugurates a new type of museum in this field, the so-called *Science Centres.* These museums are originated with the "perception of the imperative educational needs, attempting to revolutionise its teaching methods through observation and experimentation" (Ibid., p.80). Such institutions are firmly gaining space within society and among the several transformations they have been going through, some stand out: those most recent ones, related to their perception of the role of the public, since these museums were the ones to have found, through educational activities, a new way to regard the relation between visitor and displayed object.

Another way to perceive the history of these museums is indicated by Cazelli et al. (1999), based on the work produced by McManus (1992). Science Museums are thus characterised by the themes that initiated them, that is: a) the first generation ones, i.e., the Natural History Museums; b) the second generation ones, where emphasis is put on the world of labour and on the aspects related to science and industry; and c) the third generation ones, centred on scientific phenomena and concepts. To Cazelli et al., this third generation of science museums encompasses the concern to improve education and holds a central focus on scientific phenomena and concepts. At the same time, in these museums the communication between visitors and science is mediated by a stronger interactivity with the different displayed devices and the role of the visitor in the learning process is emphasised.

However, the perspective of interactivity in museums only recently has been argued (Gil e Lourenço, 1999; Falcão, 1999). It is, for instance, stated that the *hands on* type of interaction does not necessarily guarantee an intellectual engagement. Another criticism concerns the natural identification of the interactive expression with Physics, turning the application of this type of communication in fields like Chemistry and Biology a much harsher task to undertake. Besides that, the lack of concern with the historic-cultural dimension and with the scientific processes, their history and their implications in the social context are also argued.

Regarding Biology, its constitution as a discipline as we know it today is relatively new. Since its birth in the 19th Century, this area of knowledge has been kept in separate parts for a long period of time and according to Smocovitis (1992), the proposition of the Evolutionary Synthesis in the 30's, was a key factor for its unification. The autonomy and even the idea of a unified Biology are not consensual among epistemologists and science historians (Jacob, 1985 in Wortmann, 1994). However, the changes occurred in the field of Biology towards becoming a scientific discipline and the discussions related to the questions on Biology and Society as well as on Ecology and Environmental Crisis have also been influencing the conception of Natural History Museums. Brown (1997:39), for example, argues that the present role of these museums vis-à-vis the innovations in biological fields, such as the development of modern genetics, and proposes a new way of *collectionism* that is able to meet the planet's needs. Other authors have been raising the questions associated with the impact of the new research perspectives in Systematic and in Modern Biology in defining the role of museums (Mayr, 1988; Erzinçlioglu, 1993; Brandão, 1999).

As such it is possible to say that the particularities of the teaching/broadcasting and learning processes in science museums have been pointing at the necessity to consider the results produced by research in this field in the preparation and evaluation of both the exhibitions and the cultural and educational activities in these settings. One may thus say that for the elaboration of bioexhibitions in science and natural history museums today, aspects concerning the history and structure of the biological knowledge as well as the incorporation of the educational and communicational references must be considered. Questions pertaining to the relations among scientific research, collection, assets and display, as well as to aspects of management and administration, also influence the conception and construction of the expositive discourse.

## IV – The Construction of Expositive Discourse: Some Considerations

Based on the articulated study of the history of Biology and the history of museums, the exhibits from the research were described and their constitutive elements such as texts, objects, the relationship between collection, research and exhibit, the discourses that were presented and the role of the biological discourse in the formation of the expositive discourse were analysed.

Taking in account the data obtained in the research, three items were discussed. The first refers to the educational and communicational perspectives of the exhibits. A second aspect relates to the 'game' taking place in the expositive discourse constitution: the expositive discourse has a behaviour similar to Bernstein's pedagogic discourse, for it displaces other forms of discourse based on its own principles and objectives and assumes the characteristics of the "recontextualizing" discourse. Nevertheless it is worthwhile observing that the expositive discourse has specific characteristics different from the school pedagogic discourse, which results from the relationships between time, space and the objects in the museums with direct implications upon the evaluative rules of the discourse constitution. It is postulated that the expositive discourse constitutes a specific discourse, since it has its own objectives and it arranges other discourses according to its own logic, it behaves similarly to the pedagogic discourse.

Finally, modern questions on the issue of biology exhibitions in museums were discussed. After an analysis of the role of the biology discourse in the making up of the expositive discourse, challenges, limitations and possibilities that the biology area must impose in order to be presented, were discussed. Various perspectives were suggested aiming at presenting Biology in museums.

In what concerns the biological discourse in the constitution of the expositive discourse, some elements will be pointed out. From the point of view of the studies about the history of biology and the history of the museums it is possible to affirm that the presence of authentic objects, scientific and natural, as conserved beings, fossils, living creatures, etc. marks the legacy of Natural History and its role as a science at a time where the Museums of Natural History were the main centres of production of knowledge in this area. At this moment, more than understanding biological concepts, it is necessary to present natural sciences, its discourse and its logic so that the exhibits show the systematic and taxonomic organization of living creatures. That perspective considers the object the main element. On the other hand, with the sprouting of dioramas in the Museums of Natural History and, later, the increase of the use of the devices, models, rejoinders, etc.. in Museums of Science and Technique and the Science Centres, such objects had clearly more didactic objectives, related to the presentation of the concepts to the public.

As _ mentioned before, Natural History had been through deep modifications in its growth, mainly with the Theory of the Evolution. Recently, Biology became an autonomous discipline, although there is no consensus in the debate on this subject. This new picture also brought new contents, especially in Genetics, Molecular Biology, as well as Ecology. Other challenges appeared to the exhibition development at museums.

The final of the 20th century is strongly marked by the questioning of the objectives of the Natural History Museums and one of the quarrels is to which thematic choice these museums must be dedicated today. Many defend that the Natural History Museums must give priority to environment problems, since these possess a high level of penetration in the society and influence some aspects of the human life and all beings of the planet. On the other hand, some scientific researchers from the Natural History Museums criticize the perspective of assuming a thematic body _ in the displays that is not connected with the research in Biology developed in the institution. In these cases, the exhibitions would have to present the research in Zoology and Botany, mainly in the aspects related to Systematic and the Evolution, but also in Ecology if it is a subject of research in that place.

Subjects related to the human being, in Physiology, Anatomy, but also in Health, would be out of the Natural History Museums and, in this case, these issues could be presented in bioexhibitions, carried out in Centres and Museums of Sciences and Technology, where there is no research in the biological field. Bioexhibitions from other types of museums and centres of scientific culture, not the ones of Natural History, would have to develop these thematics.

Another important aspect of this debate is related to the contemporary biological knowledge presented in the Natural History Museums and bioexhibition, and to the historical perspective of construction of knowledge disclosed through the narrative of the displays. To present Biological Sciences as a historical process, a product of changes in the scientific, political, economic, social and cultural fields is something that has to be made in a consistent, dynamic and interesting way for the public who visit the museums. In this perspective, we have to mark the fact that the current quarrels in the fields of Systematic are totally absent in the Brazilian museums when they present themes related to Natural History.

The collections and displays of the Natural History Museums can be considered certifications of the development of Natural Sciences and through them one can understand not only Natural History but also the history of Biology and the contents of these fields, in such a way relative to Systematic and Taxonomy, Ecology, Biodiversity, as aspects of contemporary Biology among others. These museums are basic institutions for the study of the scientific policies in these areas of knowledge and can thus assist in the acceptance of Science as part of the culture of the society. For this, it must be guaranteed that the public can understand the message contained in objects.

The museums in this area must not only make its exhibitions to tell these histories of Biology, as to develop educative and cultural activities in this perspective. The public must have access to this information and, for this, the didactic character of the museums must be assumed as basic. As indicated by Girault and Guichard (2000), it is through the collections and the displays that a non-formal biological education in the museums can be developed.

Another subject related to the difficulty to present the biological phenomena in its integrity and complexity in exhibitions is the dimensions of time and space. When these phenomena are exposed, in some cases the information appear fragmented and reduced to its physical dimensions, as _ happens with some experiments of sensorial physiology and anatomy - and the strict biological explanations appear, in texts and pictures. These difficulties seem to surpass the time and space question imposed by the specificity of the museum's exhibitions and include, also, some particular features of Biology as knowledge. Its complexity, and the totality of the phenomenon, is not easy to present, needing the use of intermediary devices - models, simulations, iconography, for its presentation and explanation.

All exhibitions have institutional commitments related to their objectives and these must be considered when analysing them, since the expositive discourse is also a commentary on the scientific discourse (Van-Präet and Poucet, 1995). However, as it was characterized in this research, the expositive discourse recontextualizes other discourses, with a proper logic, which is related to the spreading of education through media. The scientific discourse thus is relocated by the recontextualizating principle of the expositive discourse, which has its proper selective principles, which refers to the dimension of the time, the space and the objects in the museums.

In this process of recontextualization, the biological discourse is inlaid in the logic of the expositive discourse and participates in the negotiation play that occurs in the construction of the exhibition, bringing with it its histories, its structure, its contents and its procedures. However, beyond it, other discourses also enter in this game, with its features, modes, contents and structures. A selection process takes place, elements are left aside and new approaches are taken in account, with a scope different from the one of the original discourse. Depending, among other factors, on the conceptual options - politician ones as well as the institutions' historical ones -, some voices take part of this discourses negotiation with more intensity than others, thus imposing their own logic, structure, procedures and contents.

Moreover, the more the conceptual proposal is centred on the mediation with the public, the recontextualization process is more evident and more discourses can be part of the negotiation. On the other hand, the more the exhibition conception is centred on information and its transmission, the recontextualization process, with few discourses in play, will privilege one or few discourses, often prevailing the logic and the structure of the scientific discourse.

## V – Conclusion:

The present study seeks to understand the construction process of the expositive discourse based on the idea of the recontextualising redefinition of the scientific discourse takes place when it is transposed to science museums exhibitions. However, all evidences point towards the fact that scientific discourse is not the sole responsible for regulating and determining this construction. Other discourses could be an active part of this process and, according to the conception adopted in elaborating the exhibition, these other discourses may be more or less intensely expressed in the expositive discourse.

## Bibliography:

ASTOLFI, Jean-Pierre e DEVELAY, Michel. *A Didática das Ciências.* Campinas, Papirus, São Paulo, 1990.

BERNSTEIN, B. *A Estruturação do Discurso Pedagógico – classe, códigos e controle.* Editora Vozes. Petrópolis, 1996.

BRANDÃO, C. R. F. Processo Museológico: Critérios de Exclusão – O Caso dos Museus de História Natural. In *Anais II Semana de Museus da Universidade de São Paulo*, Pró-Reitoria de Cultura e Extensão Universitária, São Paulo, 1999.

BROWN, E. H. Toward a Natural History Museum for the 21st Century – Change Catalogue. In *Museum News*, p. 39-40, November/December, 1997.

CAILLOT M. *La Théorie de la transposition didactique est-elle transposable? In Au-delá des didactiques, le didactique. Débats autour de concepts Fédérateurs.* De Boeck & Larcier, p. 19-35, Paris, Bruxelles, 1996.

CAZELLI, S., QUEIROZ, G., ALVES, F., FALCÃO, D. VALENTE, M. E., GOUVÊA, G. e COLINVAUX, D. Tendências Pedagógicas das Exposições de um Museu de Ciência. In *Atas do II Encontro Nacional de Pesquisa em Educação em Ciências*, Valinhos, São Paulo, September, 1999.

CHEVALLARD, Y. *La Transposición Didáctica: del saber sabio al saber enseñado.* Editora Aique, Argentina, 1991.

DAVALLON, J. *L'Exposition à L'Ouvre – Stratégies de communication et médiation symbolique.* L'Harmattan, France, 1999.

ERZINÇLIOGLU, Y. Z. The Failure of The Natural History Museum. In *Journal of Natural History*, N 27, p. 989-992, 1993.

FALCÃO, D. A Interatividade nos Museus de Ciências. In *VI Reunião da Red-Pop*, Museu de Astronomia e Ciências Afins/UNESCO, Rio de Janeiro, June, 1999.

FORQUIN, Jean-Claude. *Escola e Cultura: as bases sociais e epistemológicas do conhecimento escolar.* Artes Médicas, Porto Alegre, 1993.

GIL, F. Museus de Ciência. Preparação do Futuro, Memória do Passado. *Revista de Cultura Científica.* Lisboa, n.3, p. 72-89, out., 1988.

GIL, F. B. e LOURENÇO, M. C. Que Cultura para o Século XXI? O Papel Essencial dos Museus de Ciência e Técnica. In *VI Reunião da Red-Pop*, Museu de Astronomia e Ciências Afins/UNESCO, Rio de Janeiro, June, 1999.

GIRAULT, Y. e GUICHARD, F. Spécifiticité de la didactique muséale en biologie. In: La Muséologie des Sciences et ses Publics – Regards croisés sur la Grande Galerie de L'évolution du Muséum national d'histoire naturelle.Education et Formation. PUF, Paris, 2000.

LOPES, A. Organização do Conhecimento Escolar: analisando a disciplinaridade e a integração. In *Linguagens, espaços e tempos no ensinar e aprender.* Encontro Nacional de Didática e Prática de Ensino (ENDIPE), p. 147-162, DP&A, Rio de Janeiro, 2000.

LOPES, M. M. *O Brasil Descobre a Pesquisa Científica: os museus e as ciências naturais no século XIX.* Editora Hucitec, 1997.

MAYR, E. *Toward a New Philosophy of Biology – Observations of an Evolutionist.* Harvard University Press, Cambridge, 1988.

McMANUS, P. Topics in Museums and Science Education Studies. In *Science Education*, V. 20, p. 157-182, 1992.

SIMONNEAUX, L. e JACOBI, D. Language constraints in producing prefiguration posters on scientific exhibition. In *Public Understand. Sci.* Vol. 6, p. 383-408, 1997.

SMOCOVTIS, V. B. Unifying Biology: The Evolutionary Synthesis and Evolutionary Biology. In *Journal of The History of Biology*, Vol. 25, p.1-65, Cambridge, 1992

WORTMANN, M. L. C. *Programações Curriculares em Cursos de Ciências Biológicas: Um Estudo sobre as Tendências Epistemológicas Dominantes.* Tese de Doutorado em Educação, Universidade Federal do Rio Grande do Sul, Porto Alegre, 1994.

VAN-PRAET, M. e POUCET, B. Les Musées, Lieux de Contre-Éducation et de Partenariat Avec L'École, In: *Education & Pédagogies – dés élèves au musée*, No. 16, Centre International D'Études Pédagogiques, 1992.

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# PARADIGM SHIFTING AND THE NEW FACE OF SCIENCE EDUCATION"

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A vision of the future of Science Education in Canada has been suggested by the Pan Canadian Science Framework (Council of Ministers of Education, Canada, 1997).) One of the notable evolutions envisioned in this document is the mandatory inclusion of the Science Technology Society and Environment (STSE) perspective. This vision has also been creeping into the US and other global reform efforts for the past decade. Even though many believe that that this is a step to making science more inclusive, this paper seeks to problematize this emerging face of Science Education and offers an alternative or expanded perspective.

We begin by illustrating that while the inclusion of more environmental concepts in science classes can be seen as advancing the current reform efforts (using Ontario and BC as examples), we maintain that students are only being asked to understand environmental issues socially acceptable limits. Therefore, we will highlight that without a socio-cultural critique, science education maintains and promotes hegemonic beliefs and values while not addressing collateral problems relating to scientific developments. We then continue by describing how science education should be viewed as a complex undertaking involving a consideration of scientific, economic, ethical and political perspectives.

## Introduction

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We begin by illustrating that while the inclusion of more environmental concepts in science classes can be seen as advancing the current reform efforts (using Ontario and BC as examples), we maintain that students are only being asked to understand environmental issues socially acceptable limits. Therefore, we will highlight that without a socio-cultural critique, science education maintains and promotes hegemonic beliefs and values while not addressing collateral problems relating to scientific developments. We then continue by describing how science education should be viewed as a complex undertaking involving a consideration of scientific, economic, ethical and political perspectives.

## Science Education in Ontario

In the past two years have seen a new secondary science curriculum introduced in Ontario. This curriculum is reflective of the Pan Canadian Science Framework and suggests relating science to technology, society and the environment (Ministry of Education, 1999). It suggests this new STSE element should be linked to scientific concepts and skills and where possible, real-world problems (Ministry of Education, 1999). The goal being to generate scientific literacy by encouraging Canadians to understand impacts science and technology have on their lives (Ministry of Education, 2000). The science, technology, society and the environment section of every science subject is intended to be one of three core elements the students must master before passing any science courses. The core elements are:

1. basic scientific concepts;
2. developing skills, strategies and habits of mind required for scientific literacy; and
3. relating science to technology, society and the environment.

In the previous curriculum, environmental issues were taught in a separate course called environmental science that focused on scientific facts and concepts. These facts related to the natural environment and for the most part, this information can still be found in the same neutralized form in the geography curricula. In the current curriculum, environmental issues are apparently integrated into every science course through this new STSE aspect. This element mainly promotes scientific concepts as it suggests outlining the contributions science and technology have made to the daily lives of the students. Rather than promoting a critique of science and its relationship to social and environmental injustices, it requests that students investigate various careers in the different science disciplines. Its focus is on promoting the positive attributes of science/technology and how they enhance the everyday life of the student.

Within this STSE perspective there is a strong bias towards the positive 'technology' aspects of students' daily lives. The 'society' aspect does not review or critique the underlying beliefs, values and assumptions embedded within a society that promote and maintain social and environmental injustices, but rather highlights how science impacts students' lives. The 'environment' aspect has the weakest representation even though many people believe the STSE element represents the environmental side of the science curriculum. This 'environment' element has less focus on scientific facts than its predecessor, as the content section of the curriculum accounts for this, but rather encourages the exploration of dominant economic and scientific opinions of environmental problems and solutions.

## A Critique of STSE in Ontario and implications for Science Education

If the STSE element is to encourage the discipline of science education to address the positive and negative collateral social and environmental issues that arise alongside scientific and technological advancement, then I question whether Ontario's new science curriculum will reach this goal. It ignores important dimension of social and environmental issues that involve emotional concerns, beliefs, aspirations, aesthetics and vested interests. It also does not acknowledge that dominant worldviews create societies that are structurally unequal in beliefs and values that relate to class, gender, sexual orientations and race relations. To this end, what this curriculum leaves out highlights that education can never be neutral as dominant educational agendas seek to maintain and reproduce a particular social structure. The STSE element seeks to engage students about environmental issues within safe and politically acceptable limits. The curriculum mandates hegemonic beliefs and values and does not address root causes of social and environmental injustices or work towards anything but a marginal understanding of the greatest threat humanity may face in the next millenium.

Furthermore, STSE should promote more than just a holistic awareness and understanding of environment issues. It should also promote concern and work towards individual or collective action (Fien, 1993; Hines, Hungerford & Tomera, 1986/87; Huckle, 1993; Robottom, 1987). However, only a minority of science educators engage in actions and those actions tend to reflect individualistic lifestyle changes rather than collective action (Zandvliet & Sammel, 2001). It is to this collective action that greater movement towards social and environmental justices can be achieved rather than the limited amount of change that stems from individual lifestyle changes. Both are needed, but if science educators stress one to the exclusion of the other, this has implications for achieving an inclusive perspective.

In summary, the STSE element of the current Ontario curriculum stresses facts and information but due to its inclusion of only political appropriate issues, maintains the status quo and so reproduce society's ideals and inherent problems. It ignores the political agenda of whose knowledge is included in the curriculum, for whose benefit and who is disadvantaged by this knowledge. In contrast, I believe the inclusion of a critical STSE perspective has the potential to challenge the dominant social paradigm while working to explore ways of reinventing the structures and practices of schooling. If schools are shaped by a society and in turn can work to shape a society, then schools need to include a STSE perspective that promotes a reflection on past and present social beliefs, supports the opportunity to learn about political change and encourage students to feel capable of altering governmental policy to advance social and environmental justice. This, unfortunately is not the goal of the STSE perspective in Ontario's new science curriculum. Formal education in BC takes a different approach as the next section highlights.

## BC's Environmental Education Framework

British Columbia is also committed to addressing socio-cultural and environmental issues which arise alongside technological and scientific development, though it has not adopted the Pan-Canadian Science framework in doing so. There are multiple perspectives inherent in the conceptual framework which informs the pedagogy of environmental science topics in BC. These viewpoints are those that are also commonplace in the wider community and form the true context for learning about environmental issues. This framework: *Environmental Concepts in the Classroom* (Ministry of Education, 1995), describes how teaching about the environment is a complex undertaking involving a consideration of scientific, economic, ethical and political perspectives. It describes how educating students about the environment provides students with opportunities to learn about the functioning of natural systems, to identify their beliefs and issues, to consider a range of views and ultimately to make informed and responsible choices. The framework can be used at any grade level/subject and functions as a model for integrating environmental science issues throughout the broader curriculum and for inclusion of the socio-cultural context which forms the backdrop for science and technological developments.

In bridging the theory and practice of environmental education six principles central to our pedagogy are enacted in the published BC framework, those of: direct experience; responsible action; complex systems; consequences of actions; aesthetic appreciation and environmental ethic (Ministry of Education, 1995). Direct experience with the environment is a central platform to the guidelines as they provide students with a deeper understanding of natural systems and human impacts on those systems. Responsible action is considered integral to, and a consequence of environmental education. In B.C., environmental education addresses the study of complex systems in two ways: it examines the complexity and inter-relatedness of natural systems and; it looks at human-created systems, both those that our built or part of the social fabric. Students learn how human decisions and actions have environmental consequences, that environmental awareness enables students to develop an aesthetic appreciation of the environment. Finally, the study of the environment can enable students to develop an environmental ethic. In particular, frameworks such as this may provide a more inclusive model generally for the teaching and learning of science.

## Pedagogical Issues

From the perspective of the educational reform movement and for new models of teaching and learning, scientific, technological or environment topics can form an authentic context in which learning processes can be situated, thus making the learning content more meaningful to students. In turn, this facilitates deep understanding of the subject matter: a key component of the reform effort in science education. Still environmental topics can sometimes be reduced to the transmission of a body of knowledge or facts related to nature study.

A great deal of attention has been paid to the notion of other forms of intellectual capacity and learning such as social and emotional capacities. Goleman in his 1995 book *Emotional Intelligence*, provided much evidence for social and emotional intelligence as the complex and multifaceted ability to be effective in all the critical domains of life. Goleman states the key point simply: "It's a different way of being smart." These multiple intelligences are socially based and interrelated: "It's difficult to think of linguistics, musical, and interpersonal intelligence out of the context of social and cooperative activity...".

Environmental education frameworks provide opportunities for developing social and emotional competencies: described as the ability to understand, direct, and express the social and emotional aspects of one's life. They include self-awareness, control of impulsivity, working cooperatively, and caring about oneself and others. Knowledge of ourselves and others as well as the capacity to use this knowledge to solve problems creatively provides an essential foundation for both academic learning and the capacity to become an active, constructive citizen (Cohen, 1999). Still, many would argue that this type of framework does not go far enough in describing the socio-political context that underpin many scientific or technological developments.

## An Expanded Ecological Framework

To many, another framework has begun to develop which might positively inform the pedgogy of science education in the future. Termed *ecological education*: it connotes an emphasis on the inescapable 'embeddedness' of human beings in natural systems. Rather than seeing nature as other - a set of phenomena capable of being manipulated like parts of a machine - the practice of viewing human beings as one part of the natural world and human societies and cultures as an outgrowth of interactions between our species and particular places (Smith and Williams, 1999). Such an approach negates issues of 'right and wrong' and allows individuals or groups to consider multiple perspectives on an issue or problem.

The dominant principles which could inform the work of science educators subscribing to this type of ecological framework would include:

1. development of personal affinity with the earth through practical experience and an ethic of care;
2. grounding learning in a sense of place by investigating surrounding natural communities;
3. induction of students into community experience - countering the press towards individualism;
4. acquisition of practical skills needed to regenerate human and natural environments;
5. introduction to occupational alternatives that contribute to the preservation of local cultures;
6. preparation for work as activists able to negotiate structures/policies supporting social justice;
7. critique of cultural assumptions upon which modern industrial civilization has been built.

## Conclusion

A critique of the Ontario science curriculum reveals that mainly scientific facts and information are stressed. Furthermore, as this document only advocates the inclusion of politically appropriate issues within the context of the STSE element, it maintains the status quo and reproduces social and environmental injustice. If this is the only perspective of STSE taught within formal education, then this approach to science education cannot be viewed as a complex undertaking involving economic, ethical and other socio-cultural perspectives which social and environmental crises are grounded in.

We believe that students should consider multiple values-based views about science education (including the scientific view) and obtain valuable socio-developmental skills and cognitive attributes through exposure to real-world problems. There is a need for pedagogical undertakings that promote reflection on past and present social beliefs while supporting opportunities to learn about and take part in political change. Further dialogue around these important issues is required to explore the problematic nature of including environmental issues within formal curricula.

## References

Abraham, J.. Lacey, C. &Williams, R. (1990). *Deception, demonstration and debate : toward a critical environment and development education.* London : Kogan Page, 1990.

Bowers, C. A. (1993). *Education, cultural myths, and the ecological crisis : toward deep changes.* Albany, N.Y.: State University of New York Press.

Bowers, C. A. (1997). *The culture of denial : why the environmental movement needs a strategy for reforming universities and public schools.* Albany : State University of New York Press.

Bowers, C. (1999). Changing the dominant cultural perspective in education. In Smith, G.A. & Williams, D.R.(Eds.). *Ecological Education in Action: On weaving education, culture and the environment.* Albany, N.Y.: State University of New York Press.

Cohen, J. (1999). *Educating minds and hearts social emotional Llarning and the Ppssage into adolescence.* New York: Columbia University Teachers College Press.

Council of Ministers of Education, Canada (1997). *Pan-Canadian Protocol for Collaboration on School Curriculum.* Avaliable Online: HTTP://WWW.CMEC.CA/science/framework/

Deloria, V. (1995). Red Earth, White Lies: Native Americans and the Myth of Scientific Fact. New York: Scribner.

Elstgeest, J. (1990). *Environmental science in the primary curriculum.* London : Paul Chapman,

Fien, J. (1993). *Education for the Environment: Critical Curriculum Theorising and Environmental Education.* Geelong: Deakin University.

Golley, F.B. (1998). *A primer for environmental literacy.* London: Yale University Press.

Greenall, A. (1985). A new beginning for environmental education in Australia. *Australian Journal of Environmental Education*, *1*(2): 13-15.

Hart, R. (1997). Children's participation : the theory and practice of involving young citizens in community development and environmental care. London : Earthscan, 1997.

Hart, P. & Nolan, K. (1999). A critical analysis of research in environmental education. *Studies in Science Education*, *34*, 1-96.

Hines, J.M., Hungerford, H.R. & Tomera, A.N. (1986/87). Analysis and synthesis of research on responsible environmental behaviour: A meta-analysis. *Journal of Environmental Education*, *18*(2): 1-8.

Huckle, J. (1993). Environmental education and sustainability: A view from critical theory. In J. Fien (ed.), *Environmental Education: A Pathway to Sustainability.* Geelong: Deakin University.

Krapfel, P. (1999). Deepening children's participation through local ecological investigations. In Smith, G.A. & Williams, D.R.(Eds.). *Ecological education in action: On weaving education, culture and the environment.* Albany, N.Y.: State University of NY Press.

Lacey, C. & Williams, R. (1987). *Education, ecology and development : the case for an education network.* London : Kogan Page.

Lacey, C. & Williams, R. (1990). *Deception, demonstration and debate : toward a critical environment and development education.* London : Kogan Page

McBean, G.A. and Hengeveld, H.G. (2000). Communicating the science of climate change. *Canadian Journal of Environmental Education* (5).

Ministry of Education (1989). *Ontario Schools: Intermediate and Senior Divisions: Grades 7-OAC.* Toronto: Ontario Ministry of Education.

Ministry of Education, (1995). *Environmental concepts in the classroom*, Victoria: British Columbia Ministry of Education.

Ministry of Education (1999). *The Ontario Curriculum Grades 9 and 10: Science.* Toronto: Ontario Ministry of Education.

Ministry of Education (2000). *The Ontario Curriculum Grades 11 and 12: Science.* Toronto: Ontario Ministry of Education.

National Research Council, (1996). *National science education standards.* Washington DC: National Academy Press.

OECD (1995). *Environmental learning for the 21st century.* Paris : Organisation for Economic Co-operation and Development.

Robottom, I.M. (1987). Towards inquiry-based professional development in environmental education. In I.M. Robottom, (ed.), *Environmental Education: Practice and Possibility.* Geelong: Deakin University Press.

Scott, W. (2000). *The sustainable development project: Challenges and responsibilities for education.* Paper presented to the UNESCO Conference on Environmental Education, Lavissa, Greece. October 2000.

Suzuki, D. (1998). *Earth time.* Toronto: Stoddart.

Sanera, M. and Shaw, J.S. (1999). *Facts not fear* (Canadian Edition). Vancouver, Canada: Fraser Institute.

Smith, G.A. & Williams, D.R.(Eds.). *Ecological education in action: On weaving education, culture and the environment.* Albany, N.Y.: State University of NY Press.

Ten Dam, G., Vernooij, F. and Volman, M. (2000). New learning in social studies. In Simons, R., van der Linden, J. and Duffy, T. (eds.) *New Learning.* Dordrecht: Kluwer.

Thomas, A. (2000). *Multiple intelligences in the classroom* 2nd Edition. .Association for Supervision and Curriculum Dvelopment (ASCD) Available at : http://www.ascd.org/readingroom/booksarmstrong00book.html

Thomashow, M. (1995). *Ecological identity : becoming a reflective environmentalist.* Cambridge, Mass. : MIT Press.

Wass, S. (1990). *Explorations : a guide to field work in the primary school.* London : Hodder and Stoughton.

Williams, D.R. and Taylor, S. (1999). FromMargin to Center. In Smith, G.A. & Williams, D.R.(Eds.). *Ecological education in action: On weaving education, culture and the environment.* Albany, N.Y.: State University of New York Press.

Zandvliet, D. and Sammel, A. (2001, July). *Exploring the connections between science and environmental education.* Paper presented at the Environmental Education and Communications Conference, Whitehorse, Yukon, Canada. July , 2001.

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# WOMEN AND SCIENCE AND TECHNOLOGY EDUCATION IN THE TERTIARY LEVEL AND EMPLOYMENT IN INDIA

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**Abstract**

The phenomenal growth of women education in the formal Science and Technology sector in the tertiary level in India is being reviewed. The study concentrates on S & T education in the university system. The growth is reflected quite discernibly in the employment scenario in S & T in the educational field over the last few decades. Aptitude, opportunity, performance, societal demands in various sub-fields viz., mathematics, physics, chemistry, life sciences, medicine, statistics, computer science etc., are assessed on the basis of available data. Some reflections on the futuristic plane are made about the women's entry in large proportion into S & T teaching profession in the tertiary level. The question of sustainable development in the new economic context comes into focus. Comparison with male performance comes in. Comparisons are also made with the situations prevailing in the industrialized societies. Formulating strategies of assessment prevalent in some countries, on the questionable gender bias is uncalled for at the moment in the face of massive societal urge for growth. On the contrary, effectively ensuring equal opportunities through competition in S & T education will reduce the difference, if any, to irrelevance.

## Emerging Trend

India, along with some other massively populated developing countries burdened with high level illiteracy and economic backwardness has nonetheless, made great strides in women's participation in the tertiary level S & T education and employment over the last few decades. In India, in the university sector, the percentage increase in total enrollment over 10 years 1981-1991 is 50.17% in science, 66.56% in engineering, 32.22% in medicine, 19.30% in agriculture and 35.36% in vet. science, the corresponding figures in women enrolments are 74.70%, 192.02%, 63.12%, 142.95% and 157.67% respectively [1]. The growth in women enrolment in higher education since independence has been phenomenal. While women constituted only 9.3% of all students in institutions of higher education on the eve of independence, the percentage of women students enrolled in all colleges and universities was 33.2% in 1993-94 [2] and 34.1% in 1996-97 3. The facultywise percentage of women enrolment in 1996-97 is 20.1% in science and 1.2% in engineering and technology ( excluding medicine, agriculture etc.).This can be compared with total enrolment 4.9% in engineering and 19.6% in science in universities and affiliated colleges in 1996-97. The number of women's colleges has recorded a substantial increase during the period 1986-87 to 1996-97 from 780 to1195, that is by 53.21%.

This growth in women's education in S & T over the decade has consequent repercussions on the employment field in colleges, university faculties, national laboratories and institutes. A good number of women members have already joined teaching and research force in the departments of physics, mathematics, chemistry, zoology, botany etc., in colleges and universities. The I I Ts (Indian Institute of Technology) have women members in the teaching and research staff though in a small number. Women scientists have entered the colleges, universities, laboratories and institutes as also in industry through open competition, in good numbers. But the number of women in the employment field is still not comparable to that of men. Despite this, the trend of women's advances in the third level S & T education and employment has unmistakably set in. A national survey on the women's participation in the S & T education and employment, if taken up, will not fail to recognize this emerging trend. The Table I 2 will corroborate the emergence of the trend .

It is observed that percentage increase of men's enrolment was 40.33% in science, 60.64% in engg/tech, 21.26% in medicine, 14.77% in agriculture and 29.96% in vet. science, over the decade 1981-1991. By contrast therefore the women's enrolments increased by leaps and bounds and this trend is to stay for some more years to come.

The trend has indeed set in. The number of engineering and information technology colleges affiliated to universities both in government and private sectors has gone up by jumps over the decade 1991-2001. They offer degree courses in computer science, electronics and telecommunications, information technology and electrical engineering. A review of the situation if taken up on all India basis is bound to reveal exciting and hitherto unknown reality that girls have been taking up engineering and IT- courses in large numbers every year. A random glance at the enrolment records of a newly launched engineering college shows nearly 20-25% intake of girls in all these courses in the very first semester in 1999. This certainly is a great leap forward compared to a mere 8% in 1990-91.

The policy document of Government of India on education [4] mentioned in 1985: "*Even though the performance of girls compares favourably with that of boys, relatively fewer girls seek admission to professional courses other than those pertaining to medicine, teacher training and nursing*". The situation has changed in favour of girls taking up courses in basic sciences, engineering/technology, agriculture and veterinary science in large numbers.

A few more lines can be added by way of illustration. There were times when women opting for higher education in science would confine themselves in taking up courses in botany, zoology, psychology and some other soft subjects. Women in science had an excellent aptitude for chemistry as a career subject even decades ago. At the sixties, at the author's own alma mater, only one or two women would take up applied mathematics in the M.Sc classes, the total enrolment being 30. Women now constitute about 30% to 40% of the size of the same class. In the sixties there were no women teacher in the department. A good number of women professors constituting 20-25% of the faculty have now joined the department. The percentage of women students in various branches of physics, chemistry, computer science, statistics has been growing steadily. The aptitude as also opportunity patterns has gone a sea change in the emerging socio-economic cultural context. In fact women can be found in all classes of basic and applied sciences and in good numbers. Women contribute quite significantly to the ever increasing research force. A large proportion of the scholarships offered by U.G.C., C.S.I.R, D.S.T., N.B.H.M., and other research funding organizations in the country go to women scholars. The concept like gender preference for science subjects has become outdated in the face of massive societal urge for growth of science education in the country.

## Some Futuristic Observations

One may be tempted at this stage to make some futuristic observations in this emerging situation. The undergraduate teaching profession may soon come to be run primarily by female teachers, not only in humanities but also in natural sciences and mathematics. The brightest group of male achievers generally opt for engineering courses as their career subjects and ultimately get absorbed in industry or national laboratories where there is enough scope for career mobility in terms of money and research facilities. Those who are still not satisfied opt for foreign assignments and fall victim to brain-drain. The teaching profession will in the near future be able to attract the bright female candidates, the bright male candidates will be in short supply. Brain drain among male students is quite substantial but that among women is negligible. Is science teaching therefore going to be commanded by female teachers because of "competitive exclusion" 5 men from the field ? Will science teaching in the new situation in colleges and universities be far more effective under the female majorityship? Will science teaching and research be more dynamic, devoted, inspiring and disciplined? We are still in a state of transition and formulating some sort of answers to these questions at this stage may sound too far fetched. A balanced participation of both men and women is to stabilize for the sake of sustainable development.

## Socio-Cultural-Economic Problems

There are multifarious socio-cultural-economic problems affecting female participation in S & T education and employment. The bright male candidates can leave university or college teachership in preference to lucrative positions in industry and cause teaching profession to suffer from dearth of talent. The female candidates even today prefer to stick to the teaching positions, than joining industry or national laboratories. However, an attitudinal change in this regard is also coming up fast. Therefore some appropriate strategies for competitive growth of male and female education in S & T and absorption in employment in teaching and in R & D in industry or national laboratories are all that can be sought to be developed specially in the context of new economic policy and industrial globalisation. The bread-earner in an urban middle class family is still considered to be the male, the husband, father or the brother. The female employment adds up to the cherished affluence in the family in this consumer society in many cases. ("moreover, when they enter the paid labor force their contribution is still often seen as complementary", ROY et al 6). This attitude can never be construed as an ideal motivation for joining the teaching profession in sciences or taking up research positions in industry or national laboratories. Examples galore where a teacher or a scholar or a doctorate in science has to leave her assignment in pursuance to moving to the place of employment of her husband/father. Therefore, again, some effective policy guidelines aimed at bringing them back to teaching or R & D activities, especially in the context of new industrial resurgence being pursued in the country, may be formulated. The society cannot afford to have their hard-earned scientific expertise remain totally unused.

## International Context

The female participation in the tertiary education in India and in some other massively populated developing countries are quite impressive. The gross enrolment ratios (%) for 1980 and 1989 for India and China are as follows:

| | India | | China | | India | | China | |
|---|---|---|---|---|---|---|---|---|
| | 1980 | | | | 1988 | | | |
| | M | F | M | F | M | F | M | F |
| 1st level | 98 | 114 | 121 | 142 | 67 | 83 | 103 | 126 |
| 2nd level | 41 | 52 | 54 | 50 | 22 | 29 | 37 | 37 |
| 3rd level | 11.2 | 8.1 | 1.8 | 2.0 | 4.3 | 3.8 | 0.6 | 1.1 |

The female participation ratios are indeed lower than those of most of the developed countries [7]. Similarly, in India, in 1996 the percentage of female teachers in primary education is only 33% compared to China's 47.4%, Australia's 76.2% and Japan's 61.6% 8. Women enrolment in polytechnics in 1991-92 is as low as 13.1% 9. However, even in the context of this dismal situation we propose next to delve into what may be termed as an *international paradox*. It is observed that percentages of female students in sciences (natural sciences; engineering; mathematics and computer sciences; architecture and town planning; transport and communications; trade, craft and industrial programmes; agriculture, forestry and fisheries, but NOT in medical sciences, health and hygiene) expressed as percentage of the total enrolment (male + female) in the 3rd level education, in the field specified is generally higher in some of the highly populated developing countries than many of the developed ones, even though these developed countries spend much larger portion of their GNPs for the purpose. The Table II will describe the scenario [7].

In other words, female participation in the 3rd level education in mathematics, physics, chemistry, life sciences etc., in the developing countries like China, India, Brazil, Argentina, Egypt etc., are generally greater than that in the developed countries like UK, Denmark, The Netherlands, Germany, Hungary etc. A quotation from the US National Science Board (NSF) may be of relevance here [10]: "*Simply put, students in our Nation's schools are learning less mathematics, science and technology particularly in the areas of abstract thinking and problem solving; since the late 1960s, most students have taken fewer mathematics and science courses. Mathematics and science achievement scores of 17-year-olds have dropped steadily and dramatically during the same period*'.

While the developed countries spend a good proportion of their GNPs on S & T education and maintain better retention rates at all levels of education, the female participation in higher studies in these countries slows down. On the other hand an extraordinary female performance in higher studies in sciences could be achieved in these developing countries mentioned above by investing only a small portion of their GNPs for the purpose. This indeed poses a *paradox*. But possibly this can be explained by saying that a massive urge for enrolment continues unabated in these developing countries and that some sort of stability is not in the offing.

## Conclusion

'Gender dimension of science' [11] apparently has little conceptual relevance to the 3rd level education in science being discussed in the context of Indian women. Elizabeth McGregor and Sandra Harding correctly assessed that "*From the outset of their lives girls frequently experience unequal access to opportunities in education because of socio-economic and cultural obstacles. Only those able to scale these initial barriers will eventually enter through the school door' and become part of the early pool of talent available for recruitment into S & T*". The recruitment however, has come to be accomplished through competition. The word 'equity' is sometimes used in this context. If it stands to mean equal access and opportunity, then one can possibly claim that equity is being practiced all through the years in 3rd level S & T education and recruitment. However, only a few women will be found to have reached the top, as scientist or as policy maker. There were only 4 women among a total of 30 fellows of the Indian National Science Academy and there was no women member in the INSA council consisting of 28 members in 1990 [12]. "*Even in those countries with a good record of addressing gender issues, the figure (difference between female student enrolment rates at universities and the female component of their teaching staff) can be surprisingly low; for example, in Norway only 9% of professors in higher education are women*" [11]. The problem therefore seems to be an eternal and a global one. The ongoing debate on some of the apparently insurmountable constraints such as caring the family, social situations, cultural ethos etc., standing on the way against women all the time must continue for years to come. Can any sustainable development in any society be achievable if the family fabric goes destroyed? Equity and equality issues are required to be discussed in-depth in respect of various changing societies. Bikas C Sanyal [13] asserts that the labour force participation rates for women varies according to cultural traditions. "*It is quite sensitive to total income of the family*". ICME-6, 1988 (Budapest) unambiguously clarified that "*Gender perspective in the mathematics studies in the higher level does not arise*" [14].

"*While the overwhelming impression*" of the Treatise by ROY et al (1996) "*is that discrimination and segregation of women is still very much the order of the day*", the present study on the other hand foresees possibility of "competitive exclusion" of men from the field of science teaching and education in the near future. The proliferation of IT and engineering colleges about sixfold within less than ten years aggravates this possibility. The existing infrastructure for science teaching under the university system is going to get a raw deal. This probable neglect for the basic sciences teaching is quite unacceptable from the objective of sustainable development. The single most important objective in higher education must be to give teaching and research in basic sciences a chance. ABDUS SALAM laments that "*India failed – it has been stated – because it has sacrificed quality for quantity , and advanced technology has not been able to reach an acceptable level of quality without prior investment in basic research*" 15. The question therefore is to draw talent in basic sciences irrespective of gender. Thus effectively ensuring equal opportunities through competition in S & T and encouraging women specially in rural areas into taking up S & T studies will reduce the gender bias, if any, to irrelevance.

**Table I.** Percentage of women Enrolment to Total Enrolment in Science, Engg/Tech, Medicine, Veterinary science (1981-82 to 1990-91) :

| Year | Science | | | Engg /Tech | | | Medicine | | |
|---|---|---|---|---|---|---|---|---|---|
| | T | W | % | T | W | % | T | W | % |
| 81-82 | 578766 | 165666 | 28.6 | 130189 | 5866 | 4.5 | 113794 | 29792 | 26.2 |
| 82-83 | 623545 | 179650 | 28.8 | 142440 | 7173 | 5.0 | 113902 | 31648 | 27.8 |
| 83-84 | 653092 | 189685 | 29.0 | 153131 | 8469 | 5.5 | 118939 | 33676 | 28.3 |
| 84-85 | 669563 | 200632 | 30.0 | 159046 | 10052 | 6.3 | 118890 | 35190 | 29.6 |
| 85-86 | 700991 | 215730 | 30.8 | 176540 | 12182 | 6.9 | 123057 | 37549 | 30.5 |
| 86-87 | 735864 | 231061 | 31.4 | 183966 | 12694 | 6.9 | 127650 | 38933 | 30.5 |
| 87-88 | 668022 | 245720 | 32.0 | 192148 | 13555 | 7.1 | 131013 | 40484 | 30.9 |
| 88-89 | 800266 | 259061 | 32.4 | 209289 | 14591 | 7.3 | 137257 | 43205 | 31.5 |
| 89-90 | 834087 | 274509 | 32.9 | 209371 | 15840 | 7.6 | 142270 | 45321 | 31.7 |
| 90-91 | 869119 | 289413 | 33.3 | 216837 | 17130 | 7.9 | 150458 | 48598 | 32.3 |

| | Agriculture | | | Vet. Science | | |
|---|---|---|---|---|---|---|
| 81-82 | 39318 | 1390 | 3.5 | 8173 | 352 | 4.3 |
| 82-83 | 39425 | 1595 | 4.0 | 8797 | 424 | 4.8 |
| 83-84 | 41588 | 1719 | 4.1 | 9268 | 470 | 5.1 |
| 84-85 | 41741 | 2045 | 4.9 | 9413 | 506 | 5.4 |
| 85-86 | 41901 | 2345 | 5.6 | 9486 | 664 | 7.0 |
| 86-87 | 42800 | 2525 | 5.9 | 9761 | 683 | 7.0 |
| 87-88 | 43410 | 2674 | 6.2 | 10168 | 727 | 7.2 |
| 88-89 | 44007 | 2840 | 6.5 | 10594 | 779 | 7.4 |
| 89-90 | 45229 | 3106 | 6.9 | 10957 | 862 | 7.9 |
| 90-91 | 46908 | 3377 | 7.2 | 11063 | 907 | 8.2 |

T-Total Enrolment
W-Women Enrolment
%- Percentage of women enrolment to total enrolment, in the tertiary level.

**Table II.** Third Level Science Education and Public Expenditure on Education

| Country | % of students in | | | | Public Expenditure on Education as % of GNP | |
|---|---|---|---|---|---|---|
| | Natural Science Engg. & Agriculture | Medical Sciences | Females | | | |
| | | | Nat | Med | 1980 | 1988 |
| Egypt | 20 | 9 | 26 | 41 | 5.7 | 5.2 |
| Argentina | 41 | 13 | 35 | 57 | 3.6 | — |
| Brazil | 21 | 9 | — | — | 3.5 | 3.7 |
| China | 47 | 10 | — | — | 2.6 | 2.3 |
| India | 29 | 4 | 22 | 33 | 2.8 | 3.3 |
| Indonesia | 21 | 3 | 21 | 32 | 1.7 | — |
| Iran | 31 | 21 | 10 | 43 | 7.2 | — |
| Iraq | 28 | 8 | 28 | 38 | 2.6 | 3.8 |
| Japan | 23 | 6 | 7 | 42 | 5.3 | 4.9 |
| UK | 29 | 14 | 21 | 76 | 5.6 | 5.0 |
| Denmark | 28 | 14 | 23 | 81 | 6.9 | 8.3 |
| The Netherlands | 25 | 10 | 16 | 63 | 7.9 | 7.3 |
| Hungary | 29 | 9 | 19 | 59 | 4.7 | 5.4 |
| Germany Democratic Rep | 41 | 13 | 28 | 85 | — | 5.8 |
| Germany Federal Rep | 36 | 13 | 18 | 65 | 4.7 | 4.2 |
| Australia | 25 | 10 | 27 | 69 | 5.9 | 5.5 |
| USSR (Russia) | 52 | 7 | 39 | 63 | 7.3 | 7.9 |
| US | | | | | 6.7 | 6.8 |

## Reference

1. Annual Report 1990-91, University Grants Commission, New Delhi.

2. Annual Report 1993-94, University Grants Commission, New Delhi.

3. Annual Report 1996-97, University Grants Commission, New Delhi.

4. Challenge of Education - a Policy Perspective, Ministry of Education, Govt, of India, New Delhi, August 1985.

5. Studies in Environment and Mathematics :Perspectives and Approaches, 1983, Ed. D.K.Sinha, A.Misra, South Asian Publishers Pvt. Ltd., New Delhi 110002.

6. Roy, Kartic C.,Tisdell,C.A., and Blomqvist,H.C., Economic Development and Women in the World Community,1996, Praeger Publishers, Westport, Connecticut, USA.

7. World Education Report 1991, UNESCO, Paris.

8. World data on education, 2000, International Bureau of Education, published by UNESCO, Paris.

9. Education Statistics, 30 Sept 1992, Ministry of Human Resource Development, Department of Education, Govt. of India, New Delhi.

10. Educating Americans for the 21st century, A Report, National Science Board NSF, Washington, September 1983.

11. The Gender Dimension of Science and Technology, Sandra Harding and Elizabeth McGregor, World Science Report 1996, UNESCO, Paris.

12. I.N.S.A. NEWS, No.92, 1989, Indian National Science Academy, New Delhi.

13. Intensive Training Course on Education, Employment and Work, A Report, I I E P, UNESCO, Paris, 1987, Ed.Bikas C Sanyal et al.

14.. Proc. ICME-6, 1988, Budapest, International Congress of Mathematical Education ,Ed. Ann & Keith Hirst.

15. Salam, M. Abdus, 1992, Science and Technology : Challenge for the South,TWAS, ICTP, Trieste, Italy.

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# DIFFICULTIES THE SCIENCE SCHOOLTEACHER FACES TO IMPLEMENT ENVIRONMENTAL EDUCATION[1]

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**Abstract**

Considering the science teacher's role in the implementation of environmental issues in school, a survey was carried out (Benetti, 1998) to identify science schoolteachers' perspectives regarding environmental education-related activities in fundamental schools (11 to 14-year-olds). The interviewees' statements were divided into four categories for analysis. This paper discusses the category involving barriers, i.e., the difficulties encountered by schoolteachers in the development of environmental education. These difficulties are associated with both the schoolteacher's education *per se* and the school's infrastructure and organization.

## Introduction

The school is a privileged place for students to access knowledge produced by humanity. As the institution responsible for the population's education, it is crucial that important issues that concern all of society, such as environmental ones, be considered to enable the school to successfully perform its social role (Carvalho, 1994).

Without disregarding the importance of other social segments involved in environmental education activities, we believe the school to be an important space for the development of educational practices in the sense of contributing toward the debate involving this theme. As Krasilchick points out, "*Among the various possibilities for the development of environmental education programmes, the formal education system is still that which offers the best conditions, due to its having an institutional basis, the school.*" (1987a, 103).

Considering the schoolteacher's importance in the implementation of environmental issues at school, the survey carried out by Benetti (1998) aimed to identify the perspective of science schoolteachers regarding educational work involving these issues.

## The survey

This investigation was carried out in 1996/1997, at the city of Marília, state of São Paulo, Brazil, and consisted of interviews with 31 science teachers in fundamental schools (of 11 to 14-year-olds). The data was collected through semistructured interviews and analyzed using a qualitative approach. The basic questions upon which the survey was developed were:

- Is the environmental theme present in Natural Science classes?
- What place does the theme have in those classes?
- What themes does the teacher discuss or consider important for discussion?
- Which aspects of the theme has the teacher prioritized?
- What teaching procedures have been employed?
- What difficulties has the teacher faced in his work involving environmental issues?

These questions constituted the "background" of the study and their purpose was to gain a better understanding of the following broader issues:

[1] Work partially financed by CNPq, Brazil.

- Is the schoolteacher prepared to incorporate Environmental Education activities into his practices?
- What are the elements that could be identified as fundamental in continued and early teacher's education programs?

The schoolteachers involved were selected by random sampling and, at the time of the survey, they were distributed in 14 schools of the above-mentioned city.

The use of interviews as a research technique has proven to be the most suitable one for this type of study since, through his narrative, the interviewee places a variety of elements on his own unique and particular scale of values. It is, therefore, not a question of seeking direct answers to the survey's questions, but to apprehend "the participants' perspective"; in other words, to understand how the interviewed teachers see the phenomenon in question (André & Ludke, 1986; Bogdan & Biklen, 1994). Interviews provide elements from which one can infer the dynamics and unfolding of meanings, in this case those relating to the science teacher's work in the field of environmental education.

In the opinion of André & Ludke (1986), the advantage of interviews over other survey techniques is that the desired information is obtained immediately and currently, allowing for clarification, correction and adaptation, and gaining life as the dialogue between interviewee and interviewer is established.

The interviews were carried out in one, two or three meetings, depending on the schoolteacher's availability, with a total duration of one to two hours recorded on an audio cassette, with the interviewees' prior consent. The flexible, semistructured format ensured a more freely flowing dialogue, enabling the teacher to talk about his/her experiences and expectations concerning his/her pedagogic work without losing sight of the survey's objectives. The material thus collected was subsequently transcribed in full and analyzed.

Based on the survey's objectives and an analysis of the interviewees' statements, the data was divided into four categories, giving rise to a discussion of the following factors: (a) the place of environmental issues in Sciences Education, (b) the focus given to those issues, (c) the procedures and resources used, and (d) the interviewees' perceptions regarding the barriers and difficulties that hinder the development of their environment-related teaching activities.

This paper focuses on a discussion of the barriers and difficulties that interviewees identified as limitations for the development of environmental education. Based on their statements, these barriers were classified into two subgroups, the first relating to the schoolteacher's education and the second to aspects pertaining to the school's infrastructure and organization (Figure 1).

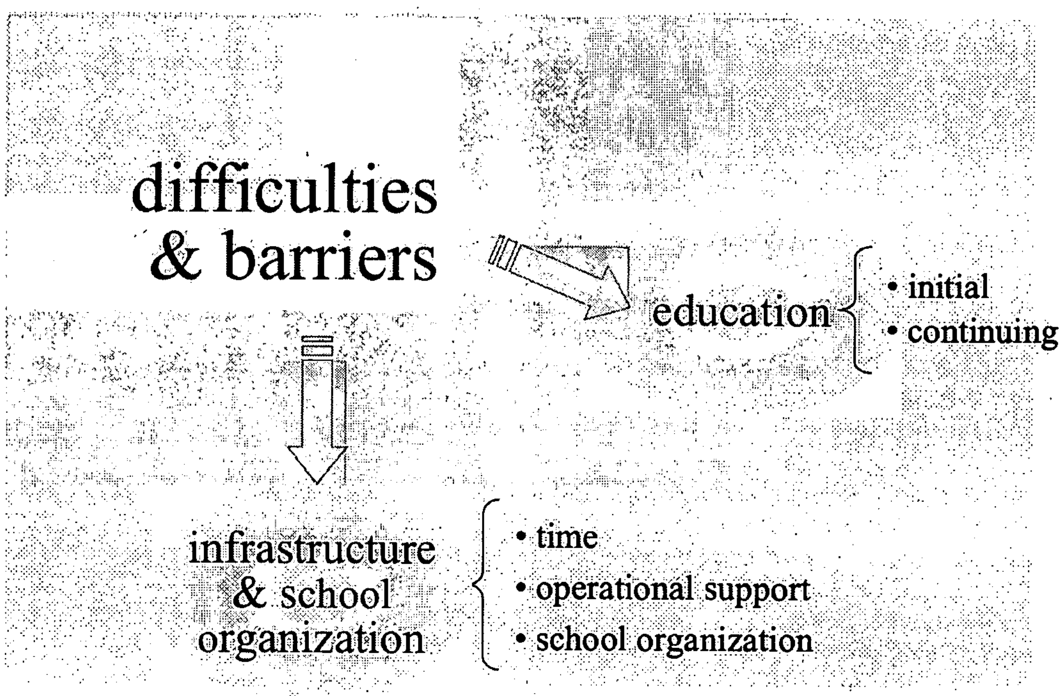


**Figure 1.** Barriers to the development of environmental education activities identified by science schoolteachers in fundamental schools (11 to 14-year-olds) of the city of Marilia, state of São Paulo, Brazil

The barriers identified by the interviewees are discussed below.

**Aspects involving teacher's education**

Among the difficulties pointed out by the science teachers, their basic education and a lack of continuing education programmes appear to be limiting factors to the development of educational work in environmental issues.

The statements of five schoolteachers indicated concern about the lack of a theoretical basis on the theme, starting from the early years of education, which may result in uncertainty in the development and deepening of discussions regarding the environment. The statement of one of the interviewees clearly illustrates this situation.

> R4[2]
> *"I guess you could say I am uninformed. It's not just me – I guess most science schoolteachers are. Take the greenhouse effect, for example. A few days ago there was a program on TV about pollution but I missed most of it because, by the time I started watching it, it was already almost at the end. It explained about thermal inversion, what acid rain is, what causes it...Related to some little thing, like those, you're uninformed. You may even tell students about it, but if a student begins asking you for more and more information, you* (find yourself thinking)[3] *–' Wait a minute! I don't know either... I need to be better informed' ..."*

[2] To protect their identities, the interviewees are identified by a code consisting of a letter and a number.
[3] Complementary explain (words or expressions) are identified by round brackets.

Four schoolteachers from this group see continuing education as a possible way to compensate for the gaps in their early education, as indicated in the following statement:

> S2
> *"More courses are needed. I have only recently started* (to teach) *and there are many things that are not taught in college. College teaches you the basics, but you have to do your own research, in depth... books don't always clarify everything, even one's doubt's. Sometimes, when we have a doubt, we ask another teacher with more experience. But sometimes you feel you're being inconvenient, that the person you're asking doesn't want to pass* (on his knowledge to you), *so you end up feeling reluctant to ask questions".*

The statement of S2 suggests that schoolteachers consider that undergraduate courses do not fully meet their own educational needs to deal with environmental issues in their teaching activities. Thus, as in the case of S2, the only possible way to offset the theoretical deficiencies of their own education is by requesting the help of a more experienced colleague or by reading up on the subject.

In addition to those five interviewees, others share the opinion that continuing education courses are needed. The schoolteachers mentioned the lack of guidance for the development of environmental-related activities, as evidenced in the statement of S1:

> S1
> *"... no one offers us courses, nobody says anything, and the whole thing is simply thrust into our hands and we have to deal with it. That's how it is, you know? I think we lack the guidance of someone who knows more than we do, to pass on the knowledge we need to work with. I think that is a very serious difficulty we face. (...) I read newspapers, I subscribe to Veja magazine* (Brazilian weekly magazine), *but I still think there is more* (she laughs) *that could be exploited and that I don't have. (...) I think we should have more guidance, you know?"*

An analysis of the above statements reveals that this difficulty is a common factor in the daily lives of these schoolteachers. Several complained of the lack of courses and of opportunities to exchange ideas with colleagues, etc. They believe that such educational elements would contribute toward an overall improvement of the way they develop their work, particularly in regard to the environmental theme.

It is worth mentioning that about 25% percent of the interviewees stated they found no difficulties regarding the content of environmental subject matter, because they had teaching experience or had read extensively on the subject. This is reflected in the statement of E3:

> E3
> *"I don't think I have many difficulties. Like I said, it depends on what content is to be discussed* (in class). *I don't consider it difficult; because it's something they* (the students) *like, it's a topic everybody is always talking about. I don't think it so difficult. Depending on the issue, of course, you sometimes don't find everything. Sometimes you find something by reading, a newspaper; that sort of thing could be done. We are doing everything that can be done."*

In the case of E3, it is obvious that the lack of difficulties reflects the superficiality and informality that the subject is dealt with. Some statements clearly indicate that professional experience is, to a certain extent, considered a substitute for formal education, in the sense that it offers solutions for content-related problems that arise on a day-to-day basis.

### Aspects relating to the school's infrastructure and organization

The difficulties listed here involve aspects relating both to the school's infrastructure – such as availability of resources, financial and institutional support and to its organization – such as availability of the schoolteacher's time (for collective work, study and preparation of classes, or even time to develop classes).

### Availability of time

The science teachers claimed that one of the most serious problems is lack of time to work with colleagues in order to exchange experiences and develop activities, and even to prepare classes. The following statement indicates that there are few opportunities for collective work due to the paucity of time for meetings.

> M2
> *"... we only do that in our collective planning activities. But that is the only time when everyone is available. It's the only time that we exchange experiences, during our joint planning activities. We have very little time to be together. We don't have enough time, most of us have many classes, many duties. In the end, we are prevented from having such a work group ".*

Some schoolteachers claimed that the excessive number of classes precluded them from dedicating more time to areas of knowledge such as the environmental themes.

It should be pointed out that the curricular organization itself fails to provide "time" for environmental issues to be explored, as interviewees L2 and L3 claimed. In the opinion of interviewee L3, the paucity of time in class would preclude the discussion of any issues other than the ones she mentioned:

> L3
> *"...school nowadays doesn't allow you to do much, there's too little time, you don't have much spare time for classes, see? Look, there are four Science classes; I had three in a row, I mean, there was still another one to give. With four classes you* (don't) *have much time to into anything in depth. Then there are meetings (...) so the students are allowed to leave* (the school). *This year there must have been about eight or nine course meetings that we had to attend, that one is obliged to attend and can't get out of (...)."*

Another difficulty identified by schoolteacher E4 is the time required for class preparation:

> E4
> *" Look, the schoolteacher's lack of time is the big problem. Because for* (me) *to sit down and prepare a class like that takes time, and time is what I have least of. So sometimes you have to prepare classes on Saturday. I prepare classes at home in the evening, I prepare classes on Sundays, I correct tests; I don't correct tests in the classroom, so I take them home. So you prepare those classes. Time has become very scarce because one has to rush..."*

Several interviewees identified some of the reasons why schoolteachers lack time. One of these reasons involves the work shift that some schoolteachers take on. The statement made by R3 exemplifies this situation:

> R3
> *"... our workday is very long. And there are teachers that teach at other schools, work in other places to earn money. Everything is a rush. Don't you rush? I do. So one rushes around a lot, takes on many classes and there's little time to prepare, to talk, to see what it is more important, and to discuss, to plan ... Drawing up a project takes time, it takes time, dedication, responsibility, integration, willingness..."*

### Operational support

The interviewees mentioned the lack of various resources such as videotapes, books, libraries, financial and institutional support, etc.

Some said they would like to have more support materials such as books, magazines, newspapers, and videotapes. Such resources are considered useful for the development of work, mainly insofar as environmental issues are concerned. However, they commented that such materials are not always available in school. About 50% of the schoolteachers mentioned the lack of the resources, and some added that they could not afford to purchase the necessary resources themselves due to their low wages, a claim that is illustrated by the statement below:

> S1
> *"... I work, read a lot, and always try to keep informed. But the way things come down from the Bureau of Education, from the government, is the same as nothing.* [Are things actually done more at the schoolteacher's level?][4] *The schoolteacher has to make things work! For instance, at the other state school they subscribed to the Globo Ciência magazine* (Brazilian scientific popular magazine) *So we had a source from which to obtain data. But then came a time when the subscription could no longer be renewed, nor could the schoolteachers, with their wages, afford it. So it's really difficult, isn't it?"*

The textbook, therefore, appears to be one of the few resources available for the schoolteacher's work, providing support for his/her teaching activities, as shown in E4's statement:

> *"... It's courses, it's I don't know what else, and so on. So you say: ' – Wait a minute, now what? I haven't prepared my class for that week, so let's see. ' You pick up a book, read it, make a summary, give them the summary, and that's how it goes. There is no material, no book that you find encompasses everything you need, you can't say 'I can even adopt this book for them, it won't be a problem'. Such a book doesn't exist."*

It should be mentioned that textbooks are available to the schoolteacher firstly due a national government program that distribute books to schools. Besides that, as we can see in R3's statements, owing to the commercial strategy of the publishers who donate copies to schoolteachers, this type of material is the most available in schools and means cost and time savings to prepare classes.

> *"... I'm only sorry that I can't subscribe to more magazines because I earn so little and can't afford to have many different things. We get the textbooks free of charge. We get them from the publishers; some publishers supply schoolteachers with books, so I think that for that reason it's sometimes more convenient for me to use textbooks to obtain information, although that isn't enough.* [Because access to them is easier?] *Also, I think, because we are given books. So every year you are given a collection, as advertising, which is to the publisher's interest. That book is available to you. That is sometimes the only material one has to work with."*

The interviewees also mentioned:

- The lack of teaching laboratories and materials (L2, C2, M2 and M4)
- The non-existence of libraries (R3 and F2)
- The lack of audiovisual equipment (slide projectors and video cameras) - (R2 and E1)

In the opinion of E1, the lack of resources prevents certain tasks from being performed, such as writing a report with his students about the living conditions in a slum close to the school, as he explains in his statement.

> E1
> *"...if that material arrived...* (referring to the possibility of the school acquiring a video recorder), *I don't know if it will, but I think it won't (...)* [And without that equipment you think it can't be done?] *Oh, no, it can't be done, it wouldn't be complete. For example, look, we're going to make up a group to have a look at the slum down there. But so what? How are they going to show it to their schoolmates later? With photos it would be rather empty. It's more interesting if it's dynamic, like a filmed report, with a host, and a reporter (...) I think the work would be much better presented if a video recording camera were used. They would become more aware, it would look good."*

[4] Questions presented by the interviewer are identified by square brackets.

This interviewee believes that, from that standpoint, his contribution to environmental issues is limited to passing on information and commenting on it. Moreover, he idealizes work that seems quite interesting. However, there is a noticeable overvaluing of technology (filming) in detriment of the subject to be studied. Such idealizing becomes an insurmountable barrier to the reflection and discussion of the issues intended to be dealt with.

According to the interviewees, other activities such as fieldwork are not carried out for lack of operational support. One of the interviewees referred to the difficulties of organizing and implementing activities outside the school by himself. Besides requiring the participation of colleagues, such activities involve several obstacles, i.e., the school's and students' resources, the difficulty of taking the student out of the school (which requires parental authorization), transportation, the number of students and classrooms. To illustrate this situation, interviewee E4 made the following statement:

> E4
> *"... taking a student out of the classroom is a very complicated, because you don't get any support (...) This year I was going to take them to that Experimental Farm in Lupércio* (village near Marília city) *but I didn't for that reason. We lack financial resources, and one has to pay an entrance fee. First you have to make a survey to find out how many would like to go, but then it's impossible to take seven fifth grades, because if I take one, the others also want to go (...). So it's very dificulty, because of the number of classes, which makes it more and more complicated. (...) And to select one student from one class, another from another class, I just can't do that, either everyone goes or no one does."*

Another concern regarding fieldwork has to do with the student's safety, as evidenced the statements of three schoolteachers and illustrated in that of R4:

> R4
> *"... I'd like to take them to the water treatment station, but to tell the truth I'm rather scared of taking them there because they're students, mostly fifth graders.(...). I'm afraid because some of those places are rather dangerous, it's over on the Marília-Assis road, near here."*

### The school's difficulties regarding work organization and administration

The difficulties discussed in this section refer to the school's organization and administration and to the work atmosphere, which *per se* is seen as a barrier to any initiative aimed at broadening the scope of teaching on environmental themes. As an example, the following were mentioned:

- the excessive number of classrooms (M2)
- the noise in the corridor originating from an environment exploring activity outside the classroom (E1)
- the impossibility of engaging in activities outside the classroom with evening students (I1, A1, R4, L2, D1)
- the students' indifference to the issue, and to reading (L2, D1, A1, C1, S3, R4, E4)
- the lack of cooperation from co-workers and the school management in setting up a work group (E1, S3)

Another barrier mentioned by science teachers from four schools refers to the use of audiovisual resources, such as VCRs and TVs, regarding both the maintenance of the equipment and the execution of the activity itself. Three schoolteachers from this group mentioned, for instance, the difficulties involved in using those resources due to lack of support from the director's office.

Finally, another difficulty is worth mentioning, although it does not relate directly to the school, but rather, to policies of teacher valuation, i.e., the salary issue. In the opinion of some schoolteachers, some of the difficulties they pointed out are directly associated with their low wages, as, for example, the fact that they teach at more than one school, the fact that they engage in another profession besides teaching, the lack of resources to purchase books and magazines or even to attend courses. These factors, in combination or separately, are reflected in the schoolteachers' work. This dissatisfaction is clearly expressed in the statements of about 30% of the interviewees. The excerpt below illustrates this situation:

L3
*"... working the way we do, the little that is left over... supposing you had the magazines, even I read those magazines. You know, the time that remains to you, to take the course outside of your work schedule... I think if we were well paid we would not engage in other activities. We would do only that work and we'd be interested in doing everything it involved. I mean, we'd be satisfied with our activities. But what happens to the schoolteacher today? He's going with the flow, he no longer feels encouraged."*

**Final considerations**

We believe that an educational effort in this area should provide the student with possibilities to reflect about the real causes of environmental problems. This means it does not suffice to merely present environmental problems and their consequences to humanity and to the environment. It is necessary to offer information and suitable conditions to enable the student to comprehend the nature of current environmental problems. As Layrargues points out, problems are often emphasized as being intrinsic to humanity rather than deriving from a model of society, so that "The social actors disappear, and the social conflict becomes invisible" (1999:51).

In this sense, reductionist or fatalistic approaches contribute little to the development of a conscience and a critical attitude regarding this theme. Several authors (Carvalho, 2000; Layrargues, 1999; Gonçalves, 1990; Krasilchick, 1986) have discussed the risks of reducing the discussion of environmental problems to their biological aspects, disregarding the socioeconomic, political and cultural factors involved in the issue.

An approach to environmental issues that meets these perspectives is a challenge that the school will have to face. It is essential, therefore, to take into account the participation of one of the main agents of the educational process – the schoolteacher. In addition to being suitably prepared, the schoolteacher must also be aware, sensitive to the importance of the educational process in the discussions, because, as Trivelato (1994) and Krasilchick (1987b) point out, the implementation of changes in school depends on the teacher's involvement.

This survey revealed that schoolteachers consider environmental issues significant. However, their statements indicate that there are a variety of barriers and difficulties for the development of educational work involving those issues, such as insufficient formal education, lack of resources and time, and the way the school is organized.

The time factor stands out as the most relevant barrier hindering the development of environmental issues in the classroom. The lack of time is actually a reality to teacher's work in Brazil and we have to recognize that this factor restrict any science teacher's activity. This problem is more relevant when we are trying to deal with issues that are not seen as traditionally linked to science curriculum.

The teacher's education in this sense is considered a cause of this problem; in other words, a schoolteacher can only teach the knowledge that he was formally educated in, which means his perspective is merely that of reproduction and multiplication. In such circumstances, continued education would, in a sense, play the role of "filling the gaps" of insufficient formal education.

The science teacher's work lacks a perspective for innovation and construction. The support material for his/her work has proved limited, be it textbooks, magazines, newspapers or television. Furthermore, the superficial and alarmist tone of the major means of social communication is reflected in the performance of most science teachers interviewed.

As for the difficulties associated with the school's infrastructure and organization, it was found that the schoolteacher feels incapable of facing the institution's inertia vis-à-vis innovative situations. A collective garbage recycling activity or more frequent outings for field activities, for instance, are seen as problems.

Admittedly, there are difficulties; however, by failing to face them, the teacher makes these barriers insurmountable.

Contreras (apud Libâneo, 2001) states that the resistance of schoolteachers to change and their scant enthusiasm for the profession may be originate from a process whereby educators adapt to some of the institution's expectations. Teachers live with the school culture and learn how to adjust their perspectives and expectations to those of the institution in regard to their work. There are three approaches upon which schoolteachers base their work: a) presentism – the schoolteacher concentrates all his/her efforts on short term classroom plans; b) conservatism – the schoolteacher resists changes in his performance and avoids discussions about commitments to them; c) individualism – the schoolteacher refuses the help of colleagues for fear of having his work judged or criticized.

Many of the obstacles listed by the schoolteachers as objective difficulties may be reflexes of others originating from the school. In a discussion about the recent theorizations regarding the introduction of practices of reflexivity in the context of schoolteacher actions, Libâneo (2001) highlights the importance of not ignoring some of the conditions of the institutional and social reality of Brazilian schools. According to this author, some of these factors involve the precariousness of the teachers' work conditions and his/her professional education, the latter involving not only educational content but also the teacher's overall culture; the forms of organization of the educational system and its policies; and the conflicting roles that the schoolteacher often has to play vis-à-vis the different issues emerging from society, such as poverty and violence.

Analyzed from this standpoint, one realizes that the question of barriers discussed herein is a far more complex one. We believe that overcoming this situation is not limited simply to improving the teacher's educational qualifications or continued education courses so that the science teachers can discuss environmental issues more widely and on a more contextualized basis.

Notwithstanding the difficulties claimed by the interviewees, we believe that they cannot be seen as definitive obstacles to any educational work differing from the normal. A study of the teacher's perspectives concerning this theme may be fundamental for the establishment of strategies to overcome these difficulties.

**Bibliographical References**

BENETTI, B. *A temática ambiental e a perspectiva do professor de ciências.* 1998, Dissertação (mestrado) - Faculdade de Filosofia e Ciências - UNESP, Marília - SP.

BOGDAN, R. C. & BIKLEN, S. K. *Investigação qualitativa em Educação.* Portugal: Porto Editora, 1994.

CARVALHO, L. M. de. *A educação ambiental e a formação de professores. in* Brasil, MEC, SEF. Textos sobre capacitação de professores em educação ambiental. Brasil, MEC: Brasília. 2000. p. 51-58.

CARVALHO, L. M. de. *A temática ambiental e a produção de material didático: uma proposta interdisciplinar.* 3ª Escola de Verão. FEUSP. 10 a 15 de outubro de 1994. Serra Negra/SP. p. 99-104.

GONÇALVES, C.W. P. *Os (des)caminhos do meio ambiente.* São Paulo: Contexto, 1990.

KRASILCHIK, M. *Educação ambiental na escola brasileira - passado, presente e futuro.* Ciência e Cultura, 38 (12), 1986, p. 1958 - 1961

KRASILCHIK, M. *Some problems and perspectives of environmental education in the school* In Baez, A. V. *et alli The environment and Science and technology education.* ICSU Press e Pergamon Press: Grã-Bretanha, 1987a., p. 101-106.

KRASILCHIK, M. O professor e o currículo das Ciências. São Paulo: EPU: EDUSP, 1987b.

LAYRARGUES, P.P. Conflitos socioambientais e cidadania: qual é o tema da educação ambiental? *In* MATA, S. F. et ali (org.) *Educação ambiental: compromisso com a sociedade.* Rio de Janeiro: MZ Editora, 1999. p. 50-55

LIBÂNEO, J. C. Produção de saberes na escola: suspeitas e apostas. *In* Candau, Vera M. (org). Didática, Currículo e Saberes Escolares. Rio de Janeiro: DP&A, 2001. p.11-45.

LÜDKE, M. e ANDRÉ, M. E. D. A. Pesquisa em educação: abordagens qualitativas. São Paulo: EPU, 1986.

TRIVELATO, S. F. *Perspectiva para formação de professores. In* Terceira Escola de Verão - Cadernos de Textos. Serra Negra - SP. FEUSP: São Paulo, 10 a 15 de outubro de 1994. p. 151-167.

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# REFLECTIONS UPON A NATIONAL PROGRAM ASSESSING SCIENCE TEXTBOOKS: WHAT IS THE IMPORTANCE OF CONTENT IN SCIENCE EDUCATION?

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## Abstract

We report on a six-year long study carried out by the Brazilian Ministry of Education (MEC) assessing science textbooks written for primary and junior high school students throughout the country. Starting in 1995, the work has involved many people in the academic sector including schoolteachers and technical staff. Six years later, after a battle in the courts between the Ministry and the copyright owners of rejected books, the study has impacted directly on more than 40 million students, has banished prejudices in texts and pictures to which students had previously been submitted, has rejected books with error and inaccuracies, and has raised a national debate about the role of educational authorities in public schools. In this paper, we stress three theoretical implications of this work to science education: the role of content and its accuracy in science education, possibilities of judging evidence in science classes, and the psychological and social roots of students' models to explain natural phenomena.

## Educational Context in Brazil

The Brazilian educational system is impressively large. Data from 2001 show that pre-schools are attended by 4.8 million children, and basic education is provided to some 35.2 million students, 91% of whom attend some 200,000 public schools. There are 8.4 million students attending high school and 2.7 million students attending higher education courses, 1.8 million in the private sector and 0.9 n the public sector (MEC/INEP, 2001). Every year there are some 175,000 adults reaching literacy, in several different programs. This means that there are more than 50 million seats being used in Brazilian schools everyday; and in rough numbers almost 1/3 of the Brazilian population attends school regularly. In other words, the school population is three times greater when compared with 1970's absolute numbers, or twice as much in relative terms. There is a clear tendency towards universal coverage in basic education (called *ensino fundamental*), which has reached 95.4% of children in the year 1999, whereas high school level covers only 32.6% of youngsters. However, the main problems in Brazilian schools are related to *efficiency* and *equity*. Teacher profiles clearly show the roots of these problems.

Data from 1997 show that in the first 8 years of *ensino fundamental* there are 1,617,611 teachers, but just 785,624 (48.5%) have a higher education degree. There are 60,053 (3.7%) teachers with no degree at all, but their relative presence varies greatly from one region to the other. In the Southeast, the most industrialized area, there are 0.6% lay- teachers at this level, compared with 9.1% in the Northeast, where there are 15 times as many lay-teachers. The same picture emerges when comparing the numbers of teachers with no high-school level degree, the minimum desired professional degree for primary education. Teachers' wages were actually very low, as 48.2% earn less than US$ 3,000 per year. Again, the problem of equity can clearly be seen when observing teachers contracts. The national mean for teachers paid by the federal government is US$ 8,537 per year; teachers employed by municipalities in the Northeast earn only 14% of that amount, hardly reaching US$ 1,200 per year.

Major actions undertaken in Brazil since 1995 have included the approval of a constitutional amendment which ensures a new mechanism to fund education (called "FUNDEF"). This amendment would redistribute resources according to the number of students who actually attend compulsory school, so that resources given to schools of rich and poor municipalities receive the same minimum amount. Another action concerns the amount spent on didactic materials for schools. The action would spend almost US$ 1 billion in 4 years, and include a major program of distribution of textbooks to all eight grade levels throughout the country (PNLD). Importantly, this program includes for the first time in years, a detailed process of textbook assessment, so that teachers using a detailed guidebook featuring short book reviews can choose qualified textbooks. Other actions include the determination of national academic directions for all grades of education.

## School Textbooks in Brazil

The first official action of the Brazilian government with respect to textbook assessment took place in 1938 (the government under a dictatorship). Getulio Vargas, the ruling president, established a National Committee (CNLD, decreto 1006/1938) aimed at assessing schoolbooks. At the time this action raised great concern about ideological and political influences, once all features were ruled under authoritarian patterns. In the year 1966, another important action took place in Brazil. Under another dictatorship and with an agreement with USAID for education, this action let to the creation of another committee on education (COLTED). Dating from this time is the tradition that school teachers can freely choose textbooks, and which would be be bought by the government. In 1971, after the dissolution of COLTED (during the worst period of the military dictatorship) the policy of textbooks was progressively transformed into a kind of social service in which students had to afford their own textbooks, even in public schools.

After the end of the military dictatorship in 1985, a national program was created (PNLD) aimed at distributing textbooks to all students in the eight years of compulsory education. The tradition of teachers choosing books themselves was maintained. There was an explicit compromise to reach all students in public schools, to adopt re-usable books, and to ensure a permanent assessment of books. However, the assessment of books led to serious difficulties, which often led to battles in the court. In the 1990's several assessments revealed serious problems in textbooks, ranging from the presence of images conveying prejudices against women, Afro-Americans, and poor workers, as well as serious problems regarding information and conceptual accuracy.

From the period between 1971 to 1995, the marketing of textbooks traditionally targeted private schools, selling recent books and new editions. After some years, remaining stocks were offered to public schools at reduced prices. There was a clear and perverse link between the lack of efficiency and the lack of equity. Rich/private schools received brand-new books; poor/public schools received old books, sometimes dating from 20 years ago. The development of new books aimed primarily "the market" or, in other words, had a costumer-satisfaction product development strategy, were school teachers were regarded as "customers" (Takahashi, 1984). A tragic incident that occurred in 1991 in a small town (Andradina, SP) seems to portray the situation of science textbooks in the country at that time. A young student died after being bitten by a poisonous snake; however the death was related to the treatment (tourniquet) and not to the snake. Local Health Services sent a report to the State Secretary of Education about the casualty, demanding inquiries about the source of the inaccurate first aid information that was administered, which was allegedly contained in the science textbook adopted by the school. The answer came some weeks later, which stated that all of the science textbooks distributed in public schools contained the inaccurate first-aid instructions. This led to the notification of book publishers in November 1991 (Gioppo, 1999). In 1995, four years later, no significant correction was made, and almost all textbooks still contained the same inaccurate information. This well documented case is representative of the inefficiency of authors, publishers and educational authorities at the time, regarding textbook development.

In August 1993 a committee was appointed by the Ministry of Education (MEC) aimed at assessing the 10 best selling textbooks in all subject areas, and all science books were rejected (Portaria MEC 1130, 5 agosto 1993). This governmental commission established the first consistent action towards textbook assessment, and designed the first detailed parameters (MEC-Brasil, 1994). Following previous assessments done in science, this one relied on controversial parameters. As objects of assessment, were considered: visions of nature, matter, space, time, transformations, living beings, human body, health, science, technology and everyday life. The emphasis of the final reports relied on the visions presented in the textbooks and also on the activities suggested for students and teachers (MEC-Brasil, 1994). For instance, if the scientific process was depicted as individual scientists carrying out experiments in order to discover the truth, the book was considered not recommended. Assessment results did not focus exactly on the statements found in the books but rather on general conclusions such as : "*In the majority of school manuals, science is referred generally to the scientists, mainly when it is stated that anyone can become a scientist; it would be enough to follow the activities proposed in the textbook. In doing so, students create a stereotyped, prejudiced and mistaken view about the process of production of scientific knowledge.*" (MEC-Brasil, 1994:91). In some regards, the criteria designed at that time were very similar to those presented in the work of Erik Knain (Knain, 2001) in his research about Norwegian science textbooks.

Despite the importance of the new actions, efforts carried out by the Ministry of Education at that time brought no practical effects, as authors and publishers went to court demanding suspension of this governmental action due to the controversies the assessment provoked. As the Brazilian Constitution assures freedom of thought, it would be very difficult to show how "inappropriate" a certain ideological view could be in public schools.

In 1995, under a new federal government, the Ministry of Education created an action team in order to design new criteria for textbook assessment. The science education group put emphasis in the use of scientific knowledge and the role in evidence in the teaching learning process. A first version was presented to authors and publishers in the search for minimum consensus. There was agreement that school textbooks should:
(**a**) lead to the correct use of scientific knowledge under proper evidence;
(**b**) protect students from any source of prejudice;
(**c**) prevent students from situations that could, under a reasonable probability, threaten their health.

There was a clear change in the direction of the official assessment. Recognizing the controversies involved in the study of ideological aspects of nature, science, society etc., the new criteria were seeking more objective parameters, which could have their legitimacy recognized in court by science-lay judges. Several textbooks were the same as in the previous assessment and the result was also the same, as they were considered non-recommended. However the argument was clearly another one. For instance in the book "Mundo Mágico" (Vallone, 1993) there were wrong first-aid recommendations regarding accidents with snakes and several conceptual errors, which were described in detail in the final report. Publishers received the result of the assessment and immediately, according to their own decision, suspended sales of the textbook throughout the country. In the previous assessment, the main problem of this specific book seemed to be the vision of science presented to students. This argument was not accepted by the publishers, who were then supported in court (see Bizzo & Kawasaki, 1999).

Some studies were also carried out regarding the image of science portrayed in Brazilian textbooks (see El-Hani, 1999), but they did not have any mandatory result. In 1997, another symposium with all interested agents from the government, publishers, authors and the academic sector, led to the improvement of the official textbook assessment criteria, including a fourth criterion, related to methodological aspects. These criteria were published previously to the release of the guidelines for inscription of textbooks for acquisition to public schools.

Assessments were carried out in 1996 (PNLD 1997), 1996-7 (PNLD 1998), 1997-8 (PNLD 1999), 1999 (PNLD 2000-2001), 2000 (PNLD 2002), and 2001-2 (PNLD 2004). These assessment resulted in an Official Guide, with book reviews of each approved book, with a detailed description of its content and recommendations for teacher use. Only books included in the guide could be chosen by teachers. These guides have been printed (paper) and distributed in 200,000 public schools throughout the country. Table 1 shows the numbers of science textbooks assessed and the number of books recommended to Primary Schools teachers.

| PNLD | Books Assessed (titles) | Books Recommended (titles) | Number of Books (millions) Distributed to Public schools (all subjects) |
|---|---|---|---|
| 1997 | 81 | 10 (12.3%) | 84.7 |
| 1998 | 89 | 19 (21.3%) | 84.3 |
| 2001 | 98 | 80 (81.6%) | 109.6 |
| 2004 | 136 | (in process) | -- |

**Table 1.** Assessment of Primary Science Textbooks

Table 1 shows two major results. First is the significant increase of books recommended in the second and, more impressively, in the third assessment. This significant increase can be better understood if one takes into consideration two facts: (a) in PNLD 1998 books were almost the same as the ones presented in PNLD 1997, but included some major corrections in many cases (b) there was a significant turnover of textbook writers in

PNLD 2001 (around 66%). Second, this turnover brought a significant increase of new editions, higher than 40%, in the most recent assessment (PNLD 2004, which is in process).

In junior high school level (table 2) the picture is almost the same, however different. In this case the unit of assessment were book-sets of 4 units (grades 5 to 8), and no individual book could be added to the PNLD 2002 Book Guide. There was a low amount of books recommended in the first assessment, and a significant increase in the second process (in practical terms 100%). Again, there was a significant turnover of textbook writers in PNLD 2002, a clear sign that the assessment criteria became an important reference to publishers. This feature has to be regarded taking into consideration that each PNLD had assessment criteria slightly different, adding new parameters. For instance, teaching methodology was focused in the criteria in PNLD 1999 for the first time, and even so the PNLD 2000 books had a very positive score, compared with PNLD 1998 books. Another remarkable change is the marketing of new editions, which are now aimed primarily at sales to public schools. In case new editions are approved by MEC, then large amounts are printed and marketed to private schools, a dramatic inversion of the cycle described above, where public schools were condemned to receive old stocks.

| PNLD | Book-Sets Assessed | Book-Sets Recommended | Number of Books Distributed to Public schools (all subjects, millions) |
|---|---|---|---|
| 1999 | 16 | 3 (18.7%) | 110 |
| 2002 | 18 | 6 (33.3%) | 100 |

**Table 2.** Assessment of Junior-High School Science Textbooks

### Situation of Brazilian Science Textbooks up to 1995

The first assessment of science textbooks aimed at primary school students (PNLD 1997) revealed a dramatic situation. From the use of almost all books there was no way in which correct scientific concepts could be achieved by students in key areas. As a result, two actions were taken in relation to the science books. The first was to publish a full report in a journal edited by the Brazilian Association for the Advancement of Science (SBPC), in June 1996 (Bizzo, 1996). The second was to design a website, at which it was possible to download all specific reports of the assessment of textbooks (November, 1996: http:www.darwin.futuro.usp.br/pnld) so that there would be public scrutiny of the reasons that had led to the exclusion of books in the official guide as well as corrections which could eventually lead to the approval in future assessments. In 1997 we presented this educational use of Internet for a skeptical audience in Montpellier (France), that included Teachers' Trade Unions representatives, in a congress where the actual uses of internet in schools were addressed in detail (Bizzo, 1997). We could show the capillarity that this action had allowed, school teachers had free access to all information on the matter, what could have never been expected by textbooks' writers and publishers.

The "state of art" of Brazilian science textbooks at that time included the following inaccurate or wrong examples (Bizzo, 1996; 2000):

**Health:** information about first-aid related to snake bites was wrong. There were no significant changes after the time of the first notification of the publishers (Nov/1991).

**Astronomy:** Winter and Summer were explained in terms of the distance between the Sun and Earth . Moon phases were explicitly modeled as eclipses, as the Earth would project its shadow on the moon on all nights except once in the cycle (full moon).

**Plant Physiology:** Plants were reported as "suffocating" inside sealed glass jars, in drawings or even pictures; explanations highlighted their need for oxygen. Photosynthesis was presented in several wrong ways, which included purification of polluted air and an antagonistic process to cell respiration.

**Gravity:** there were explicit descriptions that there is no gravity outside of the Earth's atmosphere, often illustrated with pictures by NASA.

**Motion:** Aristotelic notions of movement were clearly present, despite the fact that they often were found together with correct formulas.

**Evolution:** evolution was not only frequently confused with progress, but also was associated with absurd statements about our past or future. About our past a book stated: "*specialists say that human fossils are rare due to the fact that our ancestors were clever enough not to let themselves to be sanded alive*". In the future our brains will be much larger due to the fact that we have to think a great deal etc.

**Water Jets:** frequent drawings showed cylindrical jars with small holes and water jets emerging from them. The deeper the hole, the farther was the distance the water jet reached. A jet emerging one millimeter high from a water jar would jet away from the jar several meters before touching ground level, a self-evident error that drawings could not perceive.

**Candle in Water:** this is another "historically" wrong explanation for the popular experiment in which a candle is lighted in a dish with water and covered by a beaker. The result is the flame extinguishing and a rise in the water level inside the beaker. All books that gave this example, sometimes with pictures, explained that the consumption of oxygen opened space for the water. In one case, there was a mathematical explanation, leading to the exact determination of the relative quantity of oxygen in the air.

### Consequences of Assessment Actions

Publishers and authors were obviously unhappy with the result of the assessment in 1996 (PNLD 1997), which meant in many cases selling the sizeable stocks of old (and unapproved) textbooks to paper recycling programs instead of public schools. The Ministry of Education was sued, in the person of the State Secretary of Fundamental Education (SEF/MEC), in several actions that demanded financial reparations etc. The Federal Court pronounced final rulings in 1998-99, proclaiming that not only did the Ministry of Education have the right to assess textbooks but also had the constitutional obligation to do so because the Brazilian Constitution states that compulsory education has to meet quality standards.

The final court rulings grew out of a dispute over different viewpoints concerning what are and what are not valid ideas that can be espoused in textbooks. Some authors argued in published papers that constructivism implied that there could not be right or wrong concepts because all statements should be accepted as equally valid (e.g. Vesentini and Vlach, 1999). In Brazilian court, some argued to federal judges that freedom of thought would be offended if a conceptual enunciation was considered wrong by a federal authority. Initially, these arguments seemed to be valid in the humanities (for example, history and geography), and could conceivably be applicable to scientific ideas.

However, these proved to be weak arguments. Some evidently wrong teachings were being presented as valid viewpoints. Several examples can be cited. One author claimed the right to teach his own exotic views about energy flow and matter recycling in ecosystems; another insisted that green plants do die in sealed glass jars; a group of authors claimed that the November 1994 total eclipse of the sun had occurred only on the Brazilian side of the border with Argentina, and that vultures can feed on rotten flesh because they fly very high, reaching the ozone layer, where they breathe ozone that kills the bacteria in their stomachs! This book had been previously prized following the guidelines of an international committee under strict recommendations of a foreign bank.

The importance of the official Brazilian policy of assessment of textbooks was underscored as the result of a confrontation that resulted over which textbooks would be purchased with foreign loan money. The confrontation arose over the conditions imposed by a foreign bank offering an international loan (technically known as "an investment loan"). Under the *Projeto Nordeste* the foreign agency agreed to fund textbooks for schools in the Northeast of Brazil. The bank recommended that Brazilian State governments purchased textbooks in which serious problems were found by this assessment carried out by the Ministry of Education (some of these problems, such as the "vulture example", are described above.) In essence, what emerged from this confrontation was a dispute over which criteria would be used to judge the textbooks. The official Brazilian criteria proved to be far more appropriate than the ones put forward by the foreign agency. It is interesting that the information that vultures breath air in the Earth's atmosphere ozone layer, where they would "disinfect" themselves, was re-introduced in Brazil through another "foreign agency", as it could be found in millions of paper towels of the MacDonald's network in March, 2002.

Another direct consequence was a new strand of science textbooks, with new authors, most of them from the Brazilian science education community. The almost complete removal of the collection of anecdotes found by the first assessments was another consequence. Publishers do not rely blindly on authors, and their editorial procedures now include revisions by specialists etc. In Primary school level, the strand of new books published in all areas is significant. In the PNLD 1998 there were 118 new books presented for assessment, what was a significant number. In the PNLD 2000 there were other 315 new books presented for assessment (MEC-Brasil, 2000).

In the context of science education, the experience of assessment raises some concerns that might be addressed in the future in further detail. In this paper, we would like to focus on three aspects only: conceptions of constructivism, the role of evidence in science education, and concerns on nomologies and related studies on students' conceptions.

## Constructivism: is there a concrete target to reach?

Some argue that what is really important in educational constructivist approaches is the final result, something like "improving reasoning abilities", and not the factual and specific information related to the content. School content, in this view, is conceived of as a mere means to develop higher intellectual abilities, such as reading, reasoning and arguing. In the last example, to understand the causal link between the ozone's oxidizing power and the killing of bacteria in a vulture's stomach would require very refined reasoning abilities (perhaps associated with reading and eating hamburgers), and this would be a much more important educational acquisition than the factual knowledge of the altitude limits of bird flight, the exact height of the ozone layer, the relation between toxins and bacteria, the internal anatomy of birds etc.

The relationship between scientific accuracy and school science content is not as straightforward as it is generally acknowledged. A recent article had the emblematic title: "Does being wrong make Kettlewell wrong for science teaching?" (Rudge, 2000). The case-study of *Biston betularia* moths to demonstrate the process of natural selection is popular worldwide and is perhaps the most traditional approach to teaching evolution. It appears to be a straightforward empirical demonstration of natural selection. Black moths are now more frequent in regions where in the 19th century they were rare. As trunks became black, there is the logic tempting to explain changes in terms of differential predation. Black moths would be far less visible on black trunks, meanwhile the whitish ones would be subject to intense bird predation. This logical explanation, however, is not as well supported empirically as it would appear from biology textbooks in use worldwide.

There are several objections to the traditional approach on scientific and educational grounds. Amongst the most important is the fact that students and teachers usually are not aware that the most widely shown image of this case – a picture showing pale and dark moths in lichen-covered and soot-darkened oak tree trunks - do not show living specimens in natural settings, but rather frozen samples pinned on their presumed resting sites (Wells, 1999). Few people could believe that this image, taken from Kettlewell's known book (Kettlewell, 1973), is really part of his own assumptions about the resting sites of moths. Subsequent studies could not confirm the notion that these moths rest on trunks, rather they found that the moths rest in the shade on the undersides of the boughs of trees (Mikkola, 1984). From the technical point of view, it is simply not true that the *Biston betularia* case is a strong example of natural selection shared by the scientific community. On the contrary, there appears to be serious controversy in the scientific community about the actual status of the evidence put forward.

It is concluded by some reviewers that we should simply remove the *Biston betularia* example from pre-college biology textbooks. However, David Rudge (2000) has suggested in his thoughtful article, that we might keep the example, with the important qualification that teachers and students are made fully aware of the limitations involved in the example.

Regarding school content and its accuracy from the scientific point of view, there are two important issues which need to be properly addressed. Firstly, it is important to admit that science education includes different conceptions of science and education. In science, there might be positions ranging from post-modern perspectives, which include radical relativism and skepticism, to other perspectives such as solipsism at the other extreme. In education, accordingly, there might be several propositions ascribing different roles to students, teachers and knowledge in the teaching-learning process.

The assumption that educational constructivism leads directly to post-modern approaches to science is as false as would be assuming the other way around, i.e. that all science educators believe in a mirror relation between mind and the real world.

Solipsism is based on the assumption that real existence is limited to the cognizant individual; all the rest (human beings and objects) are elaborations of the mind due to language and sensorial inputs. As a consequence, actions carried out by an individual would bear absolute certainty about the surrounding world. Despite the fact that some philosophers (such as Wittgenstein) credit an important role to solipsism as a first step in the theory of knowledge, it is important to admit that views associated with positivism rely heavily on it. The assumption that the presence of absolute certainty (such as "the earth moves around the sun") in the classroom is restricted to non-constructivist teaching methodologies is simply false.

Radical relativism and skepticism are often associated with the concept that it is impossible to know the world in objective ways. These views deny any absolute certainty about the world, belittle the importance of empirical experience, refuse any judgment about things, and espouse that all statements are open to constant scrutiny. There is no obvious, direct or immediate association between these perspectives and educational constructivism.

There is yet another aspect to face seriously: it is the frequent ambiguity that involves social and educational constructivism. It is true that, from an anthropological point of view, the cosmology of the Zuni Indians (Western United States) or the Desana (a tribe from the High Negro River in the Amazon) are equally valid compared with those of Copernicus and Galileo. However, this does not mean that any person can write any thought and that these ideas will become as important to humanity as the ideas of Copernicus and Galileo, or important to the degree that they are considered to be relevant school contents. The reference of space and time is often omitted in arguments against school and/or school contents.

On this regard, it is not difficult to recall Paul Feyerabend's *Against Method* (1975) and the careful way in which science education appeared there. After a well known exposition against solipsism, Feyerabend pointed out that his critical views regarding the scientific enterprise did not mean that science is not important in education. While parents have the right to introduce Judaic or Christian concepts or no religious concepts at all to their children, the same right is not, he stressed, extended to them to choose between astrology or astronomy, history or a collection of myths or simply to bring up children with no instruction at all.

Educational implications of social constructivism are not straightforward, especially regarding western science. The community of science educators itself recognizes a spectrum of conceptions of educational constructivism, from more "social" approaches to more "individual-centered" ones. Geelan (1997) believes that it is important to take into account two distinct views of these conceptions. On the one hand, is the role of social processes embodied in the construction of knowledge, often perceived as a primarily individual and solitary task. On the other hand, is the belief on objectivity of the scientific enterprise. In this bi-dimensional model, there are at least four different types of educational constructivism, from personal-objectivist ones (encompassing all the literature on conceptual change) to social-relativist ones (where the works of William Cobern and others are included, see Cobern, 1996, 2000, Cobern and Aikenhead, 1998, Cobern et al, 1999 ).

Despite the many differences among these educational constructivistic views of science education, there are at least some points of consensus. One of them is that the elicitation of students' ideas *is not* the final goal of science education. While the elicitation of students' ideas is an important initial step, there is consensus among educators that students should indeed go further and reach the level of understanding that is accepted by the scientific community. Whether this resulting understanding will in fact change students' mental models or even their world views are still points of dispute in the science education literature (El-Hani and Bizzo, 2002).

**The Role of Evidence in Science Education**

To judge evidence is considered an essential achievement in science education. In fact, identifying or proposing the evidence required to answer questions or the procedures needed to gather that evidence this is one of the key processes targeted in the recent international program of students' assessment carried out by OECD (PISA 2000:77). Most science educators – probably even those associated with social-relativistic educational constructivism – would doubt that the school content of science courses would have factually wrong statements related to easily perceived facts with the use of direct observation in the classroom (such as "the sky is green"). The selection of examples of errors presented earlier in this paper deliberately included some that can be found in science textbooks all over the world and could be perceived with the use of direct observation in the classroom.

Two of them are well documented in the science education literature. The first is the case of water jets emerging from holes in a jar. This particular example was part of the bibliography of the assessment criteria issued by the Brazilian Ministry of Education in 1997, where an article (i.e. Atkin, 1989) was specifically referred. With the provocative title of "*The Great Water Jet Scandal*", Atkin analyzed a traditional statement found in British science textbooks, that is normally followed by schematic drawings. In his brief article he included a real picture in which it is evident that the jet that reaches the farthest distance is not the deepest, but the one at half height instead. This, in fact, real result can be obtained by anyone who personally conducts this very simple experiment (see also Serafini, 1998).

The second example, also known worldwide, is the case of a candle burning in a dish with water. Then candle is covered by a beaker and a sudden change can be seen. Millions of students have been taught to carefully watch the burning of the candle and the simultaneous rise of the level of water inside the beaker where it was burning. Often an explanation is offered, referring to the fact that oxygen would have disappeared. In some instances there appears the claim that the amount of oxygen in the air can be properly determined by measuring the amount of water inside the beaker. There is an evident conflict, however, between what is stated and what can be observed. It is observed that the water remains at more or less the same level while the candle is burning, and that after the flame is extinguished the water enters faster for a few seconds. Moreover, the traditional explanation of the experiment yields a clear contradiction of Lavoisier's well known law that states that no substance can actually disappear. In the science education literature this case was discussed until July 1999, at which time the conclusion emerged that the example had to be removed from science classrooms (see Birk and Lawson, 1999).

In these two examples, there are qualifications that should be mentioned. In the first example, a simple variation in the experiment often masked the true results. Lowering the ground level would change the absolute height of the emerging water jets. This can be easily done by putting the water jar on a table and measuring the distance reached by the jets. However, the measurements are not taken on the table, but rather on the floor. With this variation, the case becomes restricted to the study of what happens in the first half of the water column, where in fact there is an increase of the distance reached with depth.

In the second example (of the burning candle), however, this is not the case, as refutations are often justified by authority arguments or "theoretical experiments" which could "easily" disprove the statement and confirm Lavoisier's Law (see for example, Serafini, 1998). (It is worth mentioning that professional chemists maintain that there is indeed a variation in the volume of the gas inside the beaker, but they say that what happens inside the beaker cannot be properly established due to the fact that the exact chemical composition of the candle is uncertain to a certain degree!). However, there is a simple way to disprove this argument. One can first heat a beaker on a burning candle, and then place the heated beaker over a candle stood in a dish of water, exactly like the candle and dish which was described earlier, except that this time the candle is not alight. The rise of the water level in this beaker, which had no burning flame inside, shows clearly that the rising water occurs *not* because it is taking the place of any missing gas, but instead is due to temperature change (Bizzo, 1998:131).

The question that has to be raised here is: why haven't students and teachers, as well as science textbooks' writers, who have performed these experiments, noticed the conflict between the effect to be demonstrated and their own perceptions? After all, isn't it the "golden goal" of science education to judge evidence, especially the evidence collected by the students themselves?

## Implications for research on students' previous ideas

After the seminal work of Posner et al (1982), there have been a number of studies about students' previous ideas, including studies across different cultures. The theoretical framework of conceptual change brought a new meaning to those studies aligned with certain Piagetian perspectives, in which the learner plays an important and active role in the teaching-learning process. There are different terminologies, but the names "misconceptions", "naïve concepts", "alternative frameworks" etc. have generally been associated with the results of this kind of research. These research programs commonly rely on the assumption that the elicitation of student's ideas will bring the result of genuine thought, ranging from individual to socio-cultural perspectives. Although there are a wide range of studies of these types, it is the consensus that the aim of these studies is to understand the ways students' models work. The models are regarded as genuine and internalized to the point that they can explain the resistance that student ideas have in educational programs aimed at transforming them.

One could hardly admit, even in the framework of constructivism perspectives, that what the science education community regards as genuine and personal ideas of students – even if under the burden of "misconceptions"- could have been actively taught in science lessons. As a matter of fact, many of these ideas were found to be explicit parts of textbooks widely used. Reading the selected examples of problems found in Brazilian textbooks (see above) it is easy to find instances of what the science education literature has described as genuine student ideas.

For instance, the misconception about gravity and atmosphere, which many have regarded as a "natural misconception" in the sense that would emerge as a direct consequence of the knowledge of atmosphere and gravity, was found to be actively taught in science textbooks. This was the case of ideas regarding the lack of comprehension that substances may "disappear" in chemical reactions. Textbooks all over the world taught this lesson, as is shown in the examples previously given (candle in the jar).

This means that what was thought to be a genuine product of the reflection of a child's mind could instead have been actively taught to them. So, the elicitation of learners' models, an important step in educational constructivism approaches, would not rely entirely on personal thoughts, but rather on social interactions, in which one generation can influence the next generation by passing on their views on natural phenomena. Science textbooks would be part of this process of transmission, as the presence of typical students' "misconceptions" were found in widely used textbooks. Since many of these misconceptions were not exclusive to Brazilian books, it is worth considering a reappraisal of what has been regarded as "cross-cultural misconceptions" in the science education literature. Social interactions, including interaction in the school environment, may play far more important roles in developing students' "misconceptions" than has been previously acknowledged.

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## Bibliography

ATKIN, K. (1989). The great water-jet scandal. **School Science Review,** 70 (252): 86-88.

BIRK, J.P and E.LAWSON (1999). The persistence of the candle-and-cylinder misconception. Journal of Chemical Education (76) 7: 914-916.

BIZZO, N. (1996). Graves Erros de Conceito Em Livros Didáticos de Ciência. **Ciência Hoje** 121 (21):26-35.

BIZZO, N. (1997). Enseignement Scientifique et Télématique au Brésil. 3ème Forum de L'Innovation Pédagogique en Sciences Agronomiques: Nouvelles Technologies de Communicacion et Échanges en Matière de Formation, Actes: 42-46. Montpellier.

BIZZO, N. (1998). Ciências: fácil ou difícil? Coleção Palavra de Professor. São Paulo, Ed. Ática.

BIZZO, N. (2000). Falhas no Ensino de Ciências. **Ciência Hoje** 159:26-31.

BIZZO, N.; KAWASAKI. C. S. (1999) Este Artigo Não Contém Colesterol: pelo fim das imposturas intelectuais no ensino de ciências. *Projeto, Revista de Educação* 1(I):25-34.

BRAATHEN, C. (2000). Desfazendo o Mito da Vela para Medir o Teor de Oxigênio no Ar. **Química Nova na Escola** (12):43-45.

COBERN, W. W. (1996) Worldview theory and conceptual change in science education. **Science Education,** 80(5), 579-610.

COBERN, W. W. (2000). *Everyday Thoughts about Nature.* Dordrecht: Kluwer.

COBERN, W. W., AIKENHEAD, G. S. (1998) Cultural aspects of learning science. *In*: TOBIN, K., FRASER, B. (Eds.). *International Handbook of Science Education.* Dordrecht: Kluwer.

COBERN, W. W., GIBSON, A. T., UNDERWOOD, S. A. (1999) Everyday thoughts about nature: An interpretive study of 16 ninth graders' conceptualizations of nature. **Journal of Research in Science Teaching,** 36 (5), 541-564.

CRABBE, B., Les femmes dans les livres scolaires. Bruxelles: Mardaga, 1985.

EL-HANI, C. N. (1999). Brazilian Primary School Science Textbooks: Somewhere Between Bacon and Popper. In Toward Scientific Literacy: The History & Philosophy of Science and Science Teaching, Proceedings of the Fourth International Conference - Calgary, Alberta, Canada - June 21-24, Toward Scientific Literacy: The History & Philosophy of Science and Science Teaching Conference, Calgary, Canadá, 1997, 216-229 Calgary, Canada: Publications Office, Faculty of Education, University of Calgary.

El-HANI, C e N.BIZZO.(2002) Formas de Construtivismo: Teoria da Mudança Conceitual e Construtivismo Contextual (submitted to ENSAIOS/UFMG).

FONSECA, M. (2001). O Banco Mundial e a justiça social no Terceiro Mundo pp 314-323 IN Conferência Nacional de Educação, Cultura e Desporto, Desafios para o século XXI: coletânea de textos. Brasília: Câmara dos Deputados, Coordenação de Publicações.

GEELAN, D. R. (1997) Epistemological anarchy and the many forms of constructivism. **Science & Education**, 6(1-2), 15-28.

GIOPPO, C. (1999). O Ovo da Serpente: Uma Análise do Conteúdo de Ofidismo nos livros de Ciências do Ensino Fundamental. Master Dissertation, University of São Paulo, School of Education, São Paulo.

KNEIN, E. (2001) Ideologies in school science textbooks. **International Journal of Science Education** (23):3:319-329.

MEC, Brasil. (1994) Definição de Critérios Para Avaliação dos Livros Didáticos. Brasília (DF).

MEC, Brasil (2000) Recomendações Para uma Política Pública de Livros Didáticos. Brasília (DF).

MEC/INEP, Brasil. (2001) Sinopse Estatística da Educação Superior – ano 2000. Brasília (DF)

PISA (2000) Measuring Student Knowledge and Skills. OECD, Paris

POSNER, G. J.; STRIKE, K. A.; HEWSON, P. W.; GERZOG, W. A. (1982) Accommodation of a scientific conception: toward a theory of conceptual change. **Science Education**, 66(2), 211-227.

RUDGE, D.W. (2000) Does being wrong make Kettlewell wrong for science teaching? Journal of Biological Education 35 (1): 5-11.

SERAFINI, G. (1998) As Inquietações do Sr. K Sobre o Rigorismo dos Conteúdos Escolares pp. 91-126, IN H. Weissmann (org.), Porto Alegre, ARTMED

SANTOS, S. C. and N.BIZZO (2002). "Inheriting" Ideas About Inheritance: a study of the explanations to the genetic disorders affecting a large Brazilian family over generations. Paper presented at the X Symposium IOSTE (Foz de Iguaçu, Brazil).

SOBER, E. (1994) Why not solipsism?, in: *From a Biological Point of View: Essays in Evolutionary Philosophy.* Cambridge: Cambridge University Press.

SOLOMON, J. (1994) The rise and fall of constructivism. **Studies in Science Education**, 23, 1-19.

STRIKE, K. A.; POSNER, G. J. (1992) A revisionist theory of conceptual change, in: DUSCHL, R.; HAMILTON, R. (Eds.). Philosophy of Science, Cognitive Psychology, and Educational Theory and Practice. Albany-NY: SUNY Press.

TAKAHASHI, J. (1980). Editoração do Livro Didático. **Plural, Revista de Debates**, São Paulo, Ano III(6):21-24 – (Julho-Agosto) APUD GIOPPO, C. (1999). O Ovo da Serpente: Uma Análise do Conteúdo de Ofidismo nos livros de Ciências do Ensino Fundamental. Master Dissertation, University of São Paulo, School of Education, São Paulo.

VESENTINI, J. W. e V. VLACH (1999). Não é o que parece. **Pátio, Revista Pedagógica** (9):442-45.

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# INHERITING IDEAS ABOUT INHERITANCE: A STUDY OF THE EXPLANATIONS TO THE GENETIC DISORDERS AFFECTING A LARGE BRAZILIAN FAMILY OVER GENERATIONS

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## Abstract

The implications of the recent developments of "new Genetics" have been discussed in the scientific community as well as among educators. Outcome approaches on the public understanding of genetics have shown that the Mendelian laws are not understandable for most people and "common sense" or lay ideas are still widespread and used to explain hereditary phenomena. The aim of this paper is to consider the genesis of ideas about inheritance and the empirical evidences that support them. Lay explanations are generally considered as the result of cultural background. But how do these ideas arise? Our hypothesis is that ideas about inheritance arise frequently in families with individuals affected by genetic diseases. The proximity of genetic phenomena probably exerts an emotional motivation that induces the elaboration of new ideas based on empirical evidence existing among family members. These ideas may be socially widespread and possibly structure the "common sense" knowledge in a community.

In this study, sixty members from a large Brazilian family were interviewed in order to investigate their explanations of the origin of genetic disorders affecting individuals over the generations, as well as the justifications given to maintain the consanguinity tradition. Despite the fact that most family members were illiterate, their ideas about inheritance are able not only to explain the hereditary phenomena, but also to predict new events. A very coherent explanation was identified: most interviewees believe that the hereditary diseases present in their family derive from an ancestor infected with syphilis and have been transmitted to new generations by blood. In addition to this, they expressed generalizations based on empirical evidence from family pedigree that support their ideas, including the denial of the relation between consanguinity and hereditary diseases.

This approach may assist not only to counselors at Genetic Counseling Clinics, but also to educators involved in relevant questions such as the origin of "alternative, previous or spontaneous" ideas and the process of their social spreading.


## Introduction

The implications of the recent developments of "new Genetics" have been discussed in the scientific community as well as among educators. Legal and ethical aspects focused on policy agenda and new themes debated on the media: the appropriate use of genetic tests and population screenings; the possibility of discrimination due to genetic factors; the "destiny" of transgenic resources and lab created embryos, etc. Resulting approaches on the public understanding of genetics have shown that the Mendelian laws are not understandable for most people, as well as "common sense" ideas are still used to explain heredity phenomena. The aim of this paper is to reflect upon the genesis and the empirical evidences that support the lay knowledge of inheritance, taking into account the results of a study involving sixty members of a large Brazilian family carrying different genetic disorders for the most recent generations.

Ideas such as the transmission of characteristics through generations are widespread in different cultures. The most ancestral idea may be the incest taboo, which outlaws sexual relations among first-degree relatives. The origin of such conventions is obscured, but it represents cultural and religious sanctions (Modell, 1997). For Roman Catholics, for example, marriage to a first cousin is permitted but discouraged: a religious dispensation is required to the solemnization of such marriages. For Protestants, there are no restrictions to first cousin unions. This type of unions is still predominant in contemporary Islamic society. In addition to this, the highest rates of consanguineous marriage are usually reported in rural areas and among the poorest and uneducated community members. Another peak takes place in land owning families, which use biological relationship to keep the integrity of their landholdings (Bittles, 1991).

Other old notion is that all features, being desirable or undesirable ones, are preserved in subsequent generations. In primitive societies, attempts to breed and cultivate "genetically" may have arisen from the observation of the reproduction of domesticated animals and the cultivation of plants. The similarity between offspring and their parents, as well as the appearance of new varieties, were explained in different ways. A classical explanation was the Hippocratic doctrine of pangenesis, which considers that the similarity to parents concerning any part of the body was a result of the quantity of semen donated by each parent. For example, in organs where the father overcame the maternal contribution, the organ would resemble the male. Contrarily to this, Aristotle believed that only males produced semen, the female contributing only with menstrual blood. The form of the organism was transmitted through the blood, which carried nourishment to all the organs. Charles Darwin put forward explanations based on pangenetic views of heredity.

Myths and legends about inheritance are still alive and resist change even in highly formally educated societies. Such beliefs have been described as "devastating misunderstanding" by Hodson (1992). For instance, people believe that the father plays a more important role in heredity than the mother, who would be responsible only for the sex of the child. Inheritance is still seen as blending. The acquired characteristics or Preformation theory are still considered in spite of lack of scientific bases underlying them. Furthermore, other superstitions were considered by Turney (1995), such as telegony or "germ infection", which means that the offspring characteristics can be influenced by previous mates; the maternal impression, that can be illustrated by the history of the Jacob's cattle in the Bible; the successive degeneration, when sick parents have poor quality offspring.

Systems of beliefs are related to patterns of behavior. For instance, one of the strongest superstitions related to genetic disorders, in black population of Southern Africa, is that albinos do not die. The belief in this myth affects the interaction between albinos and others members of the population at many levels. Mothers tend psychologically to reject the child at birth and develop normal bonding behavior only by the time the child is nine months old. Other cultural beliefs associated to disease causation include the idea of maternal impression, expressed by the saying 'if you laugh at an albino when you are pregnant you will have an albino child' (Kromberg, 1997).

The existence of lay beliefs about inheritance, which may be incompatible with Mendelianism, is a major determinant of reproductive choices in family members who carry genetic diseases. Their explanations may best proceed from a prior understanding of inheritance. It may be hard for those who do not have a genetic disease to understand how their children may inherit it, as is the case of autosomal recessive disorders. Such difficulties may also arise with autosomal dominant conditions that are largely expressed in one sex, as breast and ovarian cancer. It seems hard for people to understand that such diseases can be transmitted via the male parent (Richards, 1996 and 1999). These lay knowledge may serve to intellectually evaluate a situation in the family and may form part of a psychological defense system which serves to reduce uncertainty about inheriting or not a disorder (Kesser, 1989).

Such "common sense" or lay ideas are widespread in classrooms and the knowledge of its bases is required. In general, the explanations about inheritance are considered as a result of inputs from the cultural background. But how do these ideas arise? Almost nothing is known about the genesis of ideas about inheritance and the process of their cultural spreading through time. Our hypothesis is that such ideas arise in families with individuals affected by genetic diseases. The genetic phenomena must exert an emotional motivation that induces the elaboration of new ideas based on empirical evidence existing among family members. The ideas arisen in families are socially widespread and they may structure the "common sense" ideas in a community. If this hypothesis is at least partially correct, we should find elaborated explanations and models about inheritance in families affected by different disorders. In addition, we should find some sort of evidence supporting these explanations and models.

## The study

Sixty members of a large family were interviewed in order to collect their explanations about the genetic disorders that have affected many individuals in several generations, as well as their justifications to maintain the consanguinity tradition. This is relevant because the genetic disease that affects most members in this family is the classical autosomal recessive ataxia of Friedreich, obviously related to the presence of consanguinity. Friedreich ataxia is characterized by progressive espinocerebellar degeneration, which causes paralysis of the lower limbs, affected individuals being unable to walk since childhood.

Our inquires took place in four Brazilian localities: São Paulo, a metropolitan city in the Southeast, and three rural areas in the State of Rio Grande do Norte in the Northeast. The rate of consanguineous marriage is fifteen times higher in this region than in the southeast. Other details on consanguinity rate are found in the comprehensive report on Brazilian populations published by Salzano and Freire-Maia (1969).

The parents of a woman affected by ataxia were contacted at a Genetic Counseling Service (Laboratory of Human Genetics, Department of Biology, Universidade de São Paulo). Her family *pedigree* indicated a large number of affected individuals still living in the Northeast region. These people were then contacted and, in a month in a fieldwork, we tape-recorded twenty-one in depth interviews, involving thirty-seven individuals who lived in three rural localities of Rio Grande do Norte. The interactions between one of the researchers (SS) and the families took place in their homes.

We considered relevant to study this family due to two main reasons:

1. In this family there is an extremely high incidence of consanguineous marriages and many individuals affected by an autosomal recessive form of spinocerebellar degeneration, responsible for progressive motor impairment. In addition to this, there are some sporadic genetic anomalies such as deafness, mental retardation, Turner and Down Syndromes.
2. There is reduced influence of social sources of information other than the own family members, who have restricted access to scientific and scholar knowledge. The majority of the individuals interviewed are over forty years, and they were not enrolled in any sort of schools for more than four years, having only basic skills on literacy and numeracy. Many are illiterate, especially the women. Being practicing Protestants, they do not normally watch television programs in respect to their religious rules.

The ancestors of this family were European settlers who probably arrived in that region at the beginning of 19th century to cultivate sugar cane, which was the principal economic activity ran in the Northeast of Brazil for the last two centuries. This region has however lost its economic importance, being a decisive factor in impelling emigration to metropolitan cities like São Paulo. Presently, most of family members living in the rural areas are retired, using to plant beans, cotton and sugarcane in the rainy season for their only support. Infrastructure facilities are poorly developed in this region; the electricity supply had recently been implanted, although there is no treated water distribution in the houses.

Research began by collecting information on the family relationship in order to draw the *pedigree* and to locate affected persons. During the interviews, two questions were asked: How do you explain the existence of the degenerative disease in many generations of your family? Do you think that this deficiency (ataxia) has any relation with the cousin's marriages that are common in your family? Other secondary questions were made in order to investigate ideas which were not straightforwardly understood by the researchers, or because they were related to interesting aspects that arose from the conversations, in which we did not use any directive questions. All interviews were tape-recorded, transcribed and afterwards analyzed.

For the time being, we are interested only in the explanations of the family members to the genetic disorders that occurred. Genetic tests are still being performed with affected individuals from this family and we plan to present clinical and molecular descriptions, as well as the genetic counseling sessions will be carried out eventually with all at-risk individuals.

## Results and discussion

A common explanation was identified in the family community. The majority of the interviewees did recognize the ataxia running on the family as a hereditary disorder, explaining that the disease is in the blood of all the parents, being able therefore to affect anyone. The metaphorical expression used by them to explain the origin of the disease was "*Isso vem lá dos troncos velhos*", that literally means "this disease comes from the old trunks", in the sense that the affection arose in an ancestor and it has been transmitted through the generations by the blood. They believed that the deficiency tends to appear in persons belonging to recent generations, saying that "*E pinta mais nas pontas dos galhos*", what could be translate as "and it is more common at the tip of the branches". This means that the affection is "getting stronger" with the passing of generations.

An infectious explanatory model has also emerged, because some stated that the deficiency comes from a common ancestor, "old Maximiniano", who was infected by syphilis. This disease would be transmitted to the descendents by the blood. Therefore, anyone may have an affected child. A woman added curiously that if the ancestor lived nowadays, AIDS would certainly infect him. Another woman, contrarily to the prevailing notion, said that her parents told her once that the deficiency was due to the fact that "old Maximiniano" had only one testicle.

Analyzing the *pedigree*, one seems that the family ideas actually tend to explain the hereditary events, because all ataxia-affected members descendent from "old Maximiniano" and deficiencies are more frequently found in members belonging to recent generations. In addition to this, the majority of the interviewees affirmed that the parental consanguinity was not related to the ataxia, mentioning some examples from their genealogy to support their own ideas: two brothers, married with unrelated women, have had crippled children; also, most of the family members got married with relatives, but their offspring was normal. On the other hand, unrelated couples originated children affected by mental retardation and other defects. In conclusion, the individuals understood that parental consanguinity was not related to hereditary disorders and different diseases have the same cause.

Explanations based exclusively on myths and religious beliefs were not found. Although in daily conversations individuals used to say that the deficiency was "God's desire", most of them recognized its hereditary causation. A woman, for instance, explained that her son was affected by ataxia because the disease was present on her husband's family, being transmitted to the child, and that it could not be, therefore, a divine desire.

In fact, the family explanations were based on rough empirical evidence. They believe that the deficiency arose in the "Maximiniano trunk", because the ancestor had married twice, and the offspring of both unions there occurred affected children. Besides this, some Maximiniano' parents were also crippled. Otherwise, they asserted generalizations that should come from the empirical evidence present on the family. Five different women declared that, on overage, all sibships contained ten individuals, one or two of them being affected. Another common idea was that crippled child would be born if a case of the disease had already occurred on both family sides. It is also a widespread notion that the deficiency may affect till the fifth generation, frequently coming from the male line.

The scientific information in this family has been considered irrelevant or distorted in order to make room for the individual prior understanding. For instance, two interviewees affirmed that counselors had told them that the ataxia could be caused by consanguinity. However, they quickly added that this could not be true, reporting empirical evidence in the family that confirmed their own explanation. On the other hand, some women mentioned that doctors used to say that ataxia came from an ancestor and had been transmitted to individuals of the new generations by blood. This means that sometimes they use the expression "the doctor said" to legitimate their prior explanations. The majority of family members believing that consanguinity is not related to ataxia and that there are not rational grounds to advise against marrying a relative.

The narrative contact seems to contribute to widespread lay explanations. All the individuals of this family are in constant contact with each other by daily conversations and religious meetings. Despite its "scientific ignorance", the family community showed to possess very coherent explanations to the presence of ataxia and other anomalies. In addition, these ideas both explain and predict the events. For example, some women said that if a baby presented symptoms probably related to nystagmus, then certainly he or she would later develop ataxia. Besides this, they usually are worried about the pregnancy, because they are always expecting the birth of crippled children. The family members understand that the degeneration is in their blood and it is "getting stronger", affecting more individuals in recent generations.

The family explanations are structured by elements arisen from the experience with hereditary phenomena and old ideas probably inherited from their European ancestors. It has been known that congenital syphilis may cause blindness, deafness, and mental retardation. Moreover, syphilis was understood as a hereditary disorder and considered a kind of degeneration transmitted by infected parents to their offspring (JONES, 1999). These ideas from European settlers may still be present on everyday family's conceptualizations, being used to explain observations from daily life, together with new empirical evidences. This extrapolation could indicate that ideas about inheritance would arise from the social context, rooted in evidence presented to highly motivated people, with a great deal of empirical knowledge on the subject. The diffusion of this knowledge would be part of a social process in which "commonsense" would emerge.

Interestingly, individuals that immigrated to metropolitan areas still keep the consanguinity traditions. Some of the women interviewed expressed that it was safer to get married with someone from their own family than with a stranger. Some relatives that were not married to cousins had a "terrible" marital experience that result in divorce. In addition to this, the Protestant doctrine among Northeastern Brazilians seems to favor consanguineous associations, because a special value is given to those individuals sharing the same beliefs.

Modell (1997) pointed out that consanguineous marriages in the British Pakistani population could increase the stability of the whole family, because a woman, who marries her cousin and is likely to have known him and his family since childhood, tends to stay in the same village, being thus not separated from her relatives. Consanguinity can contribute therefore as a single cohesive family unit.

The family ideas and marital patterns play a socially stabilizing role that is often overlooked by the counselors and medical practitioners. In general, their statements could be therefore inadequate, like 'your child is abnormal because you are cousins'. As discussed by Qureshi (1997), "such statements not only produce a strain within the couple, but also disrupt the whole family. Such judgment affirmation runs totally counter to the principles of genetic counseling that had been adopted in clinical practice. Just as one would never consider blaming a non-immunized mother for her child's congenital rubella, so one should never blame a couple for their child's illness, to do so it is potentially most destructive". Taking on account this discussion, counselors should consider the lay inheritance conceptualizations to plan their orientations.

This approach may contribute not only to people engaged in Genetic Counseling, but also to educators who have been pondering about relevant questions such as the origin of "alternative, previous or spontaneous" ideas and the process of their social diffusion. It is probable that individuals in a community, living in contact with specific phenomena, may elaborate explanations based on observations and empirical evidences. These ideas not only explain daily observations, but also predict events. Such explanations may constitute mental models in a community, in some regards often seen as commonsense ideas. The narrative, as daily conversation or an artist's production, may reproduce such ideas, contributing to keep them despite the scholar process.

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## References

BITTLES, A.H. et col. (1991). Reproductive behavior and health in consanguineous marriages. Science 252: 789-793.

HUDSON, A. (1992). Essencial Genetics, Bloomsbury, London.

JONES, T (1999). Deus, genes e o destino: na massa do sangue. Publicações Europa-América, Portugal.

KESSER, S. (1989). Psychological aspects of genetic counseling. VI. A critical review of the literature dealing with education and reproduction. American Journal of Medical Genetics, 34: 340-53.

KROMBERG, J. & JENKINS, T. (1997). Cultural influences n the perception of genetic disorders in the black of Southern Africa. In: A. Clarke A and E. Parson (Eds.). Culture, Kinship and Genes. Londom: Macmillan Press.

MODELL, B. (1997). Kinship and medical genetics: a clinician's perspective. In: A. Clarke A and E. Parson (Eds.). Culture, Kinship and Genes. Londom: Macmillan Press.

QURESHI, N. (1997). The relevance of cultural understanding to clinical genetic practice. In: A. Clarke A and E. Parson (Eds.). Culture, Kinship and Genes. Londom: Macmillan Press.

RICHARDS, M. (1996). Lay knowledge of inheritance and genetic risk: a review and a hypothesis. Health Care Analysis 4: 1861-4.

RICHARDS, M. (1999). Families, kinship and genetics. In: T. Marteau and M. Richards (Eds). The troubled helix: social and psychological implications of the new human genetics. Cambridge University Press.

SALZANO, F.M. & FREIRE-MAIA, N. (1969). Problems in human biology. A study of Brasilian population. Detroit, Wayne State University Press.

TURNEY, J. (1995). The public understanding of Genetics – where next? Eur. J. Gen. Soc. 1 (2): 5-20.

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# PEDAGOGIC SKILLS NEEDED BY THE UNIVERSITY PROFESSOR FOR SUCCESSFUL TEACHING AND LEARNING

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## Abstract

Pedagogic competency is currently amongst one of the most important issues in Brazilian universities dealing with the quality of teaching of university professors. This kind of competency is the main problem related to the didactics and methodology used in classroom teaching. It means that good classroom practice needs more than specific academic discipline knowledge. This study has as its focus the practical training and pedagogic skills of the university professor. The research was carried out in the Human Science department of the University of Vicosa, Brazil over a period of two years. This research is the first of its kind carried out in the Department of Human Sciences at the University of Vicosa. In Brazil there is concern about teacher training and pedagogic skills especially of University professors. To date, only a few studies in the field of pedagogic competencies have been undertaken in Brazil and none have been at the university level. The present study investigates one tertiary institution's attempt to improve the pedagogic competency and didactic skills of university professors. Brazil's rapidly expanding education system and largely teacher-centred mode of delivery makes this study timely because the study provides potentially significant insights into how the pedagogic skills and didactic capabilities of the University professor may be improved.

## Objectives of the Study

The objective of the study was to obtain the perception of students of their vision of a "good professor" and how a professor directs and leads the teaching-learning process. This descriptive exploratory research study involved students and professors. The research made use of a student questionnaire and structured interviews for professors and was guided by two main research questions:

1. What do students perceive are the qualities of a "good professor"?
2. What do professors perceive as necessary for success in pedagogic practice?

## Theoretical Framework for the Study

The studies and works of Perrenoud (2000); Alarcao (1997); Cachapuz (1997); Balzan (1994); Cunha (1992); Abreu & Masetto (1990); Menezes (1986) deal with the didactic skills and pedagogic competencies of the university professor. This group of researchers discuss the skills and qualities required for good performance in the classroom. Their work discusses the methodologies used in the classroom by a university professor, the teacher training skills imparted to a professor and the influence it has on effective student learning. Much research has been carried out into the relationship between student achievement and the quality of the classroom learning and teaching. Consistent and overwhelming evidence from these studies suggests that the pedagogic competencies of the university professor strongly influences student achievement and learning especially at the tertiary level. Lewin's (1936) seminal work in non-educational settings, recognised that both the environment and its interaction with the individual are potent determinants of human behaviour.

To analyse the life history and the work environment of the professor is important, especially at a time when the formation of the professor and conception of education has evolved through several historical stages, from the traditional stage to the modern and post-modern stage. In a democratic society, it is important for professors to search and explore what happens in the classroom and to reflect on their teaching (Silva, 1991).

The efficiency and capacity of the professors in carrying out tasks when transmitting knowledge in their area of specialization, is often affected due to lack of pedagogic skills and students are thus not able to understand and comprehend (Menezes, 1986). Beyond the domain of the knowledge in the area of which the professor is a specialist, the professor must have abilities and skills such as: ability to develop a positive student teacher relationship, have the capacity to transmit knowledge, to stimulate creativity, to encourage in the student the capacity for critical thinking, questioning and the desire for discovery and invention. The University professor must be able to connect and apply knowledge with the reality of life and society and thereby develop and establish a relationship between education and society (Cunha, 1992).

Thus being an effective professor can never be properly defined, for the teaching professor needs to change daily according to the needs of the students and the situation he encounters. The professor has to draw links between the theoretical and the practical aspect of the knowledge he imparts, as well as the need to constantly update his knowledge. In addition the professor needs to integrate the knowledge of many sciences and uses of all scientific knowledge and the practical aspects, in a creative and stimulating way, together to prompt student learning and thinking (Barros & Silva, 1990).

Pedagogical skills in a transformative perspective are characterized by new and challenging situations. It is important for the student to develop skills of critical thinking, problem solving and creative imagination. Educators must rethink the content of education in such a way, that educational institutions give freedom of space to individuals, there is a search for knowledge amongst all in the institution and there is increased learning through collective construction and a combination of the technical, human and political dimension of knowledge (Balzan,1994).

The productive combination of qualitative and quantitative methods (Tobin & Fraser, 1998) and use of interpretative research (Erickson, 1998; Tobin, 1998) is increasing rapidly in the field of education today. This study draws on and contributes to the field of teacher education at the tertiary level and investigates teaching and learning of professors and students at a university in Brazil.

## Methods

This study was guided by descriptive exploratory research (Ludke & Andre, 1986), and was carried out in two stages. This research seeks to describe, explore and study a certain situation. The research is concerned with the perception of the participants. The whole research process is important rather than the final result. In the case of this study the researchers decided to explore the perceptions of students and teachers with respect to the teaching and learning process in the Faculty of Human Sciences at the University of Vicosa, Brazil

In the first stage a simple questionnaire comprising 2 questions was administered to a sample of 111 final year students, from seven different courses, in the area of the Human Sciences. Some of the faculties are the Departments of Education, Languages, Economics, Law and Home Economics. The first stage sought to diagnose which professors the students considered good and what they perceive are the qualities and characteristics of these "good professors".

In the second stage, a sample of 10 professors considered "good professors" from students' question analysis were individually interviewed using 5 structured questions. The questions sought to elicit answers to the following questions:

- What did the professors consider as good qualities in a university professor?
- Why did they feel they had those qualities?
- How do they teach their subjects and what methodologies do they use?

- What difficulties do they experience in carrying out their duties?
- What are their perceptions about university professors today?
- What is their vision about education in Brazil in general?

All interviews were audiotaped with the permission of the professors.

## Results

The analysis of the results disclosed that, students perceived a " good professor " as one who had excellent content knowledge and could transmit this knowledge with clarity, objectivity and dynamism. The professor thus needed to have a combination of scientific and pedagogical knowledge. Students also felt that the professor must be an organized and efficient planner, must be able to put theory into practice coherently and be able to evaluate effectively. With respect to relationships students felt that a professor must be sincere, friendly and interested in student issues. He/She must be able to encourage students and permit student dialogue and expression. The sample group of students also felt that a good professor must constantly update his knowledge, must be competent, responsible and enjoy teaching.

Analysis of interview data from professors considered to be "good" by students indicated that the professors were able to express themselves in a coherent manner, easily understood by students. These professors were interested in new knowledge and issues in their field of study. They were confident and able to confront problems and situations as they arose. They enjoyed teaching and felt it was important to motivate and challenge students. They reflected on the quality and standard of their work and believed that effective teaching resulted in effective learning.

The general difficulties perceived by these professors in carrying out their duties were inadequate planning, large student numbers in classes, lack of resources for students, inability to cater to differences in student ability, the time spent in marking and testing. The difficulty in combining research, teaching and professional development duties like attending conferences and seminars and conducting workshops.

The results of this research allowed the researchers to explore and describe a "good professor" using the perceptions of the students and the professors themselves. He/She is that professor who uses different methodologies to facilitate learning, improves his/her own content knowledge, allows an affective relationship, of friendship, respect and companionship between student and teacher both inside and outside of the classroom; and still is an intellectual and capable professional.

## Discussion and Conclusion

Thus this exploratory and descriptive study indicates that the success of pedagogical work depends on the technical expertise and pedagogical competence of the professor, who creates challenging situations for the student to become competent and creative. The results of the research were disclosed to the professors of the Department of Human Sciences at a meeting and were also made known to the Department that provides help to the university professors. The department then designed and offered courses with the help of the first author in the area of pedagogic skills. The department has also been able to improve the courses it offered professors for in-service professional development.

This study is important because it is one of only a handful of studies in the field of pedagogic competency of university professors at the University of Vicosa in Brazil. In addition, the findings of the study provide useful and practical information to the university department wishing to improve the pedagogic and didactic skills of professors. The study is valuable because it has the potential to create a clearer perception of how professors and university departments can work together to create positive attitudes, improve pedagogic skills, improve teaching and learning and academic performance of students.

The study was significant in that, by exploring perceptions of students and professors and informing the university of results, a professional development course, was designed to improve the pedagogic and didactic skills of the university professor.

## References

Abreu, M.C, & Masetto, M.T. (1990). *The univesity professor in classroom: practice and theorics principles.* São Paulo, Brazil: Cortez.

Alarcao, I. (1997). *Contribution of Didacticism for teachers' formation: reflections on its teaching.* IN: PEPPER, S.G., org. Didacticism and Formation of Teachers: courses and perspectives in Brazil and in Portugal. São Paulo: Cortez. pp.159-190.

Balzan, N.C. *In*: Pimentel, M. G. (1994). *The professor in Constrution.* Campinas, São Paulo, Papirus.

Barros, D. F. & Silva, R.C. (1990). *The teacher training in university : scientific capable or teaching capable*? Impulso, São Paulo, Unimep, n7, pp.5-15.

Cachapuz, T. (1997). *Investigation in Didacticism of the Sciences in Portugal: a critical swinging.* IN: PEPPER, S.G., org. Didacticism and Formation of Teachers: courses and perspectives in Brazil and in Portugal. São Paulo: Cortez. pp.205-240.

Cunha, M. I. (1992). *The good professor and your practice.* Campinas, São Paulo, Papirus.

Erickson, F. (1998). *Qualitative research methods for science education.* In B.J. Fraser and. K. Tobin (Eds.), *The international handbook of science education* (pp. 1155-1159). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Ludke, M. e Andre, M. E. D. A. (1986). *Research in the Education: quality approach.* São Paulo, EPU.

Perrenoud, P. (2000). Ten new competences to teach. Translation: Patrícia Chittoni Ramos. Porto Alegre: South Medical arts.

Silva, E.M.V.A. (1991). *University teacher: difficulties in the educational practice.* São Paulo, UNIMEP.

Tobin, K., & Fraser, B. (1998). Qualitative and quantitative landscapes of classroom learning environments. In B. J. Fraser & K. G. Tobin (Eds.), *The international handbook of science education* (pp. 623-640). Dordrecht, The Netherlands: Kluwer Academic Publishers

**Key Words:** pedagogic skills, teacher training, university professor, student perceptions, exploratory research.

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# PARTNERSHIP IN PRIMARY SCIENCE PROJECT: DEVELOPING A COMMUNITY OF PRACTICE TO ENCOURAGE THE DEVELOPMENT OF PEDAGOGICAL CONTENT KNOWLEDGE

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## Abstract

The Partnership in Primary Science (PIPS) project aimed to provide and promote Continuing Professional Development (CPD). To date four Scottish education authorities, ten schools (involving sixteen teachers), one teacher education institution and six scientists have been involved in the project. The Project aimed through a community of practice to encourage primary school teachers to develop skills in using Information Communication Technology (ICT) at the same time as refreshing their understandings of science concepts, and teaching and learning strategies over a period of ten months. As such the aim of the project was to help develop their pedagogical content knowledge (PCK). Evidence collected to date would suggest that the PIPS model of CPD has encouraged personal appropriation of the ICT tools for science teaching and influenced their PCK. Teachers have engaged in complex, intellectual and practical activity, and this activity has influenced their classroom practice.


## Introduction

The Partnership in Primary Science (PIPS) Project aimed to encourage primary school teachers to develop skills in using Information Communication Technology (ICT) at the same time as refreshing their understandings of science concepts, and teaching and learning strategies over a period of ten months. A key aim was to enhance primary school primary teachers' ICT and science pedagogical content knowledge. The didactic and out of context delivery of CPD with respect to ICT and science has shown that few teachers expand their existing knowledge of teaching strategies to include ICT (Kelly, 2002). This lack of success may be explained by considering that 'better will not come from finding better ways for the teacher to instruct, but from giving the learner better opportunities to construct' (Papert, 1990; 3). Better CPD will come from providing teachers with opportunities to construct, because in the case of ICT in classroom science, the teachers are the learners.

Research has shown that events that resulted in ICT use in well resourced schools were a consequence of personal appropriation of the ICT tools (Dwyer, Ringstaff, and Haymore-Sandholtz, 1990). Teachers' beliefs about primary teaching and schooling, their attitudes toward ICT and their understanding of the value and purpose of ICT are determining influences in whether they use ICT. Sherwood (1993) stated that most teachers were now at a stage where they wanted CPD to help them in classroom practice, rather than provide simple information about the technology. They wanted to know how to put it into practice and wanted to see classroom strategies that demonstrated effective use.

Fullan and Hargreaves' (1992) suggest that many failures to introduce innovation successfully stemmed from the fact that innovation was not related to existing school practices. The PIPS CPD model involved the setting up of a community, promoting ownership of the change process and providing opportunities to engage in the shared construction of knowledge, and as a consequence develop pedagogical content knowledge. A key aim of the project was to develop communities of practice that help support teachers in classrooms and encourage teachers to adopt informed positions on pedagogical issues related to the use of ICT in terms of curriculum and assessment

Three agents of change influence the PIPS CPD model:

- Current CPD developments in light of the McCrone Agreement
- Belief that CPD formulaic delivery of skills and information allows for formulaic planning but limited long term change in classrooms and it ignores the richness of teacher thinking.
- Socio-constructivist views that focus on dialogue and communication.

In Scotland there has been a review of the nature of CPD, prompted by the recent McCrone agreement. At present most CPD requires attendance at prescriptive courses. The ImpaCT2 interim report signals that although many teachers have received normative CPD in the use of ICT, they still lack confidence and experience difficulty in integrating ICT into lessons. The PIPS model takes on board what Kenny (2002;42) reports as OFSTED opinion "that in spite of the intention, the lack of a subject specific focus in training programmes is a major weakness..Subject applications are referred to, but matters of pedagogy are generally not sufficiently explored". Therefore the PIPS CPD process promoted the development of ICT/Science pedagogical content knowledge; building in science and ICT subject knowledge and understanding, knowledge of teaching and learning and general craft knowledge.

The PIPS model was undeniably different to the norm. Most CPD practices involve participants attending courses during which the CPD provider disseminates information with the provider providing instruction and participants being passive recipients. According to recently disseminated information (Kenny, 2002) there is little to suggest that outcome driven CPD influences classroom practise. Outcome driven models of CPD could be considered Power–on- whereby the provider determines the decisions for direction, product and practice. The PIPS model of CPD promotes a Power-with approach whereby decisions for direction, product and practice are jointly determined by participants and provider.

**The role of a community of practice in the development of pedagogical content knowledge**

The PIPS project draws on a view promoted by Dewey, who observed that "true learning is based on discovery guided by mentoring rather than the transmission of knowledge" (cited in Boyer 1998; 15). The project assumes that classroom practice depends on the pedagogical inclination of the teacher. It also assumes that these inclinations are based on their philosophical orientations with respect to education. The project aimed to enable teachers to be instrumental contributors in a review of what it means to be a teacher of science using ICT, starting from and developing their existing classroom practice.

The PIPS model of CPD requires community development of educational practices that take on board pedagogical issues and technical know how. The project is based on two assumptions:

- CPD has to be of intrinsic value if it is to influence teaching
- Changes in pedagogical content knowledge must start from the teachers' perspectives and requires teacher ownership of the change process.

Teacher professional development is a form of learning that involves professional, social and personal development (Bell and Gilbert, 1996). Professional development requires the development of pedagogical content knowledge (PCK). Social development requires the development of ways of working that foster social interaction and allows for re-negotiation and reconstruction of ideas and thinking. Personal teacher development requires the individual to take ownership of the change process and management of feelings of agitation about the increased complexity (Cochran-Smith, 1991). The PIPS model is based on the social-personal- professional view of teacher development (Bell and Gilbert, 1996) as opposed to the research-development-dissemination model common to most teacher professional development strategies. In the social-personal- professional development model, teacher development and curriculum development are concurrent and reciprocal strands (Bell and Baker, 1997).

The promotion of various ICT tools in the PIPS project was underpinned by a view of use guided by Constructivist philosophy and Shulman's notion of pedagogical content knowledge. For ICT to be used in primary science, its significance as an effective learning tool has to be visible in terms of the pedagogy and in terms of the learning process. The online component, discussion forums and bulletin boards will show how the technology can meet socio-constructivist tenets. Face to face or online discussion have the potential to be used by participants as venues for formal and informal learning (Collins & Berge, 1996). Online activity relies on a learner-centered approach and as such relies on collaborative, semi structured egalitarian relationships (Eastmond, 1992). Online participants must take responsibility for furthering discussion (Rohfeld & Hiemstra, 1995). Miscommunication, loss of status, inhibition, and not seeing others as real people can lead to problems in an online discussion. Hence the structure of the PIPS project allows for the development of face to face and online discussion.

The model of CPD is based on Lave and Wenger's communities of practice and Constructivist tenets that focus on dialogue and communication. The PIPS project promoted a model of CPD that involved establishing a community of practice, where mentoring involved peers and experts. The model also advocated ownership of the change process with a view to developing what Shulman (1987) termed pedagogical content knowledge (PCK). Shulman identified PCK as a blending of content and pedagogy in order to inform how topics and issues are organised so as to take into account instruction and pupils' learning.

In the late 1980s there was widespread debate about PCK. Some researchers (McEwan and Bull, 1992) suggest that Shulman's distinction between PCK and subject knowledge was not justifiable, because in the act of teaching, all knowledge is presented pedagogically in some form. Other researchers suggest that teachers' PCK and subject knowledge have an impact on classroom practice and are influenced by practice (see for example, Rovegno, 1992). This would also suggest that PCK is an active process rather than simply a combination of knowledge bases. It is with this assumption in mind that the community of practice view of CPD was promoted in the PIPS project.

There are some ambiguities inherent in Shulman's concept of PCK as a combination of content and general pedagogical knowledge, and in recent times there have been moves to develop more transparent models of PCK which include various aspects of teaching. For example, Tuner Bisset (1999) promotes a view of PCK that includes substantive knowledge, syntactic knowledge, beliefs about the subject, curriculum knowledge, knowledge of contexts, knowledge of self, knowledge of teaching models, knowledge of learners, knowledge of educational ends, general pedagogical knowledge.

For me this over delineation simply serves to fragment what is really a holistic concept. For me there are three key facets to PCK: Subject matter knowledge, Teaching and learning views and General Craft knowledge. Subject matter knowledge would include substantive knowledge (knowing what and how), syntactic knowledge (generation of propositions), Beliefs about the subject (teachers' orientations towards what is important to know). Teaching and learning views would include the knowledge of self (personal identity as teachers), knowledge of models of teaching (teachers perception of teaching), knowledge of learners (includes social knowledge of children, knowledge of child development, knowledge of the individual child), knowledge of educational ends (goals and aims). Curriculum knowledge (tools of the trade- resources, materials etc), general pedagogical knowledge (classroom management and organisation principles that transcend subject boundaries) and knowledge of educational contexts (school location, class size, pupils relationships in school ) are all instrumental in determining general craft knowledge.

Through the development of a community of practice the project aimed to encourage the development of teachers' PCK in using ICT in teaching and learning science. The community of practice would encourage the development and sharing of subject matter knowledge, teaching and learning views and general craft knowledge.

## Project Methodology

It has been argued that educational change depends on what teachers do and think a rather simple and at the same time, complex, view (Corbet, Firestone, Rossman, 1987). But on the assumption that educational change does depend on what teachers do and think, the PIPS project started with the teachers' identification of broad objectives and goals. It also involved periods when teachers tried out their ideas in the classroom and provided support and feedback during face to face and online sessions. The PIPS project introduced a range of ICT tools and developed teaching and learning strategies to promote informed use of ICT in classroom science within and from the context of existing classroom practice. It aimed to provide personal and professional support through the use of face to face meetings as well as online communication. It involved a balance between theory and practice, and a balance between modelling teaching strategies and the exchange of ideas. This strategy was holistic, challenging and governed by a belief that avoiding over simplification and standardised CPD may result in empowering teachers, developing pedagogical content knowledge and ultimately changing classroom practice.

The University of Stirling Initial Teacher Education programme has a partnership arrangement with local education authorities and councils. The PIPS project drew on this partnership to invite schools to take part. Ten schools and 16 teachers from four of the authorities/councils were involved in the project. The schools included one of the smallest and one of the largest in the central region of Scotland. One school had12 pupils while another school had 500 pupils. The teachers who took part included two Head teachers.

A mail out to local scientific and engineering establishments resulted in the identification of potential scientists. The scientists received letters of invitation and a brief description of the project. Meetings with the scientists prior to their meetings with the teachers were organised to ensure that the scientists were aware of the format for the day and their anticipated roles.

The selection of teachers and scientists was relatively open in order to mirror the range of skills and confidence levels of those at the work face. The participants in the project reflect the range of skills and confidence level of teachers as well as the range of skills and communication levels of scientists.

The evaluation of the project was multifaceted. The project sponsors commissioned an independent evaluation of the project, and the project itself included an evaluation strand. The internal evaluation included pre, mid and post project surveys which were completed by the teachers. In addition Prof Sally Brown conducted interviews with individual teachers during the one day meetings over a period of three months and all WebCT communications were logged and analysed. Secondary data included pupils work.

## Some Findings

A community of practice has been established. There is clear evidence of the network established between teachers, teacher fellows and the scientists. There is strength in the network which is a consequence of the teachers support for each other and their ability and willingness to share materials and ideas online and face to face. It is worth noting that all the teachers engaged in PIPS were not familiar with either synchronous or asynchronous ‘conferencing’ and they did not know about WebCT. They received two brief sessions to familiarise themselves with this technology. It is therefore of significant importance to note the nature and degree of online engagement. Perusal of on line communication and face to face sessions illustrate the strength and cohesiveness of the community, as participants often proceed without the facilitator prompting action.

### Subject matter knowledge

Subject matter knowledge includes substantive and syntactic knowledge as well as teacher beliefs about the subject. There was some evidence to support the idea that teachers have adopted informed positions on subject matter knowledge related to the use of ICT in primary science. Teachers demonstrating the biggest changes in their ICT/Science subject content knowledge were not necessarily those who were ICT competent or ICT illiterate. Though teacher confidence in the use of ICT has increased for the majority of teachers involved in the project. As one teacher said:

> I certainly would as I now feel more confident about using the various ICT strategies and activities to develop k (*knowledge*) and u (*understanding*) in Science. (AA interim survey)

There is extensive evidence to show that continued and sustained opportunity for teachers to acquire skills that enable them to use ICT in a confident and effective manner has resulted in the majority of the PIPS teachers using new technologies.

> ICT was definitely my stumbling block- now I feel more confident to include them throughout curriculum. (BM interim survey)

There is also evidence of significant development and sharing of their science subject content knowledge. The teachers' WebCT postings show that they share science expertise on line.

> Message No. 35: [Branch from no. 26] posted by A School (A) on Fri, Sep. 21, 2001, 23:42
> Subject: Re: Animals and Plants in the Rainforest
>
> Glad you liked the plans, photos etc. Just thought they might be useful to anyone who is going to be teaching this topic. I don't think as teachers we share our work enough. It is silly to be constantly reinventing the wheel.
>
> I hadn't thought about the Rainforest Roadshow as being a viable activity for our project. But maybe you're right. It certainly was extremely interesting and valuable for the children. But the big question, how do we relate it to toys???
>
> Message No. 51: [Branch from no. 35] posted by Susan Rodrigues (PIPS) on Mon, Sep. 24, 2001, 10:58
> Subject: Re: Animals and Plants in the Rainforest
>
> I have my ways! Honest! When I was working with students preparing to be primary teachers you'd be amazed at what we did with plasticine! And we involved other activities, I think I will bring some of the stuff with me in Oct to share with others. Might be interesting, the other hand you guys might just think I'm a real twit! SR
>
> Message No. 32: [Branch from no. 9] posted by Ki1 School (Ki1) on Fri, Sep. 21, 2001, 19:05
> Subject: Re: Animals and Plants in the Rainforest
>
> You've been very busy, especially since you've done it all three times! Anyway, hope you've had a good week.
> It's Lorraine, alias Ki 1 and I've just finished reading your novel! Sounds good, although I'm a novice where the RF is concerned in comparison to others in the group. What you've got so far from the first Tuesday seems good and I look forward to next month. I'll write again if I have a brainwave. See ya!
>
> Message No. 34: posted by A School (A) on Fri, Sep. 21, 2001, 23:31
> Subject: A & P in the RF - update
>
> Hello again!

I have survived my week at Dounans and I am home safe and sound. Lovely to have some replies but where is everyone else? C'mon, I can't do this myself. I haven't a clue about powerpoint and spreadsheets etc. I will notify the Science man re classification key and also the actual recognised 5 vertebrate groups. Hope to hear from you soon. AA

The WebCT communications also indicate that teachers are working collegially See for example:

> Message No. 232: posted by S School (S) on Sat, Dec. 1, 2001, 12:45
> Subject: Energy
> I have not had time to look at this site since we met. Am I right in saying we are doing Energy/focussing on Conversion and transfer of energy Attainment target for level D. Name some energy resources and Level E explain the difference between renewable and non renewable resources? When I get that confirmed by Jan and Linda from D, Pat and Angus from K Nancy from L and Nicky whom I am sure will know from Ki. What a great day we had with you at Ki Nicky . The school had such a lovely atmosphere and all the children were helpful and mannnerly. Congratulations AC

The WebCT log clearly shows that teachers are sharing information:

> Thanks for the floppy with all the magnetism and food chain ideas. We can't wait for an opportunity to try them now! I've attached the work of the 'Classification' group at our last meeting. As you will see we are still adding the finer touches. Jan is trying out some of the ideas next week and we hope to get the P7's to prepare a Powerpoint next friday. I've still to investigate the database but that will have to wait until next week too! (We have an in-set day tomorrow and Friday and Jan and I have to give a short resume of what we have been up to on the Pips project.) Now you know why the floppy arriving when it did was so very much appreciated! Alison, could you leave a copy of your vertebrate worksheet on webct and I could then save everything together in the one folder for our next meeting. I relly (sic) enjoyed last week and felt we achieved a great deal. Susan, I've been looking at the folder you gave us tonight, since we have the short 'show and tell' at school tomorrow, and I think we are definitely meeting the proposed aims! LK

The teachers' progress is not simply a consequence of the educator's intervention. Instead it would appear that teachers' goals are being directed by their needs and school agendas.

**Teaching and learning views**

Teaching and learning views include the knowledge of self, knowledge of models of teaching, knowledge of learners and knowledge of educational ends. The data collected to date would indicate that the teachers have increased their understandings with respect to their knowledge of teaching, learning and educational goals. For example, the WebCT log confirms that teachers are learning from visits to the schools:

> Message No. 220: [Branch from no. 218] posted by K School (K) on Tue, Nov. 27, 2001, 19:48
> Subject: Re: Ki
> Thanks Ki for your hospitality. It was great to see a computer suite up and running. I hope when our new school is finished we can have something like that. You gave me some good ideas. PM

In addition, the survey data also shows that teachers' teaching and learning views have been influenced.

> I think it is important to keep changing group members within the themed groups so that everyone can share their particular knowledge and strengths. I also love visiting other schools and I think it would be lovely if it could continue next time. (AA Interim survey)

> Sharing ideas in a group- beneficial- also nice to meet with teachers outwith own region. (JC Interim survey)

> Enjoyable meeting other teachers and gaining new ideas and sharing with others. (NR Interim survey)

The project is having a significant impact on teacher confidence and hence on their perspectives of teaching and learning.

> Message No. 407: [Branch from no. 406] posted by A School (A) on Wed, Feb. 20, 2002, 22:48
> Subject: Re: Water -
>
> - I feel very lucky to be part of the project as I am enjoying it so much, I am becoming more confident in the use of ICT and more importantly I am loving meeting teachers from different authorities and being able to share ideas and experiences. So it is I who should thank you.
>
> With regard to pupil assessment sheets for Rainforest work, would you like me to post them to you or keep them until our next meeting?

> We completed our Pre-topic assessment today on water and I was very surprised by the results. The children have quite an advanced understanding already and so it will be really interesting to take them forward.

It is rewarding to note the number of teachers who have embraced the technology given their initial teacher ICT competence and confidence as identified by the pre project questionnaire. It is also interesting to note their growing awareness of the way in which children learn, and hence cater for this perspective, rather than focus on ways of delivering information.

**General Craft Knowledge**

Curriculum knowledge, general pedagogical knowledge and knowledge of educational contexts are all instrumental in determining general craft knowledge. The PIPS model of CPD indicates that it is successfully promoting the sharing of general craft knowledge. Teacher craft knowledge has developed rapidly in terms of working confidently with tools of the trade. For example, the PIPS teachers were not provided with any technical assistance and told their 'homework' was to use the Palm M105. Their online WebCT communication would indicate that this homework has been warmly welcomed even though it required them to investigate the technology without support..

> Message No. 264: posted by L School (L) on Thu, Dec. 13, 2001, 15:57
> Subject: Palm
>
> Dear Susan many thanks for the present. I took it to my son's home and he was extremely interested as he isproposing to his firm that a pilot is run using palm in schools. He would like to talk to you so I have given him your address/phone number at Stirling. Thanks again for another informative day. Have a Merry Christmas. See you in January. NG

> Message No. 293: posted by D1 School (D1) on Thu, Jan. 10, 2002, 14:05
> Subject: Palm and More classification material
>
> I'm hooked on the palm. I prepared an e.mail to my son whilst sitting in the doctors and could not believe how quickly it sent once I Hotsynced!! Its great for lists etc My six year old has also discovered the Palm and wrote out the recipe for peppermint creams so we could get the right ingredients at Asda! Keeping track on a family of five youngsters is quite difficult and inevitable someone forgets some appointment or other. I am using the palm software as the main family diary and everyone is putting appointments in. So far so good! Probably because I can now 'nip heads' prior to appointments. It's great having this facility in a handbag size. No more huge diaries being carted about to meetings. I'm trying to talk my HT into getting one for herself. I saw the same in Comet at £98. Do you know if we could get one cheaper anywhere else? I have attached the powerpoint presentations on classification. I'm not forgetting to send off the classification powerpoints but I don't think I'll get time until tomorrow. LK

The teachers were asked "Would you plan to use the technologies we've discussed in your classroom in the future? Please explain why." These are some of the comments made:

> Definitely –has shown/reinforced how technology eg powerpoint can motivate pupils with science work. (AB Interim survey)

> Yes- I have been planning to use powerpoint and could now see a use for it in science topics (MB Interim survey)

> Yes, there have been some really good ideas which I would like to use with the children. (SB Interim survey)

> Yes—- especially powerpoint. Can see the benefits of this programme and how it can be developed. (JH Interim survey)

> Yes- ICT was definitely my stumbling block- now I feel more confident to include them throughout curriculum. (BM Interim survey)

The following teacher comment also provides some evidence to support a view that prescriptive CPD does not automatically translate into classroom practice. The teacher (see webct communication below) is a part time New Opportunity Fund (NOF) trainer who has been through formal powerpoint training as part of her NOF training. Her participation in PIPS has encouraged her to use what she knows and what she has learnt from the PIPS project to encourage pupils to become ICT literate. Her ICT skills are being used to encourage learning rather than deliver teaching. The excerpt provides evidence of an increase in this teacher's pedagogical content knowledge.

> Message No. 81: posted by D1 School (D1) on Mon, Oct. 1, 2001, 19:46
> Subject: Powerpoint
> Hi AA, I'll bring a Powerpoint training booklet and CD-Rom to the next meeting for you. (There are some advantages to being a part time NoF trainer.) It's really is easy! The P7's are burrowing around collecting information and pictures and it's great to see them working with great purpose. Jan and I were talking about showing the presentations to the rest of the school and inviting parents. Susan has asked if we would to (sic) a 'show and tell' to the group on how we went about preparing the Powerpoints. I'm hoping we can add sound. I'll keep you informed, LK

## Summary

The development of a community of practice has encouraged teachers to enhance their pedagogical content knowledge by increasing their confidence in using new ICT tools, making them more aware of the way children learn and providing an opportunity to share ideas. The teachers are not solely focussing on teaching skills but are engaging and demonstrating complex reasoning and synthesis that should be seen as the underpinning of good teaching.

The PIPS model of CPD promotes a notion of PCK as ever evolving rather than static. It allows for PCK to vary depending on the composition of the community and the practice intended. Pedagogy, subject matter, children and the environment context are all interelated and dynamic facets of PCK. The PIPS project recognises this process view of PCK and uses it to encourage teachers to take on board ICT in primary science in an informed and appropriate way. The PIPS model also recognises the fact that subject matter knowledge, teaching and learning views and general craft knowledge are not independent categories, and there is overlap, hence the model of CPD is holistic rather than piecemeal didactic practice. Sherwood (1993) said that teachers were now at a stage where they wanted to know how to put things into practice and wanted to see classroom strategies that demonstrated effective use. The PIPS model demonstrates one way to address this need.

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## References

Bell, B and Baker, R (Eds) (1997) Developing the Science Curriculum in Aotearoa, New Zealand. Longman, Auckland.

Bell, B and Gilbert, J. (1996) Teacher development as personal, professional and social development. Teaching and Teacher Education, 10 pp483-497

Cochran-Smith, M. (1991) Learning to teach against the grain. Harvard Educational Review, 61 pp279-310

Collins, M. P., & Berge, Z. L. (1996, October 24-26, 1996.). Mailing lists as a venue for adult learning. Paper presented at the Eastern Adult, Continuing and Distance Education Research Conference, Pennsylvania State University.

Corbett, H. D, Firestone, W.A and Rossman, G.B (1987) Resistance to planned change and the sacred in school cultures. Educational Administrative Quarterly 23, (4), pp36-59

Dunlap, D.M and Goldman, P (1991) Rethinking power in schools. Educational Administrative Quarterly 27 (1) pp5-29

Dwyer, D. C, Ringstaff, C and Haymore-Sandholtz, J (1990) Teacher beliefs and practices, part II: Patterns of Change. The evolution of teachers' instructional beliefs and practices in high access to technology classrooms. First –fourth year findings. Apple Classrooms of Tomorrow Research Report Number 9: Apple Computer Inc.

Eastmond, D. V. (1992). Effective facilitation of computer conferencing. Continuing Higher Education Review, 56, pp155-167.

Fullan, M and Hargreaves, A (Ed) (1992) Understanding Teacher Development. New York: Teachers College Press

General Teaching Council Scotland (2001) Special Focus on: Continuing Professional Development. GTC Scotland. Teaching Scotland, Issue 8C

Hyman, R. T. (1980). Improving Discussion Leadership. New York: Teachers College Press.

Kenny, J (2002) What did we get for our training money? TES ONLINE January 4 2002

Kirkwood, V and Carr, M (1989) Final Report of the Learning in Science Project. (Energy) Hamilton, University of Waikato

McEwan, H and Bull, B (1991) The pedagogic nature of subject matter knowledge. American Educational Research Journal, 28, pp316-334

Papert, S (1990) Introduction. In I Harel (Ed) Construnctionist Learning (pp1-8) Cambridge, MA; MIT Media Laboratory

Rodrigues, S. (1999) An evaluation of an on-line masters course in science teacher education. Journal of Education for Teaching, 25, (3), pp263-270

Rohfeld, R. W., & Hiemstra, R. (1995). Moderating Discussions in the Electronic Classroom. In Z. L. Berge & M. P. Collins (Eds.), Computer-mediated communication and the on-line classroom in Distance Education. . Cresskill, NJ: Hampton Press.

Rovegno, I. C (1992) Learning to tech in a field based methods course: The development of pedagogical content knowledge. Teaching and Teacher Education, 8 pp69-82

Sherwood, C (1993) Australian experiences with effective classroom integration of information technology: Implications for teacher education. Journal of Information Technology for Teacher Education, 2 (2), pp167-179

Shulman, L. S (1987) Knowledge and teaching: Foundations of the new reform. Harvard Educational Review 57, pp1-22

Turner-Bissett, R (1999) The knowledge bases of the expert teacher. British Educational Research Journal, 25 (1) pp39-55

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# A STUDY OF THE CORRELATION BETWEEN KNOWLEDGE AND THE ATTITUDES OF STUDENTS IN THE CONTEXT OF BIOTECHNOLOGY AND GENETICS

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**Abstract**

Genetics, is a peculiar discipline of biology that enters the emotional sphere of human being. It is also one of the fastest growing branches of biology and is based on abstract concepts. The correlation between cognitive and motivational achievements of students can be measured. Generally speaking, let us try to answer the questions:

- Is a student achieving good results in genetic knowledge and skills aslo interested in genetics and manifesting a positive attitude towards this domain of science?
- Is there a correlation between cognitive results and the motivation of students?

The hypothesis assumes the existence of a directly proportional correlation.

The following methods and research tools were used:

- didactic measurement, multilevel test - 30 questions
- the motivation measure, a questionnare for measuring attitudes, known - 24 statements.

Based on the collected data, it is possible to state, that the hypothesis about the existence of positive correlation between the cognitive and motivational results of students in genetics has not been confirmed.

## I. Introduction

Research on teaching results often concerns the cognitive sphere of teaching aims, and the interest of methodologists is rarely directed towards examining the results of educational aims. Studying the correlation between these two aims is even more rare.

The cognitive result that is, simply speaking a rise in students' knowledge in a particular domain, will show a greater or smaller degree of progression from the initial situation (taking into account the differences in individual students' results). Does this premise hold also for the educational aims? A teacher of every subject is also an educator. A biology teacher aims to fulfil the educational aims by developing the interest of students in various biology disciplines, through shaping desirable attitudes towards biological issues.

Research on the interests and attitudes of students towards biology was carried out among others by Killermann, Loewe, Stawinski, Todt. The research has shown a decrease of students' interests with age (Killermann 1995, Loewe, Stawinski 1994, Todt 1995).

Genetics, which is a peculiar discipline of biology that enters the emotional sphere of a human being, is also one of the fastest growing branches of biology, based on abstract concepts. It can be measured by examining the correlation between cognitive and motivational achievements of students (Sternicka 1996).

Generally speaking, let us try to answer the question: is a student achieving good results in genetic knowledge and skills also interested in genetics and manifesting a positive attitude towards this domain of science.

## II The Research Issues, Methods And Research Tools

1. While examining the ways in which concepts of genetics are formed a particular question has appeared: Is there a correlation between cognitive results and the motivation of students?

The hypothesis assumes the existence of a directly proportional correlation.

The following methods and research tools were used:

**a. the didactic measurement, a multilevel test**

The test was designed according to the classical test theory, in two versions, based on syllabus requirements for four levels. Each version included 30 multiple-choice questions (5 distractors). Both versions were based on the same syllabus requirements. The statistical parameters, especially the test reliability, are relatively high. The reliability of the genetics test is 0,859. For the research proper, 30 questions with the best statistical parameters were used, these questions formed two parallel versions of the test.

**b. The motivation measure, a questionnaire for measuring attitudes, using a Likert scale.**

In its final version, the scale included 24 statements, expressing opinions about genetics. It has been designed according to the definition of an attitude and it included three components: behavioural, cognitive and emotional. The reliability of the scale measuring motivation was 0.907 for the first measurement and 0.950 for the final measurement.

### III. The Course Of Testing And Research Results

1. The research was carried on during two school years, from 1994 too 1996 in secondary grammar schools in Tricity. The participating students attended eleven third grade classes with various specialisations but with the basic biology syllabus: altogether over 300 students were investigated three times (twice to measure motivation, and once to measure cognitive results from genetics section entitled 'Heredity and changeability of organisms'). In order to measure the correlation, only the results of students taking part in all three tests were considered (n=176 students).
2. The testing of students' cognitive results showed that the syllabus requirements were mastered in 53% for both versions, which allows for comparability of results in the collective analysis.
3. The measurement of motivational achievements included initial motivation (after the first lesson on genetics) and final motivation (after the revision lesson, but before the test). Based on the approval indicator it is possible to state a decrease of students motivation towards genetics as a biology branch and school subject.
4. The measurement of the correlation between students' motivation variables and their knowledge of genetics was conducted based on Pearson's correlation coefficient (R).

| R Pearson's correlation | Coefficient (R) |
|---|---|
| Initial motivation - test results | 0,11 |
| Final motivation - test results | – 0,04 |
| Initial - final motivation | 0,20 |
| Motivation achievements - cognitive achievements (test) | – 0,12 |

### IV. Conclusions, Summing Up

1. Based on the data, it is possible to state that the hypothesis about the existence of a positive correlation between the cognitive and motivational results of students in genetics has not been confirmed.
   - There is a conversely proportional correlation between cognitive and motivational results of students learning genetics i.e. the students with high tests results have a low motivation level, and display negative attitudes to this domain of biology and this school subject (see enclosed item *Motivation achievements versus test result –Appendix 1*).
2. There is a correlation between the initial and final motivation, i.e. the students displaying positive attitude towards genetics before starting this part of biology have the same attitude at the end of the course and vice versa (see enclosed item *Initial motivation versus final motivation –Appendix 2).*
   - There is a conversely proportional correlation between final motivation and the test result (see enclosed item *Final motivation versus the results of a test in genetics –Appendix 3).*

There is a very small correlation between initial motivation and the test results (see enclosed item *Initial motivation versus test results –Appendix 4).*

Summing up, we should consider the possible causes for this state of affairs. It is quite obvious that if there is a small correlation between initial motivation and the test result, it is clear that we cannot expect high motivation at the end of the course; genetics is an interesting discipline but it is also difficult for students, as has been shown in teacher questionnaires (Sternicka 1996). Possibly, high motivation causes stress and restrains thinking.The results and the best results are achieved with average motivation, according to the laws of Jorkes-Dodson (Reykowski 1997).

Among the many conditions of the teaching and learning process, the individual abilities of students play a very important role. Gagne stresses that among many variables determining the learning results the student's learning skills, individual abilities and intelligence have the strongest influence. Learning skills are responsible for 50% of variations in learning results measured in relation to verbal information, intellectual skills, and cognitive strategies (Gagne 1992).

If the interests and attitudes do not directly influence students' cognitive results, and the students' success is determined mainly by their abilities, then successful teaching should concentrate on developing intellectual skills of students.

We should stress the important role of such intellectual activities in the teaching process as: analysing, synthesising, comparing, associating, and concluding. Developing these skills, not the interests of students should dominate the teachers' actions.

In conclusion, we can state that a student has to think in a biology lesson, and he does not have to be interested in it.

**Literature:**

1. Gagne R.M., Briggs L.J., Wagner W.W. *Zasady projektowania dydaktycznego* WSiP Warszawa 1992.

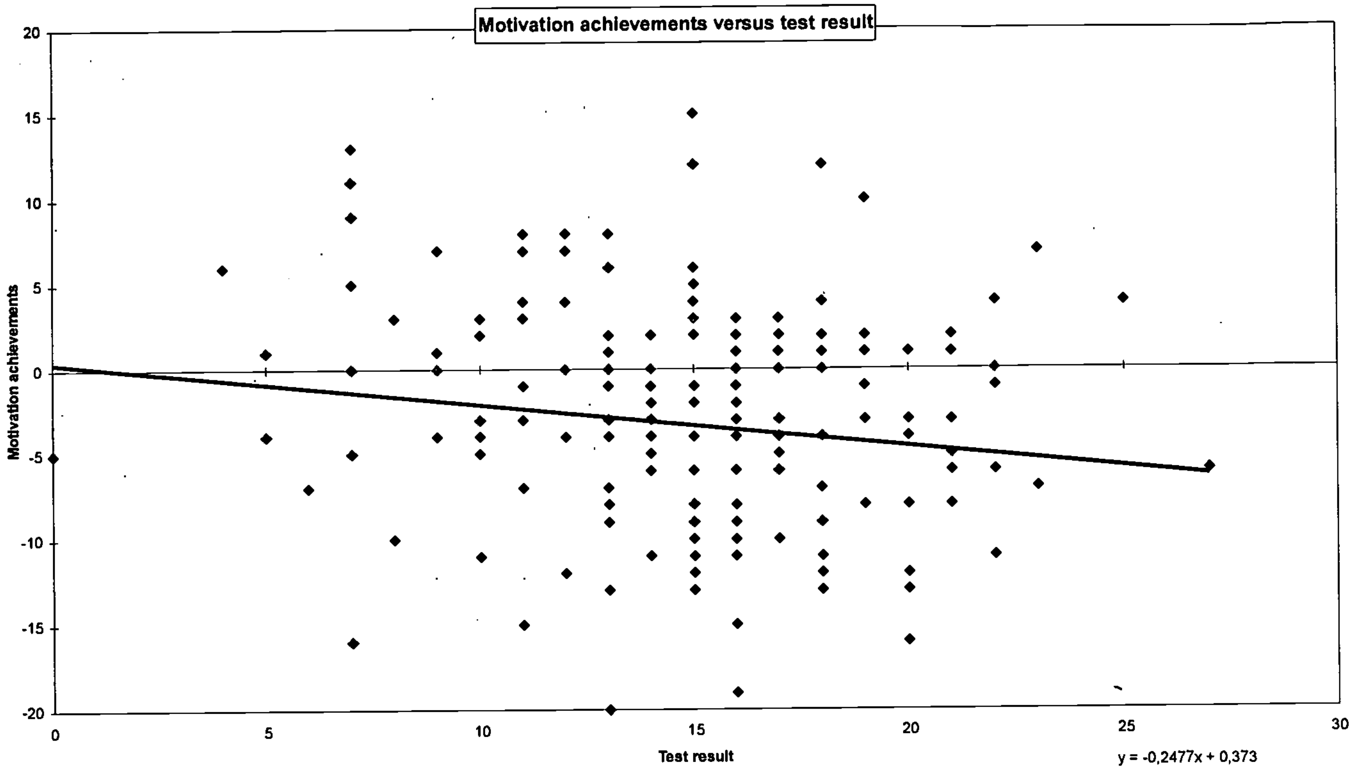
2. Stawinski W.,Loewe B. 'Zainteresowania biologiczne uczniow uczeszczajacych do szkol polskich i niemieckich'. *Materialy z IX Krajowej Konferencji Dydaktyków Szkól Wyzszych.* Lublin 1994.

3. Reykowski J. *Z zagadnien psychologii motywacji.* WSiP, Warszawa 1977

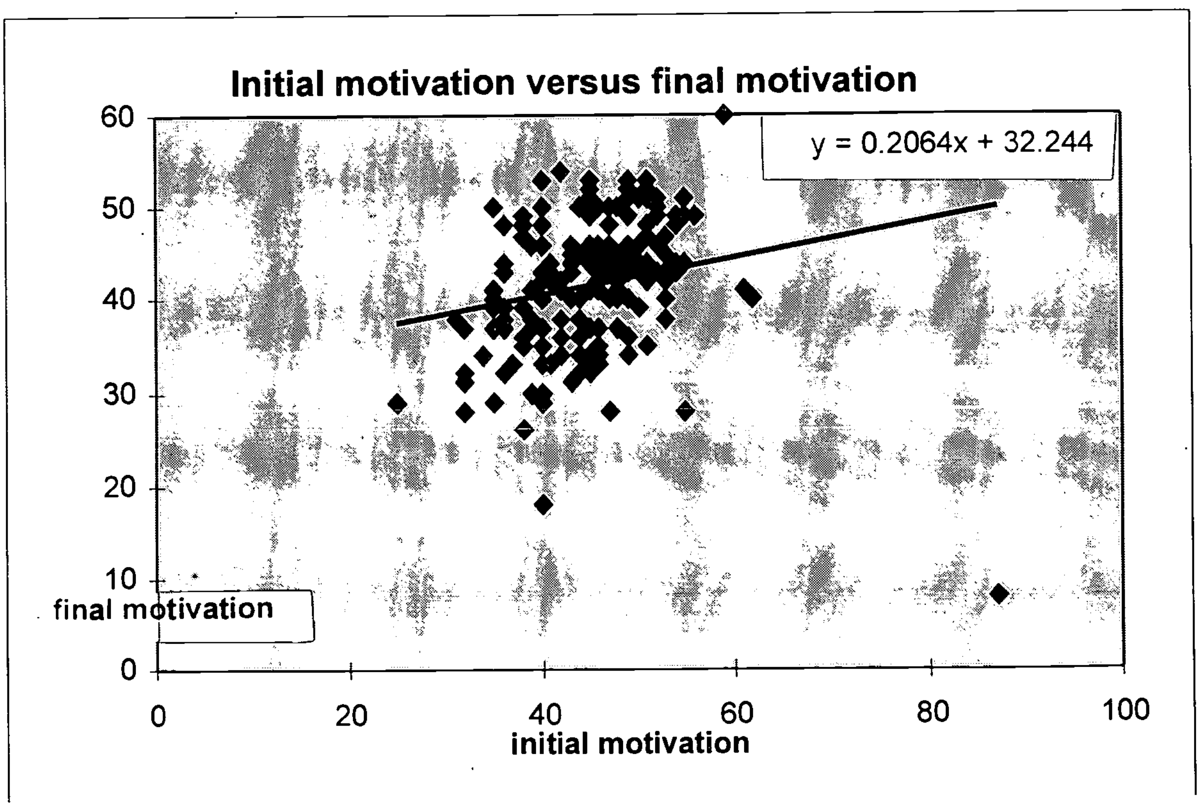
4. Killermann W. 'Badania nad skutecznoscia róznych metod nauczania'. *Materialy z X Ogolnopolskiego Seminarium Dydaktykow Biologii.* Bydgoszcz 1995.

5. Sternicka A. 'Realizacja tresci genetycznych w opinii nauczycieli'. *Biologia w Szkole* 1996/2, pp 80-85.

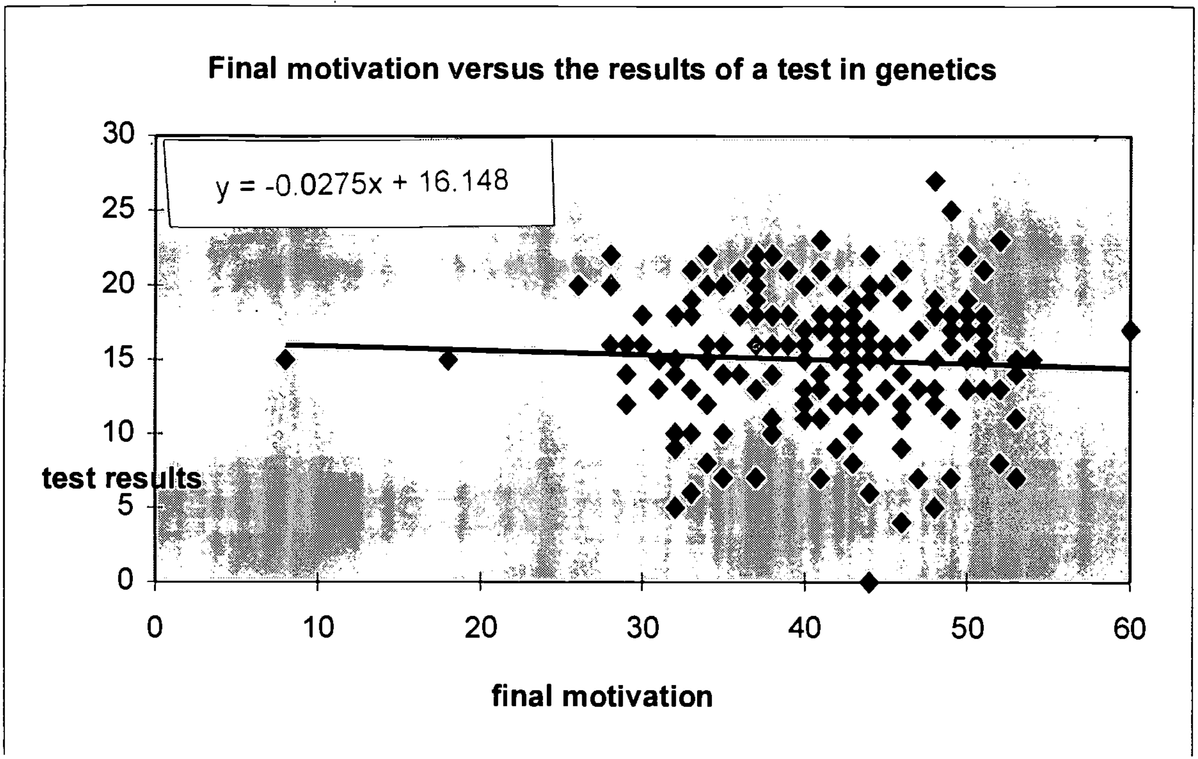
6. Todt E.,Goetz Ch.: Interessen und Einstellungen Jugendlicher gegenueber der Gentechnologie.*Biologieunterricht und Lebenswirklichkeit* IPN Kiel 1997



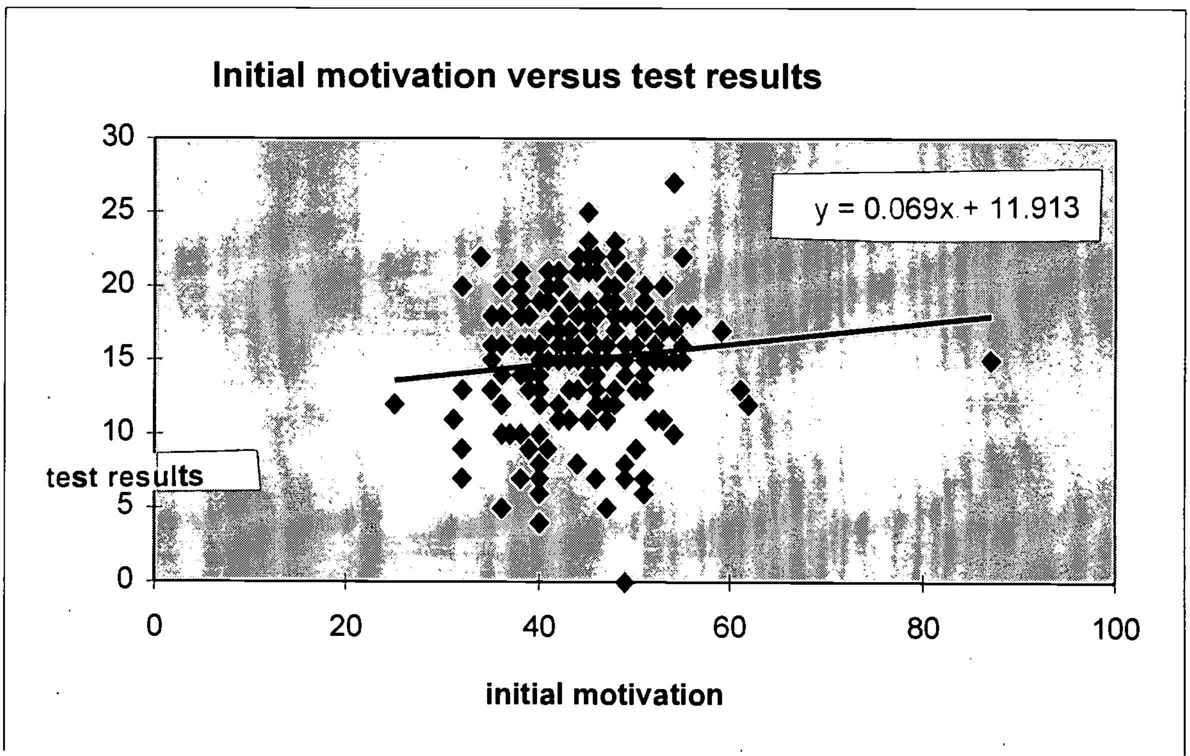

**APPENDIX 1**




**APPENDIX 2**




**APPENDIX 3**




**APPENDIX 4**

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# ROLEPLAYS IN MIDDLE SCHOOL SCIENCE TEXTBOOKS: A SIGNIFICANT CONTRIBUTION TO THE HISTORY OF SCIENCE TEACHING

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## Abstract

Over decades, a number of researchers in science curriculum and science teaching and learning have pointed out that the history of science plays a pivotal role in the achievement of science literacy. However, recent studies have shown that both practitioners and textbook writers often fail to deal with subjects such as history and philosophy of science. In this study, we describe and analyse the elaboration of a history of science teaching strategy, as part of a four book set designed by the authors for middle school science course.

Inspired by Wandersee & Roach's Interactive Historical Vignettes (IHVs) (In: Mintzes, Wandersee & Novak, *Teaching science for understanding*, 1998), which, in turn, is partially informed by conceptual change theory, the strategy comprises a set of eight roleplay activities (two per grade, one per semester), focusing on scientists whose work brought decisive contributions to the worldwide scientific knowledge. The tasks, which include the scientists' biographical information, script, costumes, and stage setting, are supposed to be done by the students under the tutelage of the science teacher or of a multidisciplinary team. To provide the necessary support for both children's and teacher's work, some guidelines are offered, as well as basic bibliography.

The critical analysis suggests that, just like the Interactive Historical Vignettes, the roleplay strategy offers a significant contribution in order to facilitate the achievement of a better understanding of the nature of science, both by students and teachers, especially because scientists are shown as human beings who live, work, and study in a real context. Thus, science appears less mystified and less mythologized. Considering that throughout the Brazilian territory there is a lack of textbooks in which the subject "history of science" is dealt with in a suitable way, the roleplay strategy, as described and analysed in this study, can be considered an innovative enterprise. Consequently, our final conclusion is that our study contributes significantly either to basic education science teachers (primary, middle and high schools) or researchers of the academic area concerned about science literacy.

## Introduction

The history of science plays a pivotal role in the achievement of science literacy, especially because it helps to enhance the meaningfulness and comprehension of science content in the context of the nature of science (Wandersee & Roach In: Mintzes, Wandersee & Novak, *Teaching science for understanding*, 1998). Despite of that, practitioners and textbook writers have been failing to deal with subjects related to history and philosophy of science in a proper way. According to Bastos (In: Nardi, *Questões atuais no ensino de Ciências*, 1998) the history of science programs, either in high school, middle school or elementary school courses[1], show several problems such as: a) commiting raw factual mistakes; b) neglecting the relationship between the process of scientific knowledge production and the social, political, economic and cultural context; c) suggesting that scientific knowledge made progress solely by means of fantastic or fabulous discoveries carried out by genius scientists; d) glorifying the present and its paradigms, neglecting the importance of the scientific branches which diverge from the recent ones, the richness of the debates that took place in the past, the discontinuity between

[1] According to the Brazilian educational system: highschool = children aged 15-18; middle school = children aged 11-14, and elementary school = children aged 7-10.

the past and the present, etc. and e) encouraging the belief in current scientific knowledge as a universal truth. This view is shared, at least in part, by Bizzo (1992), who points out that the attempts to evoke the history to enlighten the science teaching have generally been failing mainly because: a) our look to the past usually selects the elements that can explain the present, instead of trying to bring back the history of science, and b) the scientific theories proposed in the past are considered simple and ingenuous whereas the present ones are seen as complex and ingenious.

Bizzo (In: São Paulo, Secretaria de Estado da Educação. Coordenadoria de Estudos e Normas Pedagógicas. *Ensino de Biologia: dos fundamentos à prática*, 1996) also claims that these problems result of a science's amputation from the body of the history. Once separated, or as the author says, divorced from the history, science generated and gave birth to a child called "scientific knowledge neutrality". In other words, knowledge was removed from its historical context, losing a big part of its sense (Bizzo In: São Paulo, Secretaria de Estado da Educação. Coordenadoria de Estudos e Normas Pedagógicas, *Ensino de Biologia: dos fundamentos à prática*, 1996). These claims are in accordance with Chassot (1995) who has pointed out the absence of history as a constant bad habit of our science teaching. According to this author, there are very few teachers concerned in electing history as the backbone of their courses. Chassot also stresses the importance of dealing with the uncertainty as well as showing the students how different models are built in science and why, eventually, some of them are abandoned while others are modified. It is important, he completes, to recognize how different events have contributed to the gradual building of models.

Therefore, the big task that challenges the science teaching programs is to reintegrate science to its historical context, by electing history of science basically in two ways: a) as a teaching content itself, and b) as a source of inspiration to define the contents and to propose teaching strategies (Bastos In: Nardi, *Questões atuais no ensino de Ciências*, 1998). Whatever the choice is, the author warns that it is necessary to produce as well as to evaluate curriculum and support material.

### Interactive Historical Vignettes And History Of Science Teaching: Principles, Construction And Application

Wandersee & Roach (In: Mintzes, Wandersee & Novak, *Teaching science for understanding*, 1998) have proposed an approach to history of science teaching based on the belief that scientific world view, as part of nature of science, can be provided by "relevant examples of scientists who demonstrated it via their life histories". Called Interactive Historical Vignettes (IHVs), Wandersee & Roach's approach employs little science stories easier and quicker to read and tell. Actually, each IHV consists of a small and carefully chosen part or "slice" of the history of science designed and used to illustrate a single aspect of the nature of science. In order to achieve its aims, the IHV must be presented in an interactive way, taking only 10-15 minutes of the class time. Once a week, without fail, a new IHV must be designed, so the students can be constantly in contact with different pivotal cases or incidents in a certain scientist's life throughout the science course.

The first step to design an IHV is the reading of histories of science about the life of a given scientist. The second step consists in choosing an intellectual or behavioral choicepoint of a pivotal incident in the scientist's life. Once the choice is made, it is necessary to decide which attribute of the nature of science is epitomized by the selected incident. In the fourth step, an Interactive Historical Vignette is written using the following format: a) introduction to the scientist; b) context and basis of the incident; c) choicepoint and sample options; d) final outcome of the incident. The final version of the IHV is then written in docudrama style. The total presentation time must be 5 minutes maximum. The fifth step is the IHV presentation in docudrama style. It starts with the presentation of the first three parts of the vignette to the class. The students are then given some time to decide, independently, what choice the scientist focused in the vignette eventually made. After the students' answers, the fourth and last part of the vignette is told. The next step is a class discussion about current science applications of the nature of science attribute they have learned by the IHV (Wandersee & Roach In: Mintzes, Wandersee & Novak, *Teaching science for understanding*, 1998).

Although the teacher is the most appropriate person to design and apply an IHV, especially in the begining of the science course, Wandersee & Roach (In: Mintzes, Wandersee & Novak, *Teaching science for understanding*,

1998) have noticed that, after the first month of activities, it is suitable to ask the students to design their own vignettes. However, the teacher must be aware that the students need a technical support, which includes a list of sources of the information needed and systematic assistance, the latter supposing to be given from the first to the last step of the IHV construction.

Interactive Historical Vignettes strategy is partially informed by "conceptual change theory" by which learning is considered an interactive process instead of a simple accumulation of data (Wandersee & Roach In: Mintzes, Wandersee & Novak, *Teaching science for understanding*, 1998). Consequently, it is absolutely necessary that the learner actively engage in revising his or her ideas when confronted by different ones. It is important to bear in mind that, according to the conceptual change theory, the learner has a conceptual structure by which he or she explains the world. So, it is exactly in the conceptual structure the learner's ideas are embedded. Considering that new ideas are constantly interacting with the past experiences, the learner's conceptual structure is continually changing. As these changes go on, a number of rearrangements of existing conceptual structures may happen and contribute to form, elaborate and integrate the new ideas. The result of this process is an increase of understanding (Wandersee & Roach In: Mintzes, Wandersee & Novak, *Teaching science for understanding*, 1998).

## Roleplays In Science Textbooks: Towards A Nature Of Science Understanding

Artistic creation, as well as scientific research, is among the activities that occupy the highest levels of meaningful learning (Novak In: Mintzes, Wandersee & Novak, *Teaching science for understanding*, 1998; Moreira, *Aprendizagem significativa*, 1999). It is important to emphasize that "meaningful learning theory" has a close relationship with the "conceptual change theory". Firstly because , just like the latter, the "meaningful learning theory" considers learning as an active process that underlies the constructive integration between thought, feeling and action which, in turn, leads to the human empowerment (Moreira, *Aprendizagem significativa*, 1999). Secondly because there is a number of authors who have contributed to the creation of both theories, suggesting a common origin for them.

So this is how the roleplay in science textbooks strategy rises : informed by "meaningful learning theory" and inspired in Wandersee and Roach's Intercative Historical Vignettes. The approach comprises a set of eight roleplays activities two per grade, one per semester each one focusing on a given important name whose work brought decisive contributions to the worldwide scientific knowledge. The names in focus are: for the 5th grade, Jules Verne[2] and Ernst Haeckel; for the 6th grade, Robert Hooke and Georges Leclerc (Count of Buffon); for 7th grade, Gregor Mendel and Joseph Priestley and, for the 8th grade, Blaise Pascal and Edwin Hubble. The choice of these names is the result of a careful selection which took into consideration mainly two aspects: a) the relevance of the scientist as a nature of science representative, and b) the connection between the scientist and the contents developed throughout a given unit[3] or chapter.

The students work in groups under the tutelage of the science teacher, especially on those tasks related to collecting and selecting information about the scientist, as well as those related to script writing. It is also possible to organize a single big play, performed by one entire class or a big group composed by students of more than one class. In that case, it is suitable that the play becomes a school project, so the students must be tutored by a multidisciplinary team.

[2] Even though Jules Verne has not been a scientist, his name was included among the personalities in focus because of his undeniable importance in the scientific field, especially as a science divulger. The age in which Jules Verne lived is known by its plentiful and significant scientific and technological progresses, which influenced Verne's writing style considerably. The teachers were properly informed that such context, that is, the scientific progresses and their effects to people's lives and thought, should be stressed throughout the roleplay construction.

[3] For the purposes of the work reported in this text, a unit is a group of three, four or five chapters, depending on the case.

Following the book set layout, the roleplay construction task is presented to the students in a section especially designed for that purpose. Called *Vista a camisa*[4], the section has a heading which identifies it in the textbook. Immediately after the heading, the students are informed who the scientist in focus is.

**Guidelines to the students**

After beeing informed who the scientist in focus in the section is, the students are given some guidelines in order to provide them the support needed. The first group of guidelines includes the following items: a) period of time in which the scientist[5] lived; b) country(ies) in which he or she spent his/her life; c) main aspects of the age in which the scientist lived; d) how these aspects influenced his/her life; e) how his/her life was before, during and after he/she became a researcher; f) what kind of researches he/she carried out, and g) which impacts those reasearches brought up to the world.

In the second group of guidelines, students can find instructions which can help them to construct the play. The instructions are: a) select all the information they consider relevant; b) organize meetings to decide how many and who will be the characters of the play; c) write the script; d) design the costumes and the stage setting; e) rehearse the play, trying to correct the eventual mistakes, and f) make the presentation.

**Guidelines to the teachers**

The book set includes a teacher's book which comprises three parts. The first one is an introduction, where the teacher can find the educational principles of the book set as well as a brief description of the sections that can be found in the chapters, including the section *Vista a camisa.* Thus, thanks to this first part of the teacher's book, the teacher is given an overview of the section aims, as well as some hints on play designing. Among these hints there are some suggestions recommending the use of modest and/or domestic material such as worn out clothes, old textile and board paper to produce masks, clothes and other objects. The importance of the philosophical, social and economic aspects of the period in which the scientist spent his/her life is also emphasized here.

The second part of the teacher's book contains a widely detailed description of the chapters, one by one, section by section. Here, everytime the section *Vista a camisa* appears, a group of contextual and biographical information is offered, providing the basic data the teacher needs to plan and start his/her work successfully.

Finally, there is a third part of the teacher's book which contains a basic bibliography.

Besides the guidelines mentioned and described above, bi-annual meetings are organized by the publishing company in order to offer the teachers opportunities to obtain some extra information directly from the authors, as well as to share experiences among each other.

## Discussion

The science book set in which the roleplay strategy was proposed is quite new. Since the book set publishing, in 2001, the authors had only three meetings with the teachers, two of them dedicated to present the principles and aims of the book set. Due to this, the authors have very few data about the real impacts, in classroom work, of the roleplay strategy as it has originally been proposed. However, thanks to the oral reports offered by the teachers, as well as the theory that supports both the book set designing and the study described in this article, it is possible to bring out some important aspects.

[4] Literally, this expression means "wear the shirt". As a Brazilian idiomatic expression, "Vista a camisa" is usually employed with the meaning of "go for it", "engage". Naming the section reported in this article, "Vista a camisa" means "be in someone else's shoes".

[5] In the textbook, we employ the term "researcher" instead of "scientist". Our aim is to show the scientist as a human being with a special interest in studying nature's phenomena, by means of the scientific research. It is our belief that this procedure contributes to defeat the mistaken view which considers the scientist as a genius.

**Multidisciplinary work**

Teachers are not used to work in teams. Depending on the way the roleplay is designed, the roleplay strategy gives the teachers the opportunity to work in a multidisciplinary team, that is, a group of work composed by teaching professionals of different areas, such as History, Arts, Geography, Portuguese, and obviously Science.

**Interdisciplinary work**

The interdisciplinary approach is the result of a principle according to which there is no way of knowledge that can be considered self-sufficient. Thus, the interdisciplinary thought recognizes the need of estimulating a kind of dialogue among other sources of knowledge, including the commom sense. Therefore, the interdisciplinary approach depends basically on a change of attitude in the presence of knowledge matter or, in other words, on the replacement of a fragmentary conception about the human being by a unitary one (Fazenda, *Interdisciplinaridade: um projeto em parceria*, 1991).

If applied according to the principles and guidelines included in the student's textbook, as well as in the teacher's book, the roleplay strategy may offer the science teacher a rich opportunity to develop an interdisciplinary work, especially if he or she is the only person responsible for the students' tutelage. In the authors' point of view, the challenge of tutoring the students by him/herself may create the favourable environment the teacher needs to start working in an interdisciplinary way. Even if the work is carried out by a multidisciplinary team, it is still possible to do it in an interdisciplinary way. In both cases, there is a number of elements that can influence the teacher's or the team's decision, and this is something the textbook and the authors are not able to predict or change.

**Nature of science understanding**

As described before, the roleplay strategy has been designed to show scientists as human beings who live, work, and study in a real context. By the way, the context is constantly valued in the guidelines, sometimes much more than the scientist him/herself. In doing so, the authors have the intention of stressing the influences the social, economic, political and cultural environment had in the scientist's private life and work. Considering that such an approach can help science to be shown less mystified and less mythologized, it is fair to conclude that the roleplay strategy offers a significant contribution in order to facilitate the achievement of a better nature of science understanding.

**Innovative enterprise**

Innovation has a considerable variety of meanings. For the purposes of this study, the authors have chosen Goldberg & Franco's definition, according to which innovation is a planned and scientific process of developing and establishing, in an educational system, a change which has a few possibilities of occurrence but, at the same time, has effects that bring a real improvement to the system (Goldberg & Franco, *Inovação educacional: um projeto controlado por avaliação e pesquisa*, 1980).

Considering that throughout the Brazilian territory there is a lack of science textbooks in which the subject "history of science" is dealt with in a suitable way, the roleplay strategy, as described and analysed in this study, can be considered an innovatory enterprise. Consequently, our final conclusion is that our study contributes significantly either to basic education science teachers (primary, middle and high schools) or researchers of the academic area concerned about science literacy.

## AKNOWLEDGEMENTS

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## REFERENCES

Bastos F. (1998) História da ciência e pesquisa em ensino de ciências: breves consideraçöes. In R. Nardi (org.) *Questões atuais no ensino de ciências.* (pp. 43-52). São Paulo: Escrituras Editora.

Bizzo N.M.V. (1992) História da ciência e ensino: onde terminam os paralelos possíveis? *Em aberto*, **55**, 29-34.

Bizzo N.M.V. (1996) A biologia numa perspectiva histórica: o darwinismo em questão. In São Paulo (ESTADO), Secretaria de Estado da Educação, Coordenadoria de Estudos e Normas Pedagógicas. *Ensino de biologia: dos fundamentos à prática.* (pp. 27-33). São Paulo: SE/CENP.

Chassot A.I. (1995) Para que(m) é útil o ensino da ciência. *Presença Pedagógica*, **1**, 35-44.

Fazenda I.C.A. (1991) *Interdisciplinaridade: um projeto em parceria.* São Paulo: Edições Loyola.

Goldberg M.A.A., and Franco MLPB (1980) *Inovação educacional: um projeto controlado por avaliação e pesquisa.* São Paulo: Cortez & Moraes / Fundação Carlos Chagas.

Moreira M.A. (1999) *Aprendizagem significativa.* Brasília: Editora Universidade de Brasília.

Novak J.D. (1998) The pursuit of a dream: education can be improved. In J.J. Mintzes, J.H. Wandersee, and J.D. Novak (ed.) *Teaching science for understanding: a human constructivist view* (pp. 3-28). San Diego, CA, USA: Academic Press.

Wandersee J.H., and Roach L.M. (1998) Interactive Historical Vignettes. In J.J. Mintzes, J.H. Wandersee, and J.D. Novak (ed.) *Teaching science for understanding: a human constructivist view* (pp. 281-306). San Diego, CA, USA: Academic Press.

**Keywords:** roleplays, science textbook, history of science, science teaching, science curriculum.

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# FACTORS AFFECTING SCIENCE TEACHERS CHANGE TOWARDS STL TEACHING

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## Abstract

This paper describes the effectiveness of an intervention training and draws attention to the most important factors to be considered in developing in service programmes for the promotion of STL teaching skills. STL is taken to mean developing the ability to creatively utilise sound science knowledge in everyday life to solve problems, make decisions and improve the quality of life. The STL study was divided into three phases: teaching based on STL materials supplied to teachers, a six month active involvement through workshops where teachers developed and tried out their own STL materials and a follow up allowing the application of the skills acquired during the intervention. STL materials were defined as materials which were social issue based, student-centred decision-making, and/or problem-solving units, within curriculum topics (Holbrook&Rannikmäe,1997). All together 45 science teachers and 1163 students were involved in the study .

As a result of the 6 months intervention period it was found that the major factor illustrating effectiveness of teacher developed STL materials was their ownership of STL teaching, expressed in terms of the ability to develop consequence maps. The structure of the consequence maps was used to distinguish three categories of teachers: subject learning activity based, with dominance on facts and concepts; sequenced activity based, with emphasis on process skills; social issue based, including problem-solving and decision-making strategies. Data collected 10 months after the intervention indicated the need for re-categorisation of teachers , because the extent of teacher change was not sustained and ownership of STL decreased. Three new categories were found based on teachers perception of relevance of science education: motivational relevance, skills relevance and social relevance.

The effectiveness of the intervention programme was obvious: teachers who acknowledged the need for teaching social skills in conjunction with science concepts and process skills, continued to embed these ideas into their teaching ten month after the intervention. The sustained change was illustrated by phenomenographical outcome space ( Marton, 1981)

## Introduction

Change takes place slowly in schools. Many science education projects have been undertaken in the developed world over the last few decades ( Yager, 1999; Bell, 1998; Hofstein, 2001) to try to change the perception of science and the rationale for teaching science subjects in schools. But in the majority of countries, science education is seen as the transmission of science to students and science is perceived as a body of knowledge with little reference to educational gains.

Nowadays, in post-Soviet countries, especially in Estonia where independence was regained in 1991, the society is changing faster than the educational system. In-service teacher training, being linked to the educational system, is lagging behind. Furthermore, students, as members of society, seem to welcome teaching geared to economic and social development that relates to the situation in their lives, but to lose interest and motivation when it comes to studying science subjects (Rannikmäe, 1998) Science, as a body of knowledge or a particular way of thinking has always been strong in the previous Soviet countries. As Estonia has moved towards embracing Western cultures, especially in social science subjects, curricula with new content have been developed quickly. It is, therefore, more relevant to the younger generation This has proved less so in science subjects, pointing to difficulties in moving away from the previous strength in science subject matter. Current paper will be focused on solving the following problem areas:

1. Science taught at school seems to be irrelevant for students. Students do not see science useful for their lives and future developments. ( Osborne & Collins, 2001; Holbrook, 1998; Sjoberg, 2001)
2. Science education is isolated from the value components of education and communication. Collaborative behavioural (learning) skills are not appreciated as goals of science education. Science education has become value free in the eyes of students. At the same time, the community needs to address more and more moral and ethical issues and related problems (Holbrook, 1998 ).
3. Research over the last 10 years has shown that the lack of higher order learnin among students has inhibited the development of problem-solving and decision-making skills among school graduates ( Zoller, )

All the previous concerns are interrelated and can be discussed within two domains: teacher's lack of training to teach higher order thinking skills (problem-solving, decision-making) to students and concerns for the context in which the science content is taught by teachers. Besides that, it is essential to promote communication skills in a variety of forms, collaboration skills among students and a recognition of skills to form and justify social value. This gives rise to the goal of teaching science as being to promote scientific and technological literacy (STL) among the students. This is usually taken to mean developing the ability to creatively utilise science knowledge in everyday life: to solve problems, make decisions etc. (Holbrook & Rannikmäe, 1997)

Research projects carried out in Israel and USA emphasise the role of science teachers in educational reforms (Hofstein,2001; Yager, 1999) to achieve better results in science learning. It is not enough to develop curricula in isolation of the teacher and expect teachers to adopt the intentions, modify teaching materials and redevelop the instruction. The role of the teacher becomes essential for developing student centred teaching and curricula that best fit the needs of the students. It thus goes without saying that it is important to change the attitudes and understanding of all teachers ( Yager & Weld, 1999) if meaningful reforms are to take place.

## Research methodology and findings.

The current study focussed on teacher development towards teaching for scientific and technological literacy (STL). The goal of the study was to share with teachers the essential attributes that characterise STL teaching and determine whether these attributes continue to be accepted and employed in teaching ten month after the intervention. This study was planned in 3 phases. In phase 1 twenty teachers were asked to teach based on supplied teaching materials and their opinions were collected through open endede interviews and written records ( table 1).

**Table 1.** Teaching based on STL materials supplied to teachers.

| |
|---|
| 1. Most teachers (16) liked STL materials because of the group work; only 3 teachers emphasised encouragement of student thinking. |
| 2. 6 teachers were negative towards the use of STL materials as they found assessment difficult and /or interdisciplinary context complicated to teach in traditional lessons. |
| 3. Most teachers (12) saw the major goal for science lessons as the development of the subject. Only 4 teachers saw wider educational goals as essential. |
| 4. Teachers adapted materials using them as add on units for revision of science content. |

In phase 2, during a six-month workshop-type intervention, 25 teachers were guided to develop their own STL materials (Holbrook & Rannikmäe, 1996) and pilot these and other exemplary materials in teaching chemistry for 692 tenth-grade students. Teachers were put into categories based on STL attributes, which were implied in a teacher-constructed consequence map (Rannikmäe, 2001). A consequence map starts from an issue or concern and shows the implications from a number of different teaching approaches, each leading to its own special science content . Data were collected through research observations from the intervention workshops, open ended interviews and assesment schemes created by teachers ( table 2).

**Table 2.** Teacher developed STL materials during 6 months intervention study.

| |
|---|
| 1. Teachers stated 3 types of goals for teaching: subject-,general- and social-oriented. |
| 2. 10 teachers stated social-oriented goals; 7 teachers stated subject goals only. |
| 3. Less than 20% of the goals were worded in a student-centred way. |
| 4. Student-centred teaching was expressed mainly in terms of doing individual work, such as conducting an experiment. |
| 5. Problem-solving was seen as a subject-oriented activity, often in a question format (20 teachers). |
| 6. Teacher changes in creating teaching materials during the period of intervention was towards greater emphasis on interdisciplinary. |
| 7. Teaching emphasis of only 7 teachers remained unchanged throughout the whole intervention period; 5 of these remained subject-oriented. |
| 8. Recognition of social issues within the development of teaching appeared after 2 or 3 interventions by 12 teachers. |
| 9. By the end of the intervention, 20 teachers created consequence maps that included decision-making; however, 5 teachers did not distinguish between problem solving and decision-making. |
| 10. Teachers created 3 types of scenarios within STL materials – subject-oriented (5 teachers), activity–based (7 teachers) and social-issue related (12 teachers). |
| 11. Pre-intervention assessment schemes by teachers gave equal weight to higher and lower order cognitive skills (18 teachers). |
| 12. Post- intervention assessment schemes gave more weight to higher order cognitive skills (12 teachers), 7 teachers gave scores to value judgements. |
| 13. 23 teachers recognised the need for setting wider educational goals for science lessons. |
| 14. All teachers expressed a positive attitude towards the use of STL scenarios. All teachers perceived gains in the use of STL criteria in their teaching. |
| 15. Teacher gains, as judged by teachers, were mainly in the areas of pedagogical knowledge (20 teachers)and collaborative working (18 teachers). |
| 16. Twenty teachers separated problem-solving from decision-making and 15 showed examples of socially related decision-making activities which they had used in their teaching. |
| 17. Teacher concerns were applicability of STL teaching within the current curriculum framework (17 teachers), lack of teaching materials (12 teachers) and time consuming process for the development of materials (10 teachers). |

In phase 3 no in-service provision, or additional information about STL teaching, was offered after the intervention, although the teachers met twice to communicate and exchange their experiences. Ten months after the intervention, data were collected from classroom observations. Each teacher determined which lesson to be observed. Classroom observation was guided by the expected outcomes of the intervention study and the STL teaching philosophy (Holbrook & Rannikmäe, 1997). Classroom observation data were carefully compared to the information collected through an interview with the teacher after the lesson. Teachers were also asked to answer an open-ended questionnaire, which was administered during a seminar (at the end of the school year). A follow up group discussion was also held with all the teachers

**Table 3.** Sustained change 10 months later.

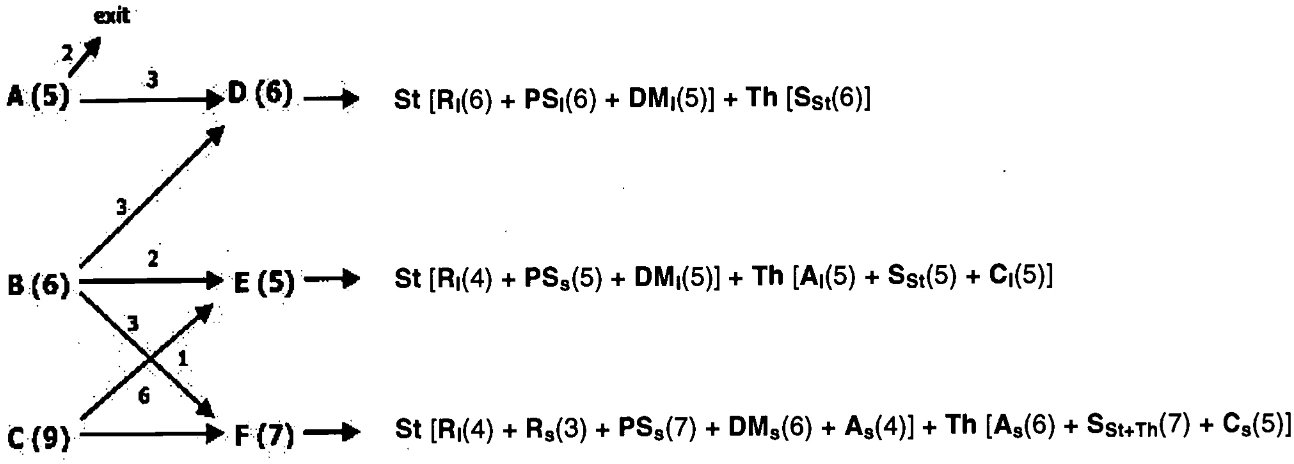
| |
|---|
| 1. Problem-solving was strongly emphasised in teaching by 13 teachers; decision–making by 6 teachers. |
| 2. 6 lessons were highly student-centred; 8 lesson lacked a student –centred component. |
| 3. 16 teachers used a scenario or fragments of scenarios in their teaching. |
| 4. Two teachers did not show any attempt to use STL approach in their teaching. |
| 5. 15 teachers did not utilise an assessment strategy in their lesson. |
| 6. Five teachers indicated they had developed new STL materials following the intervention study. |
| 7. All teachers suggested that STL teaching should be promoted to a wider audience of teachers. |
| 8. Most teachers (17 teachers) saw STL scenarios as tools for increasing motivation of learning science among the students. |
| 9. 4 teachers had forgotten the meaning of socially related scenarios. |
| 10. Teachers had three types of opinions about "relevance " for students: curriculum and examination related (6 teachers), skills related (5 teachers), social issues related (7 teachers) |
| 11. Teachers showed more confusion between problem-solving and decision-making than at the end of the intervention period (11 teachers). |
| 12. There was generally recognition of student achievement by teachers, but only 7 teachers recognised they had undergone self-professional development. |
| 13. 12 teachers used assessment strategies directly related to the curriculum: scenarios/socially related issues were used to motivate, not to assess. |
| 14. 13 teachers saw constraints related to covering the content driven curriculum. |

## Discussion

Teachers' support for teaching relevant to students' interests was identified as a key attribute of teacher change towards STL teaching. This support seems to stem from a student-related component and a teacher-related component. The student-related component describes the way the teacher presented the materials to students and what skills were targeted and assessed. The teacher-related component describes the teachers' efforts for self-change towards STL teaching. Student- and teacher-related components were identified from a range of factors. The student-related component included factors such as: (a) choice of method used to confirm student-relevant teaching, (b) inclusion of problem-solving activities, (c) inclusion of decision-making activities in a social context, and (d) formative assessment practices. The teacher-related component consisted mainly of: (a) the use of a student-centred teaching approach, (b) the way by which the teacher applied STL ideas, and (c) teachers' attitudes towards STL ideas.

The new categories: D( motivational relevance), E( skills relevance), and F (social relevance) are hierarchical in terms of STL criteria and have direct relationship with the initial categories A( subject learning activity based), B( sequenced activity based), and C( social issue based). This relationship is illustrated in Figure 1 representing the outcome space. Figure 1 indicates teachers' transition from one category to the other and describes the factors taken into consideration for teachers' re-categorisation. The weighting of each factor (given in brackets in the mathematical relationship) equals the number of teachers described by it.

In Figure 1, numbers along the arrows represent the number of teachers making that transition.. The outcome space is illustrated by two descriptors- students centred and teachers centred, the level of emphasis is given as subscripts l and s.




Emphasis of STL teaching : l = low, s = strong
St – student related descriptor
R – method of confirming relevance to students
PS – problem-solving
DM – decision making
As – assessment

Th – teacher related descriptor
A – student centred approach
S – perception of STL idea applicability (subscript St good for students, subscript Th essential for teacher development)
C – attitude towards STL idea

**Figure 1.** Outcome space of categories illustrating teacher's sustained change

## Conclusions

Teachers are strongly influenced by their perception that science teaching is very different from that in social science and facts and concepts need to dominate over issues relevant to everyday life. Teacher willingness to begin teaching from a social perspective is limited to those who recognise its relevance value. As was the case with problem-solving and decision-making, it would appear that some science teachers find it difficult to understand the meaning of social issues. Only teachers described by categories C/F perceived STL teaching as involving social decision making issues and the identification of values as part of teaching. It is not easy to change teachers' perceptions of science teaching, especially towards the inclusion of social components interrelated with, and aiding the acquisition of, conceptual science.

## References

BELL, B., (1998). Teacher Development in Science Education. In B. Fraser, P., Fullick,. and M. Ratcliffe (1996). Teaching Ethical Aspects of Science. The Bassett Press.

HOLBROOK, J. B. (1998). Operationalising Scientific and Technological Literacy – a new approach to science teaching. Science Education International, 9/2, 13-19.

HOLBROOK, J. B.,& RANNIKMÄE, M. (eds). (1997). Supplementary Teaching Materials- Promoting Scientific and Technological Litercay. Tartu, Estonia: ICASE.

HOLBROOK, J. B. & RANNIKMÄE, M. (1996). Creating exemplary teaching materials to enhance scientific and technological literacy. Science Education International. 7/4, 3-7

HOFSTEIN, A. (2001).Why Action Research? In: N. Valanides (ed) Proceedings of the 1th IOSTE Symposium in Southern Europe. SAcience and Technology Education: Preparing Future citizens. Paralimni, Cyprus, pp.4-15.

MARTON, F. (1981). Phenomenography – describing conceptions of the world around us. Instructional Science, 10, 177-200.

OSBORNE,J.,& COLINS;S: (2001) Pupils` views of the role and value of the science curriculum: a focus-group study. International Journal of Science Education , 23/5, 441-467.

RANNIKMÄE, M. (2001). Effectiveness of Teacher –Developed Scientific and Technological Literacy Materials. In O. Jong, E. Savelsbergh, E.& A. Albas, (eds).Teaching for Scientific Litercay: Content, Competency,and Curriculum.. CD-B series.Vol.38,CD-B Press, Utrecht, The Netherlands,71-86.

RANNIKMÄE, M. (1998). STL teaching – theoretical background and practical evidence. Science Education International. 9/4, 9-15.

SJOBERG; S.(2001) ROSE: The relevance of science education. A comparative and cooperative international study of the contents and contexts of science education. http://flok.uio.no/sveinsj/ROSE/20project/html

ZOLLER;U. (1993) Are lecture and learning compatible? Maybe for LOCS: unlikely for HOCS.Journal of Chemical Education, 70, 195-197.

YAGER,R., & WELD,D. (1999) Scope,sequence and coordination: The Iowa Project, a national reform effort in the USA. International Journal of Science Education, 21/2, 169-194.

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# HERE IS THE BEST PART OF THERE

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## Abstract

This paper examines the issues of teaching effectiveness and learning success.

The theme of the conference, *"Rethinking Science and Technology Education to Meet the Demands for Future Generations in a Changing World"* expresses anxiety over the potential of present education practices to enable future generations to cope with the demands placed on them. In the context of South African science education, this anxiety is justified. It is acknowledged that what learners need to learn, how they need to learn and what purpose their learning has to serve, have all changed quite significantly over the years. New and more advanced skills e.g. calculated risk-taking are needed. Motivated learning - which manifests itself in deep engagement and persistence with the task - is enabling and equips learners with these requisite skills. My study examines the extent to which teachers are consciously aware of this. It focuses on the deliberate choices teachers make to ensure the deep engagement of learners.

There are two problems that repeatedly escape the attention of science educators. The first is *conceptualizing the role of the teacher.* As teachers perceive their role, their main concern is with *getting there* now: there is urgency to complete the syllabus and fit in as much revision before the examinations. For these teachers time is an inelastic and scarce resource. The second problem is *teacher perceptions of learning and of learners* and the consequent *neglect of the need to provide learners with opportunities to engage deeply* in order to make sense of what is being learned. Particularly with science and science-related learning, the cognitive load, as perceived by learners, is much higher. Learners feel the need to *spend more time* with what they are doing *now.* This moment, the present, *here* is important to them. My research has found that *investment of time now* is, therefore, more likely to enhance learner efficacy and to positively influence learning and learner success (even in examinations). For this reason, the paper makes the claim that "**HERE** *is* the best part of *t*HERE".

## Introduction – Conceptualizing the Problem

Historically, South African learners have demonstrated a lack of potential to perform well at science and mathematics. They appear to lack the requisite skills for success in these subjects and to lack the necessary motivation and interest to apply themselves successfully to their learning. The TIMMS study findings support this.

There have also been research reports that have expressed a concern over the increased lack of enthusiasm and associated passivity of learners as they "progress" through formal schooling. This contrasts sharply with their natural inquisitiveness and ability to ask questions and their natural urge to find answers as pre-school children.

Associated with, and exacerbating, the problem is the power differential between teachers and learners. In choosing to relay the absolute, objective truth (teachers' perceptions of science), *teachers tell learners what they should know.* This method of transmission ignores the affective and cognitive investments of learners and reduces them to passive recipients of the revealed truth.

As with all learners, teachers are also strongly influenced by signals *they* receive. Authorities, and parents, send out strong signals about the value they place on examination results. Emphasis on the "product" (examination performance), reinforces teachers' beliefs that their survival depends on learner attainments. This means *teaching for examinations.*

Learners also demonstrate the strong influence of signals by playing the "guess what the teacher expects" game. They thrive on *doing the least to get by* (low mental exertion as far as possible). They regard risk-taking as too costly.

Some questions the learners asked me during my research are:

- *What careers would high school science lead to*? The extrinsic motive for learning science appears to be absent. Learners do not know how learning science might benefit them.
- *How could we learn science better*? The absence of structure to which learners can relate and the fragmented learning of facts presents learning problems.
- *We ordinarily feel that science is not difficult and that we are able to follow it. Why, then, are we doing so badly in tests and examinations?* While what the teacher does seems logical at the time, what learners experience in tests and examinations appears to require different skills and processing from what normal lessons socialize them to expect.

## What Do Teachers Actually Do?

Of the various "pedagogical" choices that educators make:

- writing notes on the chalkboard and allowing learners to transcribe these;
- reading from a text book whilst learners listen or follow by reference to their own textbooks;
- telling learners what they should know;
- assigning work for learners to read;
- providing learners with a workbook with spaces for answers to be filled in and
- providing opportunities and support for learners to learn (not a popular choice with educators),

I have chosen to describe the following example to illustrate what teachers of science in South African schools traditionally do. An analysis of the impact of this approach on the depth of learner engagement follows by reference to theory.

The context is a deep rural school with limited resources (the physical plant is in poor condition, there is no water supply or electricity, there is no formal staff room or designated office space, there is an absence of playing fields, it is situated in an undulating poorly-maintained landscape, with poor drainage and a poorly graded route of access with a corrugated surface.). The educator has a three-year teaching diploma – not having specialized in science. She is currently studying science by correspondence through a university.

The lesson is in grade 10 (a class in its tenth year of study since their formal schooling began). The topic is "Optics". Specifically, the educator is teaching a lesson on lenses and the images formed by convex lenses. The lesson commences with notes being written on the chalkboard and learners transcribing these. The educator describes a lens: "*A lens is a curved transparent object*". Learners are asked to repeat this definition. Some read the definition from their notes; others from the chalkboard. They are requested to repeat this several times. They do so in chorus.

In a cupboard with a missing door there are a cool drink can (curved and opaque), a perspex cylinder (curved and transparent) and the top half of a "geographical" globe (curved and opaque). The teacher is wearing lenses. No reference is made to any of these.

The lesson proceeds with a description of types of lenses and images formed by a convex lens.

I chose to intervene. With the educator's permission I questioned the learners to assess their grasp of what was taught in this lesson. I asked pointing to the window: "Is this window pane a lens?" There was a silence. I felt I needed to prompt for an answer and did so. Responses were without due consideration of the key ideas given earlier! I then chose to place each of the three items taken from the cupboard on a desk and, by reference to each, I repeated my question. Learners were not able to comprehend that they had to consider both curvature and transparency together in order to decide. Neither learners nor educator realized that, in addition to being transparent and curved, the object had to be of a different optical density from the air around it.

This line of probing and prompting aroused much interest and participation in their attempts to arrive at answers. The educator then spoke out with a genuine feeling of need: "I wish I had a lens!" to which my response was: "Do you really want a lens?" Her response was: "Yes!" I asked if she had a bottle. She responded: "Yes". I asked for it to be filled with water (the water was obtained from a tank that is used to collect storm water. The water was a little turbid). The bottle of water was placed on a block and the can – which had print on it – was used as the object. As I changed the can's distance from the bottle (lens), the educator was asked to view the image characteristics from the side opposite to that where I held the can. She was visibly excited. Her excitement was so infectious that the learners came around without an invitation to view what their teacher had seen.

The following features characterize the lesson:

- teacher summary transcribed by learners;
- teacher talk including the description of concepts and image characteristics;
- learner recitation and regurgitation;
- learner failure to make connections or to transfer learning;
- teacher failure to make connections (of e.g. resources from the cupboard with concepts being taught;
- learner inability to make decisions;
- inadequate teacher prompting;
- no probing;
- inadequate assessment opportunities, inadequate opportunities to provide feedback to learners on their progress; inadequate opportunities to acknowledge learner worth;
- teacher control and dominance; and
- the absence of learner assumption of the responsibility for learning.

Whilst there are more and less sophisticated methods that educators use to communicate with learners what they should know, the foregoing was most instructive. It raised several issues.

## Issues That This Teacher's And Parallel Approaches Raise

### The Teacher's Choice of Approach

Perceptions of *learners* and of *how they learn* influence a teacher's choice of approach. Teachers popularly argue that they do not have a choice. In the approach used in the sample lesson there was the assumption that, if I have taught and given them notes, they will have learnt. A second assumption was that this knowledge that is about to be imparted is specialized knowledge which means that the learners cannot know about it. Hence, her choice to tell them what they should know.

The **ancient** Chinese proverb "*The teacher opens the door. You walk through by yourself*" has not lost its appeal (even in the post-modern and technological era) due to its acknowledgement that :

> the teacher can best strive to *interest, inspire, incite or excite* the learner;
>
> ***learning***, however, ***is a personal and private process*** – the **final responsibility for which rests with the learner**.

Hence, if the teacher has taught, it does not necessarily follow that learners will have learnt. *There is much more that teachers have to do to ensure that learners learn.*

### The Learners' Lack of Potential

The apparent *lack of potential* demonstrated by learners is related to the *lack of requisite skills* to engage more deeply: comprehension, ability to probe, ability to make connections/associations, ability to make decisions and to take risks. Learners need to acquire these skills by *exposure to opportunities* that require their use. This exposure to the use of skills was completely missing from the sample lesson.

**Motivated Learning: Opportunities To Process Deeply**
Note-taking, recitation and regurgitation – all of which are regular learner activities - do not provide opportunities for deep processing. Deeper levels of processing such as *interpreting*, *representing ideas* by use of symbols, equations and drawings and *explaining* were not required in this lesson.

**Learner Choice To Participate**
What the teacher failed to realize was that the learners needed to engage deeply in order to learn. The choice to engage is that of the learner. This choice, however, is influenced by the teacher. How much effort is invested by the learner is a function of learner perceptions of *efficacy* (ability to cope), *task demand characteristics* and the *value* of the task. Learners continually make assessments of these in order to decide on how much effort to invest. It is a natural tendency for *learners to do the least to get by.* Often, these learner assessments are made to ensure that effort investments are minimal. This makes the teacher's responsibility a challenging one.

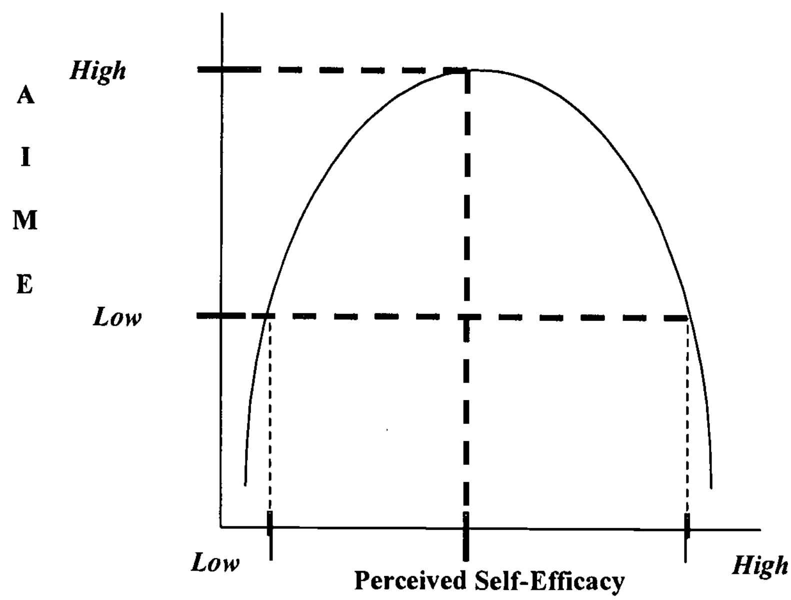
**What choices teachers can make to ensure deep processing?**
To enable a teacher to make choices of how to provide for optimal learner engagement, a teacher needs to understand how ***learner** perceptions* of efficacy, task demand characteristics and task value influence effort investment. It is also essential for teachers to understand that *different types of learners* respond differently to learning structure.

It may be helpful for teachers to know that the following variables influence learner perceptions of ability to manage (efficacy) a task: social comparisons, performance comparisons, performance outcomes, outcome patterns, attributional feedback, the learning context, similarity to models, persuader credibility and teacher and peer signals. Before they choose to invest effort, learners generally ask the following questions: how much do I know? enough to enable me to manage?; will I complete the task successfully?; how hard is it?; how much effort will it need?; how long will it take?; how interesting is it? how important is it?

## What Teachers Need To Know About Motivated Learning?

**Investing Mental Effort**
The following graph, after Gavriel Salomon, shows the relationship between *the **learner's** perceptions of efficacy* and *choice to invest mental effort*:

**The relationship between Perceived Self-Efficacy &**
**Amount of Invested Mental Effort AIME**



Moderate efficacy and task demands have the potential to secure high mental effort investments. Low efficacy – associated with perceptions of difficult or high task demands – result in task avoidance, particularly in the case of defensive learners (failure-avoiding and anxious learners). Very high efficacy – associated with high structuring, low task demands – results in low effort investments. This is particularly true of constructive learners (achievement-oriented).

The following characteristics of human nature are brought out in this representation:

- The *importance of the self* (involvement of the self and ..self-esteem)
- The *element of choice*. Each learner makes choices at every stage. These *choices are personal.*
- The choice *to invest effort depends on self-perceptions.* It is not the perceptions of others – however significant they may appear to be - that determines that choice.
- That *challenges* that learners perceive to be manageable *are essential* to prompt effort investment.

*Learners need* ***challenges*** ..which they perceive to be ***manageable***.

**Learners and Learning**
*Different learners learn differently.*
Clarke, in Mandl et al:1990 – after Cronbach and Snow:1977 distinguishes two categories of learners: *defensive* (anxious, conforming and failure-avoiding) and *constructive* (relaxed, independent and achievement-oriented).

Defensive learners work with the belief that failure is more controllable with higher levels of structure and direction. Conforming learners seem not to invest sufficient effort in unstructured, more independent settings and therefore achieve less.

Constructive learners place high value in success and seem to believe that greater freedom during learning will produce more success. When faced with instructional methods that impose relatively high levels of external learning control – methods that contain more structure, external monitoring, specific directions and frequent progress testing – the constructive learner reduces the amount of effort invested.

Learners in the sample lesson did not feel adequately challenged in order to make the choice to invest high amounts of mental effort. Effort expenditure, upon which *motivated learning* depends, is influenced by the number of mental elaborations and the degree to which these are non-automatic.

**There's More That Teachers Can Do!**

Some strategies that are recommended for ensuring deep learner engagement:

*Learner Levels of Operation: The Actual, Representational and Notional*
To assume that the learners know because they are able to "describe" (operate at the *actual* level) what the teacher has communicated with them is misleading. When learners are asked to *represent* their ideas, what emerges are perceptions that are often at variance with those of the teacher. These perceptions are very instructive in respect of how learners think and what informs their thinking. Deeper probing (which is a skilful activity) leads to an improved understanding (*notional* level) of how learners think. This enables teachers to decide on what provisions to make for effective learning.

*Predict, Observe, Explain* **POE**
This strategy requires learners to write down the *predictions* they make and to give reasons for these.
They are then asked to make *observations* and to write these down.
When asked for an explanation of their observations, learners engage more deeply by compiling

an agenda of questions which enables them to observe more keenly. This method is particularly useful in challenging learner perceptions and beliefs. More effort expenditure and more mental elaborations that are non-automatic are assured when there is *conflict* between what was predicted and what was observed.

*Describe, Interpret, Explain* ***DIE***
Following Fairclough's model for critical discourse analysis, three processes for deep engagement are apparent: *describe, interpret* and *explain.*
The general trend in lessons characterized by the transmission method is to *describe* concepts and principles. Learners are provided with limited opportunities to process the information.
If learners are challenged to interpret, they may be afforded opportunities to learn other skills e.g. how to analyze and how to probe. They can then be asked to explain some observation or phenomenon. These steps demand greater effort investment.

*The Bigger Picture*
Often facts are presented as fragments in a linear progression. Learners go for meaning. This is enhanced by coherence and logic. Unless teachers are aware of the bigger picture, they are not able to present facts in a logical and psychological order. "*It is the string of wisdom that links the beads of fact in the necklace of reality.*" If teachers are able to paint a bigger picture, the relevance and appeal of science shows up and this also serves a motivational purpose.

## Conclusion

How enabling and empowering are present classroom practices in South Africa?

South Africa has recently celebrated its new democracy after the dismantling of apartheid. A pertinent question that may be asked is whether the incapacity of learners which manifests itself in poor performances in subjects such as science and mathematics, is not due to a more powerful parallel form of oppression – that of silencing learners' voices. Teachers often send out strong signals in respect of which learners' answers are valued, when learners may talk and for how long. Peers send out strong signals that indicate which learners' contributions are valued. Categories of learners' voices become silenced for the greater part of most lessons.

How and what a teacher presents and, to what end, impact strongly on the extent to which learners choose to engage. High structure and a high degree of teacher control result in low cognitive load. Mental elaborations become automatic and this encourages perceptions that other learners are able to answer. Consequently effort investment, on the part of most learners is minimal and learning success is compromised.

A mismatch between the effort a task demands and perceptions that learners have of the effort the task requires leads to a mathemantic spiral. (*Mathemantics is used to describe the process "when teaching kills learning*".) Care needs to be taken by teachers to ensure that this match is assured.

One way of preventing this spiral is for teachers to ***provide learners with opportunities*** to develop: skills of responsibility, effective communication and discussion, and creative problem-solving as well as satisfaction in learning.

Several personal and situational variables influence the pedagogical choices that teachers make. These choices have become so institutionalized that teachers often claim that they do not have a choice. Teachers also make continuous assessments of their own efficacy as well as those of the task demand characteristics, task outcomes and task value.

The following situational factors seem to direct the choice of teachers:

- Low efficacy assessments: from a lack of confidence stemming from inadequate preparation and/or inadequate qualification; from feedback from learners and authorities; from the absence of resourcefulness on the part of teachers.
- Perceptions of the task outcome: perceptions that learner performance is the only indicator of the effectiveness of teaching and that syllabus coverage and revision of the work covered are the best ways to secure good learner performance.
- Perceptions of Task Demand Characteristics: perceptions that teaching demands too much effort – especially on administrative work. Consequently little time is available for proper task analysis and thorough preparation.
- Perceptions of the Importance of Assessment and Feedback: assessments are generally perceived as summative. Assessments are, therefore done to satisfy official requirements rather than to provide learners with essential and appropriate feedback and acknowledgement of their worth. This feedback can serve to motivate learning.

Teachers tend to operate in – what Edward Hall* refers to as - the "monochromic time frame": *doing one thing at a time, in a series, as a linear progression through a set of discrete stages. ..There is little sensitivity to the particularities of the context or the needs of the moment. It is the schedule and its successful completion that have priority.*

Learners, on the other hand, seem to be characterized by what Edward Hall refers to as the "polychromic time frame": *doing several things at once, in combination. Their interest is ..in successfully completing transactions. Relationships dominate this time frame.*

A factor further exacerbating the problem is the impact of technology. The pace of everything around us has increased. It is easy to get caught up in this fast pace. In classrooms, teachers – whose facility with the subject has improved over the years – have become less sensitive to learners' needs to process deeply: Hence, they rush through the syllabus at the expense of this deep processing.

"Man*y human activities such as developing relationships, require commitment, self-sacrifice, continuity and time. The high-speed culture and the power of "now" is undermining the value of these experiences*" (A.E. Wiens).

***Learning is one such relationship.***

Our challenge in trying *to meet the demands for future generations in a changing world* is to prepare learners to cope with the anticipated *new load on their nervous systems.* This entails equipping them with essential skills to enable and empower them, not just to cope and survive but to progress and prosper. Rushing to cover the syllabus means ignoring the affective and cognitive investments of learners. Uncovering the syllabus and allowing learners the opportunity to dig deeper are more likely to improve learner capability to systematically increase the cognitive load that s/he can handle.

**References**

BRANDES, D. & Ginnis, P. (1986), A Guide to Student-Centred Learning. Redwood Books, Trowbridge.

BRUBACHER, M., Case, C.W., Reagan, T.C. (1994), *Becoming A Reflective Educator.* How To Build A Culture of Inquiry in Schools. Corwin Press Inc. SAGE Publication Co.

CLARK, R.E., *When Teaching Kills Learning.* Research on Mathemantics. In Mandl et al (1990). 3-22

COGGIN, P.A. (1979), *Education For the Future.* A Case for Radical Change. Pergamon Press, Oxford.

EDWARDS, A.D. & Westgate, D.P.G. (1994), Investigating Classroom Talk. The Falmer Press, London.

FAIRCLOUGH, N. (Ed.) (1992), Critical Language Awareness. Longman, U.K. Ltd.

FREIRE, P. (1985), *The Politics of Education.* Power and Liberation. Macmillan, London.

GIROUX, H.A. (1992), *Border Crossings.* Cultural Workers and the Politics of Education. Routeledge.

HARGREAVES, A. (1994), Changing Teachers, Changing Times. Teachers' Work and Culture in the Post-modern Age. Cassell, London.

MANDL, E., de Corte, E., Bennett, S.N., Friedrich, H.F. (Eds.) (1990), *Learning And Instruction.* European Research in an International Context. Vol 2.2 Analysis of Complex Skills and Complex Knowledge Domains. Pergamon Press.

MOODLEY, R.D. (2000),: A Study of Teacher Prompting in a Science Classroom. Unpublished Masters Dissertation

SALOMON, G. (1981), *Communication and Education* – Social and Psychological Interactions. SAGE Publications.

SARASON, S.B. (1983), *The Case for Change - Rethinking the Preparation of Educators.* Josey-Vass Publishers, San Francisco.

SCOTT, P. (1998), *Teacher Talk and Meaning Making in Science Classrooms.* A Vygotskian Analysis and Review in Studies in Science Education, Vol 32 1998.

SPAULDING, C.L. (1992), *Motivation in the Classroom.* McGraw-Hill, Inc.

STEWART, D.L. (1993), *Creating the Teachable Moment.* McGraw-Hill, Inc.

WHITE, R.T. (1988), *Learning Science.* Basil Blackwell Ltd. U.K.

YOUNG, R.E. (1990), *A Critical Theory of Education* – Habermas and Our Children's Future.

**Keywords:** perceived self-efficacy, motivated learning, deep engagement, requisite skills, task demand characteristics.

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# EMERGING TRENDS IN SCIENCE EDUCATION IN INDIA[1]

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## Abstract

The existing knowledge base, accumulated over time, reminds us of our unique heritage, which favored the purity of mind and soul over worldly and materialistic achievements. Knowledge creation, absorption and dissemination, which were considered to be the prime concern of our thinkers, have become secondary and the prime slot is being occupied by finance and technology. Before globalisation, which started in early nineties in real sense, the importance of science was reflected in technological and socio-economic development but now we notice that the roles are interchanged. Even though the choice between science and technology was always a subject of debate in the last century but still science education was pursued with vigour. As emerging patterns of education and manpower growth are indicating a paradigm shift, an analysis of this trend will be appropriate for shaping the future of tomorrow and for taking the desired course of action. In the present study the emerging trend in higher education is analysed with the help of mathematical models. Scenario presented here may be useful in policy reviews and can provide a base for S&T planning and policymaking. A quantitative analysis of this kind suggests that academics and knowledge seekers are disappearing from academic field and are being replaced by so called knowledge workers, who are more interested in money matters. Growing interest in the fields of engineering and medicine and saturation in basic science research only suggests a shift from science to technology. Growing trend in the number of Ph. D. degrees awarded in Mathematics is the only exception in basic sciences and may be indicative of the importance of the subject in the present ICT revolution.


## Introduction

Globalisation and liberalization has not only changed the economic structure of the whole world in the form of new economic order but also the human resource development and education pattern. Globalisation resulted a boom in more qualified manpower in managerial and technical skill and science education in particular has witnessed structural changes, which is reflected in the form of S&T workers. Human resource potential in general and S&T personnel in particular is a measure of a country's competitiveness in the emerging knowledge society. Science and engineering degree holders may be recognized as an important indicator of a nation's S&T effort.

Past trend in science education may be used to gain some insight and, also, to project the future demand and supply of human resources. Every year thousands of thousands of post-graduates and Ph.D. holders are coming out from our academic institutions and contributing in the growth and developmental activities on the national as well as international level. Suitable deployment of this work force can bring in changes in all walks of life. The effectiveness lies in planning the manpower requirement in the desired areas to create a base for scientific and industrial research. The progress in scientific and industrial research in the past has been impressive and now is the time to look around and assess the overall prospects in this direction. It is essential for policy formulation and programme development.

Human resource potential is a measure of a country's competitiveness in the emerging knowledge society. Science and engineering degree holders may be recognised as an important indicator of a nation's S&T effort. Such indicators are useful in policy formulations and development of plans for the future. A trend forecast in science education will be helpful in decision-making. Trend analysis of the outturn of highly qualified S&T manpower in India is presented along with future projections. The subject areas include Natural Sciences, Engineering and Technology, Medical Sciences, Agricultural Sciences, and Veterinary Sciences. As regards

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basic sciences, a trend analysis of Ph. Ds. awarded in Physics, Mathematics and Chemistry is presented here. An important aspect of this study being that the highly qualified manpower in due course of time can become a powerful tool of the nation and thereby can create an effective influence at the national and international level for advancement of knowledge.

Data used here for analysis pertains to Ph.D. awardees in science, engineering, medicine, agriculture and vetanary science for the period 1990-1998[1]. It is listed in Table-1 and is also depicted graphically in Fig.-1. From this graph it is evident that there has been commensurate increase in the outturn of doctorate degree holders in various disciplines during the period 1990 to 1996, but decrease in the outturn is observed during the year 1996-97. The change in the trend might have been affected by the policies adopted in the past and as such the factors responsible for this turnover calls for immediate attention of the higher education authorities. It may be observed by comparing the outturn data for 1995-96 and 1996-97 that the change in science and engineering outturns is quite significant, i.e. the figure of 3861 dropped to 3498 in science faculty, whereas in engineering outturn dropped from 374 to 298. There is slight change in the outturns of medicine for the years 1995-96 and 1996-97. The remaining faculties, e.g. agriculture and veterinary science follow a commensurate increase in the outturn during the years 1990 to 1997 but a noticeable decrease is observed for the year 1997-98.

**Table-1:** Ph. D. Produced in different fields

| **Faculty** | **Year** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **1990-91** | **91-92** | **92-93** | **93-94** | **94-95** | **95-96** | **96-97** | **97-98** |
| **Science** | 3002 | 3226 | 3386 | 3467 | 3657 | 3861 | 3498 | 3798 |
| **Engg./Tech** | 260 | 299 | 323 | 329 | 337 | 374 | 298 | 709 |
| **Medicine** | 101 | 107 | 116 | 145 | 116 | 135 | 133 | 193 |
| **Agriculture** | 690 | 653 | 611 | 769 | 766 | 780 | 968 | 800 |
| **Vet. science** | 152 | 129 | 112 | 114 | 129 | 138 | 152 | 133 |
| **Total** | 4205 | 4414 | 4548 | 4824 | 5005 | 5288 | 5049 | 5633 |

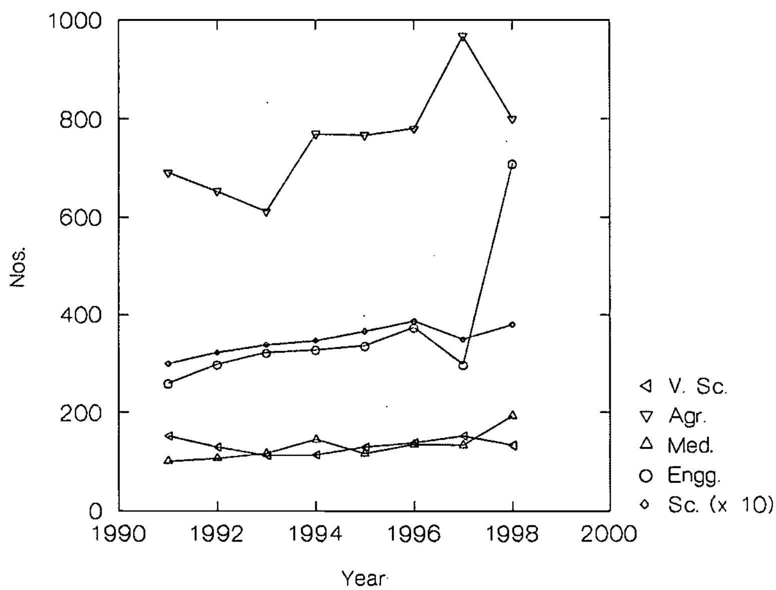


**Fig. 1:** S&T outturn data ofdoctorate degree holders

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The second data set belongs to Ph. D. awarded in basic sciences viz. Physics, Chemistry and Mathematical sciences during the period 1966 and 1997[2,3]. In basic sciences it may be noticed that maximum Ph. D. awardees were in Chemistry; second place is occupied by physics and mathematics gets the third position. Number of scholars receiving Ph. D. degree in Mathematics depicts a growing linear trend whereas in Chemistry and Physics it follows a logistic trend and has reached a saturation phase. The data pertaining to Ph. D. awarded in Physics, Chemistry and Mathematics during 1966 and 1997 is listed below in Table-2 and presented graphically in Figures 2-4.

**Table-2:** Ph.D. awardees in basic sciences

| Year | Mathematics | Physics | Chemistry | Total |
|---|---|---|---|---|
| 1966 | 66 | 127 | 284 | 477 |
| 1967 | 123 | 155 | 315 | 593 |
| 1968 | 130 | 174 | 343 | 647 |
| 1969 | 128 | 202 | 355 | 685 |
| 1970 | 106 | 199 | 411 | 716 |
| 1971 | 126 | 215 | 371 | 712 |
| 1972 | 138 | 223 | 427 | 788 |
| 1973 | 170 | 242 | 410 | 822 |
| 1974 | 171 | 214 | 439 | 824 |
| 1975 | 193 | 275 | 534 | 1002 |
| 1976 | 198 | 279 | 548 | 1025 |
| 1977 | 231 | 287 | 690 | 1208 |
| 1978 | 222 | 289 | 651 | 1162 |
| 1979 | 218 | 320 | 706 | 1244 |
| 1980 | 267 | 342 | 774 | 1383 |
| 1981 | 259 | 328 | 880 | 1467 |
| 1982 | 253 | 369 | 796 | 1418 |
| 1983 | 229 | 382 | 848 | 1459 |
| 1984 | 285 | 389 | 789 | 1463 |
| 1985 | 250 | 342 | 872 | 1464 |
| 1986 | 241 | 440 | 898 | 1579 |
| 1987 | 236 | 341 | 770 | 1347 |
| 1988 | 265 | 389 | 876 | 1530 |
| 1989 | 261 | 420 | 834 | 1515 |
| 1990 | 290 | 363 | 877 | 1530 |
| 1991 | 329 | 386 | 856 | 1571 |

| | | | | |
|---|---|---|---|---|
| 1992 | 306 | 390 | 917 | 1613 |
| 1993 | 371 | 399 | 856 | 1626 |
| 1994 | 422 | 423 | 877 | 1722 |
| 1995 | 513 | 430 | 880 | 1823 |
| 1996 | 354 | 388 | 787 | 1529 |
| 1997 | 349 | 455 | 875 | 1679 |

Unit: Numbers

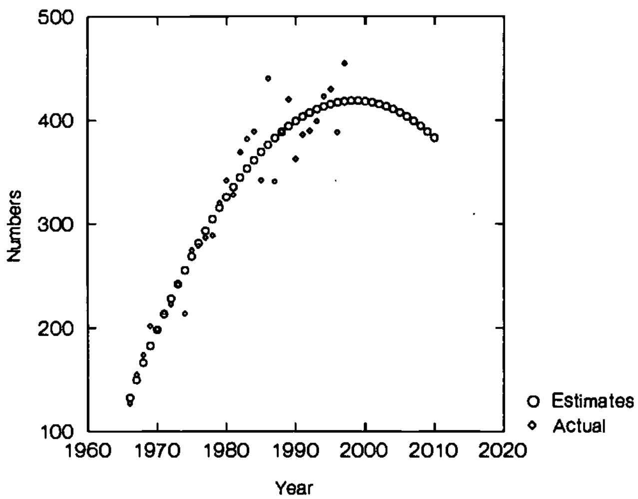


**Fig. 2:** Ph. Ds produced in Physics

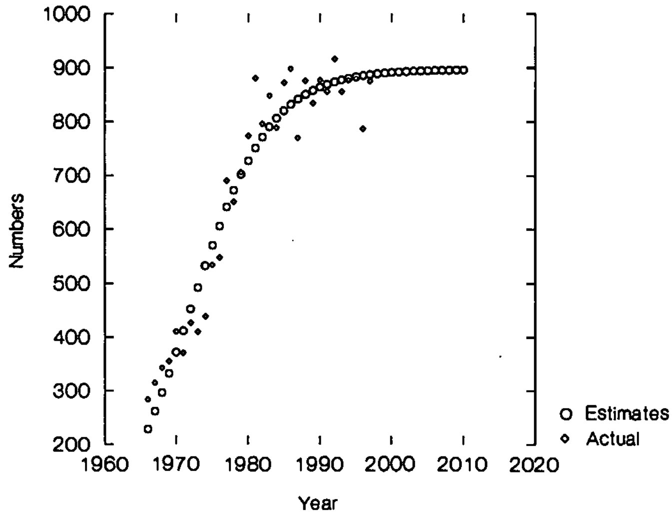


**Fig. 3:** Ph. Ds produced in Chemistry

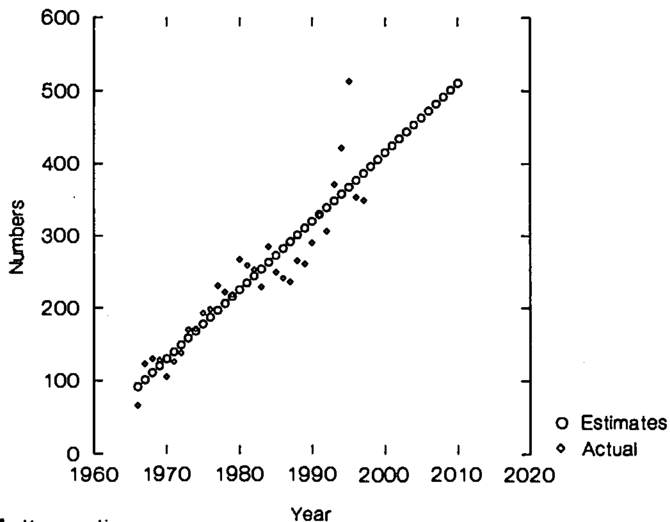


**Fig. 4:** Ph Ds produced in Mathematics

On the other hand when we look at the investment figures on education and R&D, we find that it has a decreasing trend over time after 1992. These figures, relating to expenditure on education as percentage of total expenditure[4] and national expenditure on R&D[5] as (%) of GNP are graphically presented below in Figs. 5 & 6 respectively. Their trends indicate decreasing government support for higher education and R&D work in the form of fellowships and project grants, which may be interpreted in the form of lesser number of scholars opting for higher education. Instead of choosing research and development as their carrier they prefer a job or some other profession.

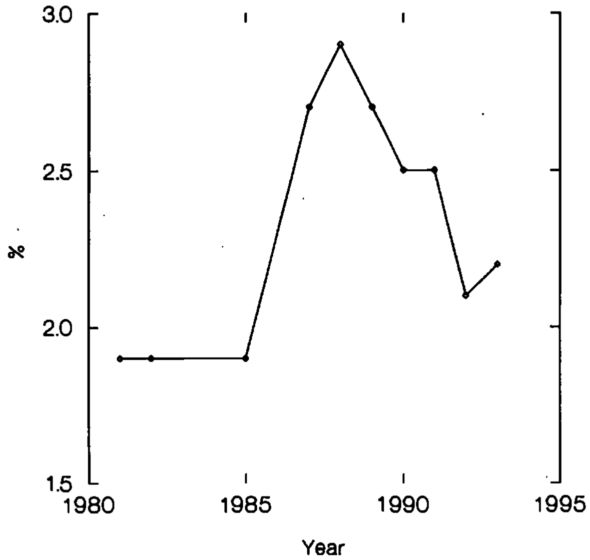


Fig.5: Expenditure on education as % of total expenditure

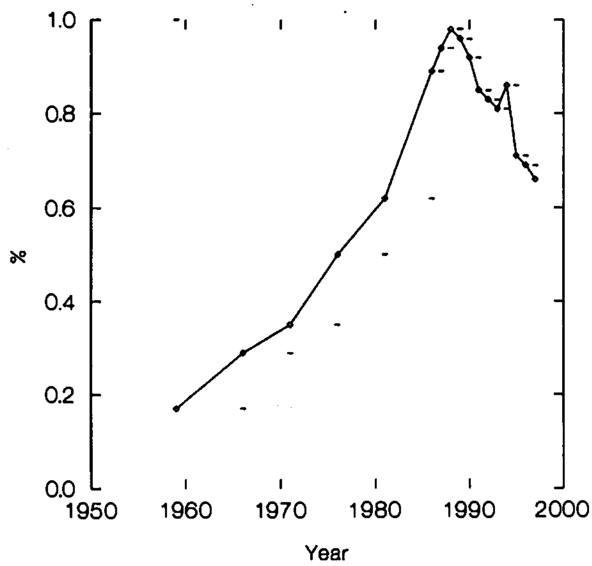


Fig.6: National expenditure on R&D as % of GNP

## Analysis

To analyse the manpower data and for making future projections we have used mathematical models proposed by Bass[6], which is mathematically defined in the following form:

$$dN_t/dt = \{p+(q/M)\,N_t\}\,(M-N_t). \qquad (1)$$

Here $p$ is the coefficient of external influence, $q$ is the coefficient of internal influence, $M$ is the total market potential and $N_t$ stands for the cumulative number of adopters at time $t$.

Parameter estimates have been obtained with the help of SYSTAT[7] package. Forecasts have been made for the outturn of S&T personnel in India using values of the parameter $p$, $q$, and $M$. These parameter estimates are listed in Table -3 and projected values obtained using these parameters are shown in Fig.-7 and tabulated in Table-4.

**Table 3:** Parameter Estimates for Bass Model

| Item | p | q | M |
|---|---|---|---|
| Science | 0.063 | 0.262 | 38611 |
| Engg /Tech | 0.038 | 0.415 | 3594 |
| Medicine | 0.00005 | 0.079 | 1999424 |
| Agriculture | 0.042 | 0.181 | 12479 |
| Vet. science | 0.052 | 0.275 | 1458 |

**Table 4:** Projections Using Bass Model

| Year | Science | Eng./Tech. | Medicine | Agriculture | V. Science |
|---|---|---|---|---|---|
| 1998 | 3288 | 404 | 167 | 854 | 121 |
| 1999 | 2793 | 331 | 181 | 833 | 102 |
| 2000 | 2258 | 243 | 194 | 791 | 83 |
| 2001 | 1748 | 161 | 211 | 733 | 65 |
| 2002 | 1306 | 100 | 226 | 664 | 48 |
| 2003 | 948 | 59 | 245 | 586 | 31 |
| 2004 | 674 | 34 | 263 | 508 | 25 |
| 2005 | 472 | 19 | 285 | 432 | 17 |

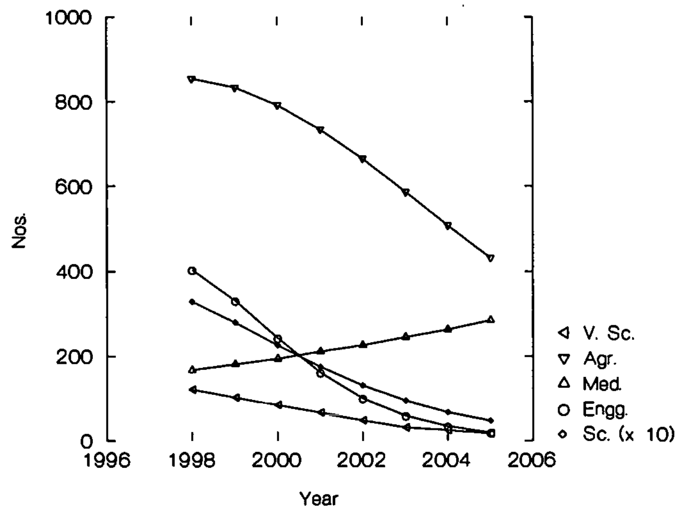


**Fig. 7:** Bass model projections

To find out the comparative preferences for different subjects among the researchers, Fisher-Pry[8] model has been applied. Fisher-Pry model is one of the most widely studied models by researchers for the analysis of competition between competing technologies. It may be expressed in the following mathematical form:

$$\log (f/(1-f)) = a + bt, \quad (2)$$

where f denotes the share of the new technology at any time t; a and b are the parameters.

Parameter estimates for this model are listed in Table-5 and projections obtained with the help of this model are given in Table 6 and graphically presented in Fig.-8.

**Table 5:** Parameter Estimates for Fisher-Pry Model

| Parameters | Science | Engg. | Medicine | Agriculture | V. Science |
|---|---|---|---|---|---|
| a | 1.06 | -2.807 | -3.752 | -1.735 | -3.437 |
| b | -0.029 | 0.056 | 0.032 | 0.008 | -0.32 |
| MSE | 3.491 | 26.174 | 52.038 | 11.574 | 51.262 |
| CRS, | 0.389 | 0.282 | 0.346 | 0.021 | 0.262 |

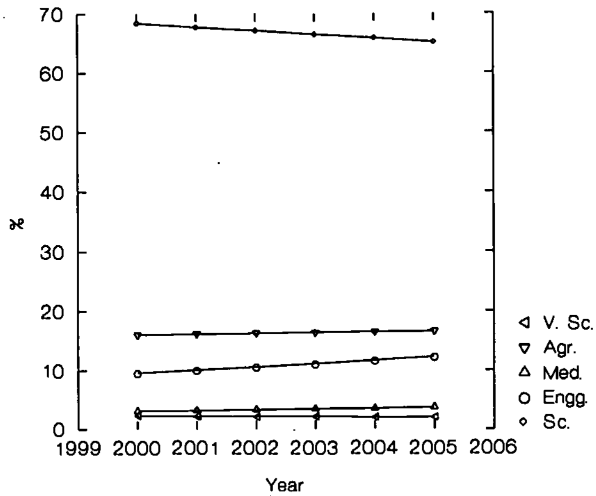


**Fig. 8:** Fisher-Pry model projections

**Table 6:** Projections for the share of doctorate degree (%)

| Year | Subjects | | | | |
|---|---|---|---|---|---|
| | Science | Eng./Tech. | Medicine | Agriculture | V. Science |
| 2000 | 68.40 | 9.60 | 3.10 | 16.00 | 2.30 |
| 2001 | 67.70 | 10.10 | 3.20 | 16.20 | 2.20 |
| 2002 | 67.10 | 10.60 | 3.30 | 16.30 | 2.10 |
| 2003 | 66.40 | 11.10 | 3.40 | 16.40 | 2.10 |
| 2004 | 65.80 | 11.70 | 3.50 | 16.50 | 2.00 |
| 2005 | 65.10 | 12.30 | 3.70 | 16.60 | 2.00 |

Future projections indicate a decreasing trend for all the subjects except medicine. This presents an alarming situation as students are turning away from science education and requires immediate policy support by policy makers and academicians. Medicine is the only research area in which researchers/scientists are showing an increasing interest. Other subjects are no more considered as prestigious and worth a profession. Science and engineering is the worst sufferer followed by agriculture and vetenary science.

Results of Bass model show a decline in the number of doctorate degree holders in future except in the field of medicine. Fisher-Pry model shows an increase in the percentage of Ph. D. holders in all the areas except science and vetenary science. This simply indicates that now a day's researchers are moving towards engineering, medicine and agriculture. Here it may be noted that the fraction of researchers in the case of substitution depends only upon the number of total degree holders whereas these degree holders are decided from the total potential market.

## Dynamics of Science Production

Research resources may be put in two categories for the present discussion viz. human and financial. Human resources are of prime concern for the nation's strength in science and technology. Very large number of graduates, postgraduates and Ph. Ds. emerge every year from our educational institutions. Their quality and quantity both are important in this context. To encourage students for academic and R&D work, it is important to have grounding in the broad fundamentals of the field and sub-field.

Accumulated scientific knowledge should percolate down over time in the society via technological root in the form of economic growth and social welfare. However, in practice it is noticed that a reverse route is being followed in many developing countries. Skilled scientific workers / R&D personnel are seen moving away from science to commerce and other business oriented activities in search of a greener pasture. Further the lack of incentives and assistance in basic science research is also one of the main causes of this transition from science education to commerce and engineering. Potential scientists of the future are moving to other areas, where financial gains are apparently better. This will hinder scientific growth, which in turn will affect developmental activities. For sustaining development we need high science, as it is an integral part of development itself. Basic research has to be complimented with financial rewards.

Working environment also plays an important role in career development. Miserable conditions, mediocrity, non-stimulating environment, hierarchy, bureaucracy, and the like factors are some of the major bottlenecks in the present surroundings and causes of repulsion from S&T research. Further, in some cases our talented scientists succumb to mediocrity and are not able to present their views forcefully. In this process they are eliminated or suppressed and mediocrity further gets a boost.

Decreasing popularity of science among students coupled with poor understanding of scientific concepts may prove to be a major deterrent in preparing future citizens for the post information society. Growing dissatisfaction with research and education among scientists and researchers requires immediate attention of the concerned authorities and policy makers. Empowering research scientists to take decisions in S&T affairs, enhancing the status of scientific research as a profession and central funding for basic research may be helpful in this direction. In fact basic sciences need a policy push where the government has to play a major role. Development of centres of excellence for scientific research along with incentives and better career opportunities may save the society from turning to a conglomerate of *techno-baboos*. Encouraging post Ph. D. research is also important as most of the research scholars and university professors are engaged in non-academic activities after receiving Ph. D. degree and being promoted as professors respectively.

## Conclusion

The outturn information regarding doctorates in India is a glaring example of a change of the mind set in researchers, where we notice the preference for technology in place of basic sciences. This diversion may retard the process of contribution to fundamental knowledge, from where technological developments evolve. India's S&T work force, which is ranked as the third largest in the world, may loose its position because of this paradigm shift and quality may also deteriorate. We know that engineers and technologists play a vital role in enhancing the industrial production. However, one should not forget that "science is the mother of technology". All technological developments depend to a large extent on scientific inputs. We can't sustain technological progress without proper scientific backing. Immediate action by S&T planners and decision makers is required to ensure technological progress itself otherwise mediocrity in basic sciences will create a vicious cycle in the field of research and development.

Education is directly linked today with job opportunities and earnings. For a Ph. D. student job market corresponding to his qualification is shrinking and accordingly students are moving to those areas where they find greener pasture. Lack of job opportunities is weakening the link between a good student and scientific production. This may in turn generate mediocrity in science. The other reason may be the lack of information among postgraduates about the incentives in pursuing science. The criterions for getting a job in private sector and public sector also vary and the salary structure leaves enormous disparity. Further, there is a little scope to switch over from academic to the private sector and vice - versa. Decline in the number of Ph. D. graduates may be attributed to some extent to a series of successful technological developments. Blinded by it bright students are opting for engineering and medicines and this may be another reason of the flight from basic sciences. One must learn from the history of those countries, which banked upon technological developments and came out with flying colours. Otherwise also the perceived role of scientist to extend the existing knowledge base in the society is no more looked upon as prestigious and rewarding.

The declining trend in the number of Ph. D. degree awarded in basic sciences clearly indicates that no more our scientists and academics are satisfied with the sense of fulfillment it has to be complimented with financial rewards as well. The sprit of excellence in further contribution to the knowledge has disappeared from the objectives of the higher education. In the long run this kind of exodus may damage the basic fabric of higher education and needs prompt attention. When other countries are investing their time and resources for the development of basic sciences, we can't afford to sit idle and be a silent spectator. Basic sciences are vital elements in technological development Research in basic sciences should be promoted not only to generate world-class contribution in fundamental knowledge but also to support and sustain technological development.

## References:

1. L. P. Rai and Naresh Kumar, Structural Changes in S&T Research in India, Scientometrics, Vol. 50, No. 2, pp. 313-321, 2001.

2. Rajagopal, N. R., Sehgal, Y. P., and Ahuja, M. L., Trends in Outturn of Scientific and Technical Manpower in India, Asia and the USA-Acomparative Analysis, Journal of scientific and Industrial Research, Vol. 56, pp. 73-85, 1997.

3. Madan, S., Sehgal, Y. P., and Gandhi, S.N., The Outturn of Highly Qualified S&T Manpower of India, Journal of Scientific and Industrial Research, Vol. 59, pp. 791-807, 2000.

4. World Bank, World Development Report, 1994 &1995.

5. R&D Statistics, Department of Science & Technology, GOI, New Delhi, 1996-97.

6. F. M. Bass, A New Product Growth Model for Consumer Durables, Management Science, Vol. 15, pp. 215-227, 1969.

7. SYSTAT, SYSTAT Inc., 1800, Sherman Avenue, Evanston, IL 60201 (312) 864-5670, 1988.

8. J. C. Fisher, R. H Pry, A Simple Substitution Model for Technological Change, Technology Forecasting and Social Change, Vol. 2, pp. 75-88, 1971.

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# INTERACTIONS AMONG PARTICIPANTS OF AN INTERDISCIPLINARY MODALITY OF TEACHING AND TEACHER EDUCATION IN SCIENCES

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Lenir Basso Zanon[2]
Otavio Aloisio Maldaner[2]

## Abstract

One of the critiques systematically made to teaching and teacher education in the natural sciences refers to the widespread view of science as a dogma, centered in what is true, definite, right, in the only right answer for any kind of posed question or problem. According to this view, originated in the positivistic paradigm, *scientific* is something positive, unquestionable and accurate, generated by a unique method, the *scientific method.* Scientific knowledge is viewed as objective and trustworthy and the researcher as somebody who is free from any preconception or ideas prior to his or her findings. It also follows from the same positivistic source that the universal theories and laws of Science originate from the objective observations and generalization.

This way of conceiving Science, the scientist and the scientific activity has greatly influenced the teaching of sciences. It disregards the idea that observation is always theory dependent, theory determines *'what'* and *'how'* one observes, and the lack of theoretical knowledge makes observation empty, unsuccessful and senseless.

According to Chalmers (1993, p. 20), the positivistic idea of science is derived from the conception of *scientific method* as formulated by Francis Bacon, in the beginning of the XVIIth century: *the goal of science is the life improvement of men in earth. To him this goal would be reached by the collection of facts through organized observation and deriving theories from that.* It follows from this positivistic paradigm, dominant for a long period of time, the epistemological conception of teaching and teacher education as centered in the technical rationality, according to which in order to solve any practical problem it suffices to master and apply the scientific theories. Such a conception idealizes, deforms and overestimates the *scientific knowledge.* On the other hand, it disregards the complexity, dynamics, and singularity of practice and the real problems of practice (Schön, 1983).

Carr and Kemmis (1988) mention the introduction of the term positivistic philosophy by the Frenchman Auguste Comte, whose own work clearly exemplifies such an attitude.

> *By choosing the word 'positive' Comte tried to emphasize that no kind of experience learned through non sensory means could serve as a basis for valid knowledge. It was this desire to free the thought of the dogmatic certainties, associated with an optimistic faith in the power of 'positive' knowledge to solve the great practical problems, that conferred to positivism its initial interest* (1988, p. 77).

This positivistic conception of science and knowledge does not consider the complexity of scientific activity and the teaching processes, with their several possibilities of points of departure and reference to each context of knowledge production. It does not consider knowledge processes that are normally utilized by the students in and outside the school or the fundamental role of the teacher as a mediator in the development of a relevant and significant dynamic scholarly knowledge. Regarding the teaching model merely based on transmission – lacking argumentative practices and emancipatory interests, learning is generally superficial due to the absence of interrelations with living contexts and social implications and insertions. This kind of learning is characterized as transitory and non-relevant to human/social development.

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This study analyzes alternative forms to the model of teaching in natural sciences which is centered on the mere transmissive and straightforward reproduction of ready-made school contents, in which learning means passively memorizing dogmatic truths; a model originated from the wide predominance of the positivistic conception of science and the relation between science and reality.

> *the empirical analytical sciences are constituted by human acts, supported by a scientific community and inserted in the wider cultural process of ordinary language. They are subjected to the validation process of their premisses and the proof of argumentation: not the argumentation by itself because they turn to interpretation, not the simple production of* ad infinitum *new experiences. Therefore, the technical interest of knowledge cannot detach itself from the practical and emancipatory interests.* (Marques 1992, p.151-152).

One's purpose is to contribute to the overcomming of the positivisitc perspective, according to which the resolution of practical problems consists of the mere application of theories and techniques learnt in school in a standardized and overviewed way, without taking into account the conditioners inherent to the concrete situations – complex, singular, dynamic, unexpected and uncertain, in which one ignores the dynamics of the interrelations between, always diversified, theoretical and practical, daily-life and scientific knowledge.

Educational research has revealed the inadequacy and insufficiency of the dominant learning-teaching model to account for the education of the new generations. In such a context it is essential to discuss the education of teachers, which demands a reconceptualization process as a professional education capable of potentiating the reconstruction of educative practices at several levels of education. In the center of this problematic lies the need of paying attention to the *interaction processes* that constitute the dynamics of teaching and teacher education in sciences.

### The Intersubjective Interactions In Sciences Classes

The *pedagogical interactions* studied in the present investigation refer to practical contexts of knowledge production in the classroom, as processes more or less capable of pointing to changes simultaneously theoretical and practical in teaching and teacher education in sciences. (Maldaner, 2000). The study makes it explicit and analyzes characteristics of *interaction* among participants in an alternative interdisciplinary teacher education program, to discuss how such *interactions* relate themselves to the perspective of reducing the distance between theory and practice in teacher education.

Gauthier (1998) points to two fundamental obstacles that interpose themselves in the processes needed for the improvement of teaching: one relative to the teaching activity itself, an activity carried out without revealing its inherent knowledge, and the other referring to the academic research, which produces knowledge that does not take into account the concrete conditions of the teaching profession.

Paraphrasing Gauthier's words about teaching, *teacher education* also lags behind in terms of reflecting about itself. Confined to the secrets of what happens in the educational programs, it resists to its own conceptualization and barely gets to express itself. According to the author, the tendency toward the formalization of *teacher education* reduces its complexity in such a way that it does not find a correspondence with reality anymore; it shows itself as an occupation without knowledge or reduced to academic knowledge, which provokes the drainning of the concrete context related to the practice of this professional education. (Gauthier, 1998).

The investigation considers that both, student and teacher, are active in the processes of teaching and teacher education. It considers that the relationship between research and practice [pedagogical/social] *is not a relationship between one theory and one practice, but an asymmetric relationship among actors-participants whose practices carry diversified knowledge* (Tardif 2000, p. 121). One studies *interaction* contexts in which teacher educators and future teachers interact as individuals who produce and own more or less grounded, explicit and systematized knowledge, as forms of *professional interaction* that can contribute to the overcomming of the vicious and widely instituted distance between 'scholars who produce theories' and 'practitioners who carry out the teaching practice' and apply theories produced by others.

As it is possible to confer visibility to practices, conceptions and beliefs that determine characteristics of *professional interaction* and analyze their influences on the teaching and teacher education – the ways conceptions and practices influence the interactions and interventions occur, during the negotiation of meanings regarding learning and changes, seen in their intentionalities and underlying models – new interactive processes can be produced to constitute the participants. *The construction of understanding is related to the several ways through which two or more voices meet. This means that in classroom interactions the voices of the textbook, the teacher, the colleagues, the experiences and the common sense meet and oppose each other dynamically.* (Machado 1999, p. 59).

The study analyzes *interactions* in the development of *Study Situations* organized by the Grupo Interdepartamental de Pesquisa sobre Educação em Ciências da UNIJUÍ[3] (GIPEC-UNIJUÍ) [UNIJUÍ Interdepartmental Research Group on Science Education]. The *Study Situation* consists of an interdisciplinary approach to a daily-life context, conceptually rich for several fields of Science, limited in time (approximately two months). It allows the explicitness and discussion of concepts through diversified socio-historical-cultural interactions in which knowledge, concepts and languages that structure the specific knowledge of Biology, Chemistry and Physics, meet in daily-life contexts (Maldaner and Zanon, 2001).

The study is based on a reconceptualization regarding the meaning of teaching and teacher education. It is aimed at contributing to the overcomming of the restricted perspective relative to the pedagogical act as it analyzes *interactions* among individuals (undergraduates and their educators) participants in interdisciplinary formative situations, in teacher education classes for the teaching of sciences, articulated by GIPEC-UNIJUÍ. The analysis considers the perspective of the *dialogic intercommunicative and intersubjective action* supported by the argument, as based in Habermas (1988), through which the construction of *schooling knowledge* is constituted as a dynamic/dialectic mediation between diversified daily-life and scientific knowledge.

As suggested by Marques (1996),

> *the focus of investigation moves from the cognitive-instrumental rationality to the communicative rationality. Knowledge is not based anymore on the relationship subject-object, but on the intersubjective relationship assumed by social actors capable of speaking-acting while agreeing with each other about something in the world. The category of* understanding *becomes fundamental: an intersubjective process in which the interacting participants coordinate their actions through acts of speech that raise* validity claims *supported by* argumentation. (1996, p. 86).

Therefore, due to the limits of the dominant teacher education model which, as already mentioned, follows the *technical rationalism*, one considers the emergence of another form of thought about practice, another epistemology of practice, not anymore restricted to the positivistic perspective and alienated from practice. Aiming at contributing to the production of alternative ways to reduce the wide distance between theory and practice in teacher education, we value the idea that intercommunicative, reflective and dialogical interactions among social individuals produce, constitute and reconstruct, dynamically and systematically, the formative practices, the processes of knowing and the individuals themselves, who are always capable of intervening through distinct ways in the permanently reconstructing practices.

This epistemological perspective of practice – as an intercommunicative, dialogical and social action which produces the real [the practices] through the meeting of always diversified argumentative knowledge – is in opposition to the education based on the merely applicable perspective of scientific theory and technique, technical rationaliy derived from the positivistic epistemology. According to Maldaner, what must be done is to rescue what is lost and redirect the instrumental reason to the limits needed in society. It is the values and norms placed by technique that must be questioned, thus regenerating the communicative action of all social actors through the best argumentation. (2000, p. 140).

[3] Regional University of the Rio Grande do Sul State's Northwest.

Based on the idea of *reflected practice* and *reflected education* we want to bring new perspectives to the fore, facing the challenge of individually and collectively reflecting and analyzing practice and education to help individuals underestand each other through intercommunicative interaction with other social ones about the meaning of the practical situations put into discussion. We based ourselves on the idea of *reflective inquiry* as proposed by Garcia (1992) to discuss means of reviewing *interactions* in education through conscience raising and reflectivity with respect to problems inherent to the social practices and ways to face them. Such a discussion is based on reflections about what lies behind determined interactive classroom behavior. These interactions; being exposed and discussed, can revert to forms of reflectivity about the environmentalist education, always in a process of reconstruction regarding the perspective of a learning that does not come from a non-reflective experience but from the critical reflection on one´s own experience and that of the others. *Reflective inquiry can serve as a strategy to be utilized with prospective and in service teachers, making it easier the raising of conscience regarding teaching practice problems. Reflective inquiry questions the causes and consequences of teaching behavior, surpassing the didactical limits and those related to the class.* (Garcia. 1992, p. 53).

This epistemological perspective considers that the historical and social individual [distinctly from the maturational, individualist and empiricist perspective] constitutes him or herself in the interaction with others, in constant development, in his or her world, with his or her peculiar life history and fomative processes, always in a constant process of social reconstruction. As observed by Paulo Freire, no one teaches anyone. Men educate themselves mediated by argumentative discourses capable of being systematically amplified and reconstructed through continually renewed forms expression and comprehension [via theories] of practices. As referred by Marques, education and teacher education undertake an active role in collective learning which makes possible a development

> *in which one assures the control of the situations to face in the world of cultural traditions, the social environment of group conviviality and regarding the respect to and affirmation of the personal identities. Education constitutes the enlargement of intelectual, relational and expressive horizons within the dynamics of life experiences and the totality of mankind knowledge. It allows people and groups with diversified experiences to confront themselves in an adventurous dialogue, in which both, in their own ways, attest to the multiple human possibilities.* (Marques 1993, p. 13)

More than the world of illusion perceived by one´s eyes, more than the world of hidden causes, knowledge needs *to found itself in the world of men who listen to each other in touch with the voices that question them.* (Marques 1993, p. 90). This does not refer to any ordinary look and listening. It refers to a critical reflection due to its mediated kind of argumentation, i. e., a reflection supplied and sustained by a ´communicative acting`, continuously reviewed, which requires new theories – discursive forms of comprehension regarding the meanings put into discussion. People in the process of education reconstruct themselves by making explicit and discussing the interactions that confer new meanings to the specified practices and theories, thus systematically amplifying the horizons of interactive practices within their theories and underlying conceptions, which are always susceptible to new meanings and forms of production. The theoretical and practical practices of education reconstruct the individual who reconstructs his or her worlds through them. People understand each other, their realities, the world and their own formative processes through ´communicative acting` as they make explicit and discuss meanings and validity claims which are always being reconstructed.

We analyzed intersubjective interactions capable of constituting processes of didactical intermediation which, in the dialectic sense, *is a process of constitution of a reality from opposing mediations, of non-immediate, complex relationships. A deep sense of dialogy.* (Lopes 1999, p. 208 e 209). In the analysis of the dialogical meaning of the interactions, the reflectiviness and questioning attitude are focused as possible articulating elements of the processes of conceptualization, argumentatively mediated as systematic, careful and active review of beliefs, knowledge and attitudes in the light of fundaments, interlocutions and propositions. The analysis focuses on a hermeneutical perspective of the individuals` social reconstruction processes via class interactions. In this sense,

> *it is important that one begins to treat the practical situations, the world of life and the structural contexts as a global complex, without making the simplifications and reductions proper to the positivisitc paradigm. (...). It is mediated by language and other linguistic forms that the individual interacts with others and develops his or her specifically human potentialities* (Vygotsky, 1987*), becoming an active participant in his or her cultural context.*(Maldaner 2000, p. 142 e 143).

This way, we analyzed, in alternative contexts of teaching and teacher education, the presence of *interactions* which relate to the dynamic/dialectic mediating action between new theoretical and practical knowledge, both inherent to the processuality and complexity of school knowledge, teacher education in sciences and the teaching of sciences. We expect that the study may configurate new *interaction* processes, in a more intentionally and explicitly expressed way, so as to oppose the model of our critiques, as interactive practices are analyzed and discussed in the formative groups, taking into account their conceptions, underlying beliefs and didactical-pedagogical influences.

## Methodological Organization Of The Study

The **general objective** of the investigation, which finds itself in its beginning, is to make explicit and analyze typologies of *interaction* among research individuals – undergraduate students and teacher educators – based on more or less interactive, participative and dialogical models of teaching and teacher education in sciences and for the teaching of sciences. From the analysis of the *interactions* **research questions** can be expressed as follows:

> - Which typologies of *interaction* are more frequent in the classroom? How do they connect with the processes of teacher education in sciences and for the teaching in sciences? Which kinds of *interactions* organize the practices and teacher education in the investigated processes? What determines these interactions? How do they change along the processes of teacher education and performance? In these processes, how do theoretical and practical knowledge, beliefs, conceptions and experiences meet? Which processes of knowledge and teacher education are involved in the analyzed *interactions*? To what extent and in what ways do the *interactions* enfold interrelations among diversified knowledge, in opposition to the usual teaching models based on the *technical rationality*?

This is an essentially qualitative research whose methodological organization is based on the analysis of interpretative planning forms regarding the educative theory and practice as founded in social phenomenology (Carr and Kemmis, 1988, p. 114). As action research, social phenomenology intends to contribute to the social reconstruction of the *interaction* practices examined through the reflective questionning of the participants, regarding the betterment and understanding of their social practices and the situations in which they take place. The **methodological procedures** regarding data collection and analysis are based on **empirical material** developed via tape recording and transcription of aproximately 72 periods in Sciences II e IV, disciplines from the curriculum of the Licenciatura de Ciências, Habilitação em Biologia ou Química da UNIJUÍ[4], related to the following two *Study Situations*: *'How does Human Being Perceive and Interact with the Environment'* and *'Food: Production and Consumption'*.

Based on propositions of the literature we are developing initial analysis parameters and criteria to establish procedures and instruments regarding data collection and discussion. The fragments of the collected empirical material refer to speech sequences related, in one way or another, to the problematic and the questions of the investigation. The analyzed interactions refer to modalities of speeches, interlocutions, dialogues, questionning attitudes, ways of expressing ideas and points of view, more or less dialogical ways of didactical mediation and negotiation of meanings for concepts.

4 Teacher Education Course in Sciences (Biology and Chemistry).

## Preliminary Results And Considerations

We present now examples of teaching episodes, which are being analyzed, intending to show preliminarily qualified *interaction* typologies in the research process.

**Problematizing Dialogical Interaction - Episode 1**

1. Maria (teacher): *I believe that throughout the Study Situation we can answer all these questions in better ways, but they are going to be part of the beginning of our activities and I would like to review and hear something from you, what you wrote about why we feed ourselves. (.).*
2. Maria (teacher): after class, *do you eat something?*
3. Ângela (student): *I usually eat a hot dog or a ´pastel`.*
4. Maria (teacher): who *else?*
5. Laura (student): *bread with butter, coffee and milk. At lunch, lettuce, steak and a little bit of rice,* I´m on a diet. At night I eat the same as breakfast. After I get home from university, I had some lasagna and a mango, because we get home starving after class, first I ate a mango and then a lasagna, but that´s not a balanced diet.
6. Maria (teacher): since when are you on that diet?
7. Laura (student): it´s been a week that I´m trying to lose one kilo.
8. Maria (teacher): who else?
9. Marta (student): when I get back, I eat something if it´s different.
10. Maria (teacher): who else?
11. Carmem (student): I would like to ask something,it´s said that we need to drink two liters of water a day, that would be perfect.And if drink chimarrão[5], *is it the same thing?*
12. Maria (teacher): *I know about the two liters of water a day, but if that comes from the Chimarrão then I don´t know. Good question! I can´t answer. (.).Who else would like to say something?*

Many times we introduce a discipline with a mere presentation of its content/program. The teacher makes an initial problematization through questions. This expresses the intention of listenning to and problematizing with the students, in order to establish relationships between the teaching contents and the contexts of implication and insertion in the students` daily-life experiences and professional perspectives.

The interactions are not always dialogical because, even when the teacher asks and listens to the students, she does not always consider their speeches in the classroom discussion sequence. Sometimes she makes brief comments. In the 12th turn of the episode, the teacher firmly expresses that she does not have answers to the question presented by the student: it is implicit the conception that the teacher is not somebody who knows everything, who always has a ready-made answer. It seems that the variation in the students` speeches was somewhat anticipated by the teacher. Such a variation did not seem to intervene in the class sequence, considering the teaching/class plan.

The validity of this kind of interaction could be considered as a way to establish a communication channel among the individuals in the group, especially between the educator and the students, about the social relevance and significance of learning to their education. It is important to pay attention to the ways students' answers are treated in the continuity of classes, in the mediations around the respective teaching program and and corresponding learning.

**Extensive Monological Interaction - Episode 2**

Felipe (teacher): *Whoever took the previous class must´ve studied electric charges. For instance, what does electric charge mean? Well, to summarize a bit about the subject, all matter is electric charge (.).an electric field is supposed, around each charge there is, an electrical field is inherent to each charge, now, what is an electric field? If anyone thought (.).*[a long text of approximately 2000 words, transmissive in character, follows]

[5] Chimarrão is a bitter drink very popular in the southern states of Brazil. It is a herbal (mate) tea usually served hot.

This episode refers to a pedagogical moment in which Felipe, the teacher, was explaining that in order for an object to be perceived there was a need for a sign external to the eye [sense organ]. It was an explanation about the sight through the detection of an electromagnetic sign, which required the concept of "field". In order to introduce this concept, the teacher made a long speech, without allowing any time for dialoguing. He did not offer any room for the students` speeches. Even though some students looked absentminded and engaged in parallel conversation, he continued with his explanations.

This is a monological kind of interaction, in which the teacher does not pay attention to the students`s points of view, going on with his transmissive conceptual explanation. The teacher expects that the students give a meaning to the taught concepts. However, there is no perception regarding the students` comprehensive activity. This is the most traditional teaching way, still very present in the classroom, in which the teacher is active but, many times, the student does not corresponds to the expected cognitive task. Several times the teacher asked questions to the students, giving them the answers immediatelly after that. The students did not have even time to reflect on these questions, let alone to express their points of view.

**Conceptualizing Dialogical Interaction - Episode 3**

1. José (teacher): *So, knowledge changes. Do not try to move knowledge from here to there. (.).try to transfer already made concepts. that´s nonsense. We really need to learn, understand things, but for that we need to form a thoughtful mind. That means thinking about real situations through the knowledge of several sciences. (.).my invitation is that we think about the matter and energy interaction, that we understand Chemistry, that will let us understand Biology, and so on. So,the senses of smell and taste have exactly the same relationship. It´s important to undersand this fact. (.).Remember, there is matter and substance. You could help me distinguish matter from substance. What´s the differene? Are matter and substance the same thing? (.).Here I have a perfume sample. Let´s see if you guys like it! Let´s see. ..What have I drop there, substance or matter?*
   Students: *It´s substance.*
   José (teacher): *Substance. So, if it´s substance, what does it need to have? Is it going that way* [points to the back of the classroom] *or not?*
   Students: *No!*
   José (teacher): *I already feel it.*
   Marcia (student): *It´s from Natura [brand], I know that because of the bottle.*
   José (teacher): So, I ask you – it´s from Natura, she said – what I´ve dropped, is it substance or matter?
2. Marcos (student): Substance.
3. José (teacher): If it´s substance, what does it need to have? She said it´s from Natura. So, did Natura isolate a substance? Did it? Or did it mix several substances?
4. Ana (student): It mixed.
5. José (teacher): It mixed. So, if you mix many things, is it substance or matter?
6. João (student): Substance.
7. José (teacher): Milk, what would it be? Substance or matter?
8. Marcos (student): A mixture of substances.
9. José (teacher): Oh, so, is it matter or substance?
10. Joana (student): Wouldn´t matter be a mixture of substances that form matter?
11. José (teacher): It´d be better if you say it this ways: matter is always a mixture of substances. So, this is matter. Remember that we said in our first class that substance has a name, has a characteristic and a chemical representation. What I know about this perfume is that it is from Natura. If I say ´it´s from Natura`, am I representing this perfume chemically? No, we can´t represent it chemically. This perfume is a mixture. Just like milk is a mixture, meaning that it´s matter.It´s matter or substance?
    Students: It´s mixture.
    José (teacher): Mixture. So, is is matter or substance? It´s matter with many substances...

There is in this kind of interaction a negotiation of meanings regarding the concept through argumentation, relationships between phenomena and theoretical explanations by using specific languages, in an intercommunicative way, in which all individuals were active, not only the teacher.

Therefore, the preliminary analysis of the interactions shows the presence of interactions more or less dialogical and argumentative, which indicate greater or lesser degree of reflectivity about experienced formative processes. These processes can be configurated as somewhat collaborative interactions as intercommunicative relationships mediated by arguments among diversified knowledge, more or less practical, theoretical, theoretical-practical, daily, scientific, disciplinary and interdisciplinary. Although in an incipient way, dialogue and reflectivity reveal themselves as formative components that potentiate the knowledge processes and the research attitude, in opposition to the merely transmissive teaching models based on the technical rationality.

The investigation points to the contributions related to in-group interactions as an education directed toward a more dynamic and plural approach to reality, through argumentative didactical mediations in the interdisciplinary form of the Study Situations, meaning that

> *to argument is not to convince or persuade someone of something, but it means for interlocutors to come to a new understanding about something, a cooperatively produced understanding, as it does not result from the victory of one over the others and is not the simple sum of the diverse points of view, but consists of the collective reconstruction of a plural knowledge that, even not being true, was based on rules capable of producing it. (Marques 1992, p. 99).*

## Bibliographical References


CARR, W. e KEMMIS, S. *Teoria Crítica de la enseñanza: la investigación-acción en la formação del professorado.* Barcelona – Espanha: Martinez Roca, 1988.

CHALMERS, A. F. *O que é Ciência Afinal?* São Paulo: Brasiliensis, 1993.

GARCIA, C. M. *A formação de professores: novas perspectivas baseadas na investigação sobre o pensamento do professor. In:* NOVOA, A. (org.); *os professores e a sua formação.* Lisboa: Dom Quixote, 1992.

GAUTHIER, C. *Por uma teoria da pedagogia: pesquisas contemporâneas sobre o saber docente.* Ijuí: Unijuí Ed., 1998.

HABERMAS, Jürgen. *Teoria de la acción comunicativa.* Madrid: Taurus, 1988, Tomos 1 e 2.

LOPES, Alice Ribeiro Casimiro. *Conhecimento escolar: ciência e cotidiano.* Rio de Janeiro: EdUERJ, 1999.

MACHADO, Andréa Horta. *Aula de química: discurso e conhecimento.* Ijuí: Editora UNIJUÍ, 1999.

MALDANER, Otavio Aloisio. *A formação inicial e continuada de professores de química:* professores pesquisadores. Ijuí: Editora UNIJUÍ, 2000.

MALDANER, Otavio Aloisio e ZANON, Lenir Basso. *Situação de Estudo: Uma organização do Ensino que extrapola a formação disciplinar em Ciências.* Ijuí: Ed. UNIJUÍ, *In* Espaços da Escola 41, 45-60, 2001.

MARQUES, Mario Osorio. *A formação do profissional da educação.* Ijuí, Editora UNIJUÍ. 1992.

________. *Conhecimento e modernidade em reconstrução.* Ijuí: Editora UNIJUÍ. 1993.

________. *Educação/interlocução, aprendizagem/reconstrução de saberes.* Ijuí: Ed. UNIJUÍ, 1996.

SCHÖN, Donald A. *The Reflective Practitioner: How Professionals Think in Accion.* Basic Books, New York, 1983.

TARDIF, M. *Os professores enquanto sujeitos do conhecimento: subjetividade, prática e saberes do magistério,* In CANDAU, V. M. (org) *Didática, Currículo e Saberes Escolares,* Rio de Janeiro: DP&A Ed., 2.000.

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# STUDENTS' MULTI-MODAL RE-PRESENTATION OF SCIENTIFIC KNOWLEDGE

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## Abstract

Learning within schools is based on resources that were prepared by external to school experts and are mainly using the dominant verbal - written mode for transmitting the legitimized objective scientific bodies of knowledge. This environment encultures students in to a culture that some of its features are: **a**. Legitimate knowledge is that which was constructed by scientists; **b**. Learning is a passive activity; **c**. Students belong to the sector that only consumes knowledge; **d**. The verbal modality is the most suitable and appropriate one for dealing with knowledge and knowing; **e**. The dominant intelligence is the verbal-formal one; **f**. There is hardly place for students' creative expressions in different modes other than the verbal.

These messages, whether hidden or explicit, do not prepare students for coping in the new capitalist, knowledge centered culture that is legitimizing different kinds of knowledge, different modes of presentation, and endorses the context embedded nature of issues. To participate in the new culture students have to acquire multiliteracies that are essential for becoming an active and conscious learner. Meaning, schools should move towards a culture that provides students with opportunities to explore and shape their own understandings by re-presenting and recontextualizing abstract ideas into their 'lifeworlds'.

The paper describes a project that based learning on students' production of resource materials for learning that were utilized as learning resources by their peers. Multiple modes of re-presentation were encouraged and legitimized by getting students acquainted with Gardner's theory of multiple intelligences.

Some of the effects of this project on students' learning is addressed via the following questions: What is students' perception of the uniqueness of the resource materials they have prepared and used; to what extent students gave freedom to their creative imagination in adopting modes of re-presentation other than the verbal one; and the relationship between the constructed resource materials and students' different intelligences.

## Introduction

Most of students' learning in school is focused on the study of formal bodies of knowledge transmitted via standardized resources. The latter include books, or other curriculum packages that most of the times have been constructed by disciplinary experts from outside of the school e.g. supervisors or academics. These resources are using the school dominant verbal - written mode for transmitting the legitimized objective scientific bodies of knowledge. Such an environment actually socializes students into a culture that some of its features are: **a**. Legitimate knowledge is that which was constructed by scientists; **b**. Learning is a passive activity whereby the learner absorbs the transmitted knowledge from experts, e.g. teachers or books; **c**. Students belong to the sector that consumes knowledge and do not take part in its construction; **d**. The verbal modality is the most suitable and appropriate one for dealing with knowledge and knowing; **e**. The dominant intelligence is the verbal-formal one (though visual elements such as graphs and tables are employed) and **f**. There is hardly place for students' creative expressions in different modes other than the verbal.

This school culture does not provide students with skills for coping in the new capitalist, knowledge centered society that demands coping capabilities with different kinds of knowledge, with different modes of presentation, with the need to be an active critical consumer and producer of knowledge for context embedded problems. It does not prepare the students for the wave of information resources, e.g. internet, television and others, that impart on the learner the responsibilities to determine what to learn, how, when, where and with whom. Paradoxically, even if students gained new capabilities from their multi-modal out of school experiences, these are useless in the formal school setting.

The answers to the w-questions are flexible, changing from situation to situation, and rely on students' free choice of preferred modes for engagement as well as their preferences to the other issues. Coping with such unstructured conditions is a learning process that involves creative and entrepreneurial ways of 'juggling' with knowledge and the understanding of the many facets of dynamic and context embedded issues. To participate in such processes of learning students have to acquire multiliteracies that are basic for understanding the multi-modal communicative channels, to be reflective and critical in judging the explicit and implicit information. This actually calls for a change in the school pedagogy towards one that provides students with experiential settings of learning to master multiliteracies that fit the new culture.

The schools' new pedagogy should provide students with the opportunity to explore their interests and intentions and shape their own understandings by re-presenting and recontextualizing abstract ideas into their world of being. Gee (2000, p. 66) refers to the latter as students' 'lifeworlds', meaning "culturally distinctive ways of being, acting as, and talking as an 'everyday', non-specialist person". Students' ability to recontextualize the scientific language into their 'lifeworlds' is an important aspect of scientific literacy as it provides students with the opportunity for bridging between domains of specialists and their own worlds. Thus, the new pedagogy should bring to the learning situation different languages, different modes and the subjectivities of the learners all of which should be incorporated into the learning activities. These should be the core of the new pedagogy that should aim " to develop an epistemology of pluralism that provides access without people having to erase or leave behind different subjectivities"(The New London Grou, 2000, p. 18). It is a participative learning pedagogy that enables the learner to mold his knowledge in an active hybridization of his subjectivity, intelligences and creative abilities. The incorporation of different modes of meaning making and their interactions for coping in various realms is also supported by Gardner's multiple intelligences theory (Gardner, 1983) and provides additional support towards adopting this direction. The importance of multi-modal presentations in learning is also supported by our findings that different populations (gifted/regular) cope in a different way in solving problems presented in the verbal or the visual (cartoons) mode (Klavir & Gorodetsky, 2000).

We believed that a possible learning environment that incorporates some of the critical constituents of the multiliteracy pedagogy is one that involves students in active re-construction of their scientific knowledge. This was achieved by passing on to students the responsibility for the construction of multi-modal 'learning resources' that were to be used by their peers. It was believed that being involved in creative constructive processes of resources does, concurrently, employ and develop multiliteracies. We felt that resource materials that are prepared by students and that employ multi-modal representations will engage the learners (through preparation) in recontextualizing the scientific concepts into their worlds of metaphors and into their everyday language. By such a process it was hoped that students will gain authorship on the recontextualized bodies of knowledge that were to become the legitimate curriculum resources. It was also believed that children's exposure to scientific resources that were molded through the eyes of their peers, will better generate the connections among their 'lifeworlds', the scientific concepts, and their socio-cultural context.

This belief was interpreted into a science project that subjected elementary school six graders to a pedagogy of multiliteracies by involving them in the construction and the utilization of students' resource materials.

## The project

The setting of the project was in a community elementary school that was open for educational experimentation. It involved six graders that were studying the formal science curriculum that included the subjects: power stations, light, and the human body. Each student had to choose two of these subjects, one each semester, meaning each student studied two subjects during the academic year. The project lasted two years, i.e. it involved two cohorts each of them studying two subjects. The first 2/3rds of the semester were devoted to the study of a subject and the last third was devoted to the construction of resource materials. The first cohort, studied the subjects in the first 2/3 of the first semester with a teacher, mainly via frontal presentations. In the second semester they studied only from resources that were prepared by their peers. The second cohort studied in both semesters from resources prepared by their peers without any frontal instruction. This arrangement established a difference between the two cohorts – the first being exposed to learning from teachers and peer resources and the second studying only from peer resources. Each student had the opportunity to develop at least two resource units each one on a different subject. Students were encouraged to construct, in groups or individually, re-presentations in different modes of their recontextualized knowledge. They were told that their materials will be used by their peers as learning resources and will substitute the common textbooks and teachers' instruction. All students were encouraged to be creative and employ their preferred modes in re-presenting the scientific concepts. Creativity and preference for individualized modes of expression were advocated by intentionally acquainting students with Gardner's theory of multiple intelligences (Gardner, 1993).

Different aspects of the newly established learning environment were followed by various questionnaires. These also referred to students' perception of the unique features of the materials they have constructed and their understanding of the difference between these materials and the established curriculum books. For the analysis of the possible connection between students' intelligences and the nature of the constructed resource materials, mapping of their intelligences was achieved by a Likert-type questionnaire (Likert, 1932; Coolican, 1994).

In this presentation we wish to concentrate on some issues that were central to the new learning environment. Beyond the elementary question that refers to students' achievements on knowledge in the specific subject matter we were specifically interested in students' choice of the various modes for re-presentation, their creative ways in recontextualizing science in their worlds and their sense of authorship. In this presentation three issues are addressed: What is students' perception of the uniqueness of the materials they have prepared and used; to what extent students gave freedom to their creative imagination in adopting modes of re-presentation other than the verbal one; and the relationship between the constructed resources and students' different intelligences.

**1. Students' understandings of the uniqueness of learning resources that were constructed by their peers.**
Though the school culture is dominated by the verbal modality it was surprising to see the variance in the modes, other than the verbal, employed by the students in constructing the resource materials. These modes included multimedia, video films, games, concrete models, etc. Not only did students show preference for other modes in constructing the materials, but they also expressed a similar preference in the use of resource materials prepared by their peers. They claimed that the latter are more interesting than textbooks; "You have much more choice.more humor.and more freedom".

The language that was utilized in the different re-presentations was that of children, that drew from their life worlds and better suited their linguistic capabilities;

"They (materials) are more suited to our level and they speak in the everyday language whereas in the books they speak in a not so comprehensible language", or another citation that expresses their comfort with these materials;
"It is talking at the eye to eye level and it is focused".
Students were aware to the recontextualized and personalized nature of the representation of the subject matter by students as clearly distinctive from that of the academics. Actually they claimed that these features contributed to their learning;
"There are things that the children invented and also things that they tell were of interest to them", and "In learning materials prepared by the students you have their personal knowledge .and also their opinion".
Students grasped the unique features of the new resources that differentiate them from the familiar genre of summaries; "The summary is only the beginning of your work..then you have to think how to transmit the subject: comics, movie, newspaper, game, information sheet, so it will be interesting".

They also were aware to the serious responsibility they are undertaking - "You approach it seriously because somebody has to learn from it" - and invested efforts in ensuring that the resources will be appealing and attractive to the learners;

"Here (in learning resources) you choose what to say, what to do, what to film, but in a summary you don't have the freedom, you just have the staff and you have to summarize, here you <u>make</u> the staff".

In the last quotation the student actually declares authorship on his production. It is possible that what the student wanted to convey is the differentiation between knowing *what* and knowing *how*. In a summary it is knowing *what* because you attend only to the content, however in constructing resource materials it is knowing *how* as there are multiple ways of knowing and multiple modes of re-presenting.

**2. To what extent were students creative in adopting new modes for re-presentation?**
Though the dominant mode of communication in school is the verbal mode most of students' resource materials were in other modes. The array of resources included: puzzles, questionnaires, posters, memory games, comics, video, multimedia presentation, models, table games, experiments and written essays. Students' digression from the common verbal mode for re-presentation was considered as an act of creativity. The more distant students' resources were from the common school curriculum materials they were considered more creative. With this in mind the resource materials were categorized into three categories: 1. Conservative resources that were mainly verbal, e.g. essay; 2. Semi-conservative resources that though being based on the verbal mode they were structured into a non-conservative re-presentation, e.g. puzzle or memory game; 3. Non-conservative resources that mainly used new modes of presentation, e.g. video movie, or model. It is interesting to note that students took advantage of the freedom that was granted to them to express their preferences for modes of re-presentation. The majority of the resources that were constructed after the first semester as well as those constructed after the second semester were of the third category, i.e. non-conservative resources. Their frequency was significantly higher than those in the conservative mode. In the first semester it was 56.4% vs. 20.6%, (Chi Square test for one sample: $X^{2=}$ 30.14 d.f. = 2 $p<0.0001$ ) and in the second semester 68.5% vs. 12.1% respectively (Chi Square test for one sample: $X^{2=}$ 30.14 d.f. = 2 $p<0.0001$ ). The frequencies of resources in the non-conservative mode, i.e. the most creative ones, were after the second semester significantly higher than after the first semester (68.5% vs 56.4%; Z=1912 $p < 0.05$). This result indicates that prolonged exposure to different modes, whether via learning or construction, encourages the production of resources in new modes. It seems that prolonged exposure to new modes also encouraged students to play with different modes and possibly express their preferred intelligences. This is supported by the fact that 75% of the students constructed at the second semester resources in a different mode than that after the first semester. Students seemed to enjoy playing with different modes though switching from one mode to another demanded familiarization with new tools and capabilities. It is as if the responsibility that was bestowed on them encouraged them to be serious, creative and productive.

**3. The relationship between students' constructed resources and their intelligences.**
It was assumed that the culture of creativity and freedom that dominated these environments will encourage the students for self fulfillment of their dominant intelligences. Thus it was interesting to see whether there is a correlation between students' intelligences and the nature of the constructed resource materials. The answer to this question was given in two parts. The first part looked for a possible correlation between students' dominant intelligence and the nature of the mode (in terms of conservative or non-conservative) that was employed for constructing the resources. No connection was found between students' dominant intelligence and the nature of the resource materials they chose to construct. [In a Kruskal-Wallis One-Way Analysis of Variance by Ranks for K independent samples (k=7 groups of students according to their dominant intelligence [(no connection was found between students' dominant intelligence and the nature of the mode of the resource materials they chose to construct. However, regardless the nature of students' dominant intelligence, in each of the semesters, they preferred to construct non-conservative materials. The second part addressed a possible connection between students' intelligence and the specific kind of the non-conservative resource materials they constructed. By using Contingency Coefficient nonparametric test, no significant correlation was found for the first semester but a significant correlation between the dominant intelligence and the specific kind of the non-conservative resources was found in the second semester (C=0.616 n=74 $P<0.05$). This finding indicates that there is a correlation between a certain dominant intelligence and the mode of the resources that were constructed. Further analysis of

this finding indicated that among the non-conservative resources, multimedia presentation was the most frequent one that was constructed by students regardless their dominant intelligence. The second most frequent mode of re-presentation was table game, then model, and video films. Comics were constructed only by students with intra-personal and inter-personal dominant intelligence and experiments were constructed only by students with an inter-personal intelligence. The significant correlation at the second semester as opposed to the non-significant result after the first semester can be attributed to the longer exposure of students to the culture of choice and variance in modes for the construction of resource materials. It is also possible that prolonged experiencing with resources in different modes sharpened students' acquaintance with their personal preferences.

## Discussion

The described project intended to provide students with an opportunity to practice multiple modes of representational and communicational channels that are part of the electronic age. At present our dominant theories of meaning are shaped by and derive from theories founded on the assumption of the dominance of language (Kress, 2000). Even more, all other possible modes of expression have been suppressed. However the advanced communication channels impose on us to get familiar with multi-modal presentations and knowledgeable in multiliteracies, for interpretation and making sense of the communicated messages. Thus multiliteracies and the transduction of meaning from one mode to another should be practiced in school.

Students' immersion into activities that demand the intertwining the scientific formal concepts into their 'lifeworlds', in the process of constructing new re-presentational resources of knowledge, was actually a continuous process whereby students constructed their own meaning of the learning environments they were exposed to. This process of constructing meaning relates not only to the scientific concepts they were exposed to but also to the unique environment of learning. The unique learning environment transmitted the notion of learning as a personalized-social process, that involves personal preferences and attitudes not only along the process but also as imprints on the constructed knowledge. It was through the process of experiencing that they have constructed their ways of knowing and understanding.

## References

COOLICAN, H. (1990), *Research Methods and Statistics in Psychology* London: Hodder Stoughton.

GARDNER, H. (1993). *Multiple Intelligence: The Theory in Practice.* New York: Basic Books.

GEE, J. P. (2000). New people in new worlds: networks, the new capitalism and schools. In: Bill Cope & Mary Kalantzis (eds), *Multiliteracies:literacy learning and the design of social futures*, London: Routledge.

GORODETSKY, M., Keiny, S., Barak, J. & Weiss, T. (2001). Contextual Pedagogy: Teachers' journey beyond interdisciplinarity, *Teachers and Teaching*, in print.

KLAVIR, R. & Gorodetsky, M. (2001). The processing of analogous problems in the verbal and visual-humorous (cartoons) modalities by gifted/average children, *Gifted Child Quarterly*, 45(3), 205-215.

KRESS, G. (2000). Design and transformation, new theories of meaning. In: Cope, B. & Kalantzis, M. (eds.), *Multiliteracies: literacy learning and the design of social futures*, London: Routledge, pp. 153-168.

LIKERT, R.A. (1932), A Technique for the the Measurement of Attitudes, *Archives of Psychology*, 140, 55.

THE NEW LONDON GROUP (2000). A pedagogy of multiliteracies, in: Cope, B. & Kalantzis, M. (eds.), *Multiliteracies:literacy learning and the design of social futures*, London: Routledge, pp. 9-37.

**Keywords:** multi modes, multiliteracies, re-presentation, recontextualization, learning science, resource materials.

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# GENE-GHOSTS: EXPLORING THE BORDERLAND OF KNOWING, BIOTECHNOLOGY AND HENRIK IBSEN'S DRAMATIC WORLD.

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## Abstract

The liberal arts and science has traditionally been seen as two very different arenas, where scientists and artists perform dissimilar work. We often say they belong to unlike cultures. Art and science education seem to have adopted this mainstream comprehension. It is asserted here that there are perhaps more likenesses between the two than traditionally assumed. Imagination plays a critical role in the process of learning. Learning an art form like drama or learning science both requires imagination and creativity. Can these two arenas mutually help and inspire each other? The purpose of this paper is to shed light on my doctoral dissertation by giving a picture of a project built on a collaboration between a drama educator, his drama students in upper secondary school, and a science education researcher. A dramatic presentation, *Gene-Ghosts*, was produced by using results from my research on public understanding of biotechnology and science education, Henrik Ibsen's dramatic works, and the students' own understandings of science.

Research results show that respondents to a survey demonstrate a complicated relationship to modern biotechnology. Philosophical and ethical issues are frequently mentioned as the reasons for such perceptions. It is suggested that science educators take this picture into consideration. This survey data serve as a basis for the *Gene-Ghosts* project. Further in my doctoral study, an analysis of a role-play about genetic testing indicates that in a contextualized and personalized situation scientific issues are discussed in ways where the learners' imagination is encouraged and different views and arguments are revealed. The analysis also indicates that the ethical discussion depends on the scientific knowledge available to the learners at the time of the deliberations.

With *Gene-Ghosts* as an example, I seek to inform and transform ideas of science education by exploring knowledge of public understanding of science, together with knowledge of the value of drama in the teaching-learning process. The vision I propose is a critical science education that is inclusive of all students. The prediction is that a combination of an active experience and personal, critical reflection will empower learners in science education. It is suggested that with professional guidance, learners may reflect on a drama experience and relate personally to the scientific issue involved.

> STORYTELLER: *Never again will you rejoice like Eve in the Garden of Eden, because you are now tamed by learning. You opened your eye and became equal to God. Your life will be formed by knowledge of pain and evil.*
>
> DR. STOCKMAN: *What should you cherish and choose; I .. or we? Your own conscience, and above all the truth, or society's future and progress? Do I have to live behind the lie the rest of my life? The lie is the serpent in Paradise. You do not see it, but you know it is there in the wet grass. The truth will come forth a beautiful day..or..maybe there will not be a beautiful day? On the day the truth comes forth perhaps the birds will be dead, children will cry because they are cold. Parents will sit and look down in their hands and think about the eternal dilemma of truth.*
>
> BRANN: *Every minute our own mask of carelessness is stupefying us. The truth leads us again towards eating new fruit from the tree of wisdom, which also was the start of sinning. Osvald, the truth is starring in your eyes; Let us see ..Come, and let yourself be genetically tested.*
>
> ...
>
> BRANN: *Osvald, you carry the rare gene of a heritable and lethal disease. Where did you get it? Who is your father? How can this be punished? You must not spread your seeds. Lock him up!*

STUDENT 7: *The twelfth day. The human positions himself above God, and honors himself by creating his own life. What is hidden by the shadows of science, is disclosed. Genes are discovered. Genes are mapped. Genes are changed. Qualities are trashed and disappear. The original humans are replaced by copies. The birds disappear from heaven, the air is no longer shaken by rushing wings. Everything can be bought. Everything can be consumed.*

SERPENT: *And in the human hearts I smile. Because what the humans never understand is that as they eventually stepped into the absolute light, I stand in the shadows of death on the side, and cut over the threads of life. One after one after one. I, the serpent, the knowledge. Always a step ahead, at the same time as I unexpectedly breathe in their necks. I, the tempter, the lover. The one that gives the humans the bittersweet off taste of eternal life.*

*Selected excerpts from* ***Gene-Ghosts****, by students, 17 years old.*

## Introduction

What kind of science education will help people make necessary social and societal judgments for the 21st century? This is an essential question for science, and the answer might partly be seeked in people's present relationship to science, and partly in the science curriculum and its emphasis on life-long learning. There may lay a tension here between society's desire of economic growth and development, and individuals' wish of making the world a better place to live. There may also be a conflict between preserving tradition and denouncing the hegemonic culture, whether it is a Western 'scientific' culture or another indigenous culture.

A conflict between his own wish and knowledge of a better world and society's prospects seems to be Dr. Stockman's dilemma, which is sighted above. The excerpt is drawn from the manuscript of the play *Gene-Ghosts*, developed by drama students during a cross-curriculum project that combined research on public understanding of biotechnology, drama, science education and the dramatic works of Henrik Ibsen. The performance was created by 10 students, 17 years of age, specializing in music, dance and drama at an upper secondary school in Norway, in collaboration with their drama teacher and me, a science education researcher. In the play we hear the voice of Ibsen, the students' own voices, and the voices of the Norwegian public. The above excerpts provide us with a sample of some of these voices. In this paper I wish to offer some insight into my doctoral studies by telling the story of the *Gene-Ghosts* project.

Using results from my doctoral work as a framework, the students elaborated on the theme of biotechnology. The aim was to give my PhD research a dramatic interpretation and mediation, and concurrently make a contribution to the annual Ibsen drama competion. In this way the students combined two, for them, unfamiliar subject areas: biotechnology and Ibsen's dramatic world. During the project they deconstructed their knowledge on the subjects and then reconstructed them in a meaningful way. The classic role figures of Ibsen were introduced to our current biotechnological era and placed in the context of modern dilemmas identified by the students and created by this new technology.

## Science and art

Having teaching experience from two quite different educational areas; science and drama, I have come to an understanding that the two subjects are not necessarily as different as first assumed. In a learning process I am convinced they can mutually help and inspire each other.

The practice of science is inspired by imagination and creativity. Bronowski (1956/1990) defines science as "the organization of our knowledge in such a way that it commands more of the hidden potential in nature...it admits no sharp boundary between knowledge and use" (p. 7). He asks, "What is the insight with which the scientist tries to see into nature?" and "Can it indeed be called either imagination or creativity?" (p. 10). Further, Bronowski claims that there is a likeness between the creative acts of the mind in art and in science. Both a painter and a scientist will be instantly wakened by pleasure by "a sense of exploring his own activity. This sense lies at the heart of creation" (p. 8).

Science is inspired by imagination and creativity. Similarly, imagination and creativity play a critical role in the process of learning. Further, when learners come together, they have the potential to reveal themselves as subjects, as unique individuals. The educational value of imagination, creativity, and student disclosure is seldom tapped in a curriculum oriented toward cultural reproduction and transmission of knowledge. Education should focus upon enabling learners to make sense of their lived lives, to make connections, and to construct meanings. Further, as educators we must find ways to integrate notions of community, collaborative action, and critical reflection. (Ødegaárd and Kyle, 2000)

It is the nature of drama to create different worlds with different cultures. The participants also create fictitious persons and through them may explore unfamiliar cultures and obtain experiences, which originally belong to these dramatic worlds. Thus, if we look upon science as a subculture in our society (Aikenhead, 1996), students may explore for instance, a scientific research community, or another setting involving a scientific issue. By reflecting on these experiences, and relating to them to in real life and in their own subculture, the students may broaden their perspectives, gain empathy, and empowerment. (Shor, 1992; Ødegaard, 2001) In this interaction between experiences in role and experiences from real life, new knowledge and insight may emerge. The interaction between nearness and distance, between empathy and reflection is the basis for drama's epistemology. The goal is that students transform knowledge to knowing, based on cognitive, affective and active aspects of learning.

## Doctoral research results

### In the shadow of Frankenstein

The idea of the project and play *Gene-Ghosts* emerged from my doctoral study (Ødegaard 2001) about public understanding of biotechnology, which was part of a larger science education project called *Science, Technology and Citizenship.* (See also Sjøberg, 1998) One paper included in my study, *In the shadow of Frankenstein*, is based on data from the Norwegian segment of a European survey about biotechnology, Eurobarometer 46.1, (see Durant, Bauer & Gaskell, 1998). The Norwegian survey had approx. 1000 respondents drawn from the adult population. This is an empirical study of the public and their relationship to modern biotechnology. In order to presuppose as little as possible and let the respondents themselves choose the angle of incidence into the complex area of modern biotechnology, I chose to analyze an open-ended question in the survey. The respondents were asked: "What comes into mind when you think about modern biotechnology in a broad sense, that is including genetic engineering?"(official English version). The responses were written down and later analyzed. I wished to illuminate the public's immediate response to the issue, and perhaps capture a part of their 'gut feeling' about it. This open-ended question revealed an ocean of associations to be statistically grouped and scrutinized. Here are some examples of responses:

- Tampering with nature can be good now, but it will strike back on us in a couple of years.
- Cloning, gene manipulation, test tubes, gene modified tomatoes.
- Animals that are so big that their legs break under them or their udders burst because of milk.
- Our knowledge will be much greater. We learn to take care of our environment. The prospects for the future will be better with this new knowledge.
- Something about patterns of inheritance.
- The danger of uncontrolled spreading of artificial life.
- Vaccines against illnesses. Research makes life better.
- A way humanity faster can reach a better exploitation of nature. Politicians must distribute the benefits. Possibly better the world's poverty.
- *They mess up with what is created by Mother Nature ['naturens hånd']. It is like when they made the atomic bomb. That was also a mistake. People should keep their fingers away from this.*
- *I don't know.*
- *Looks very scary.*

The associative replies were analyzed in line with variables of the public's evaluation of biotechnology and the area of content to which they refer. Each reply was categorized as either positive, negative, neutral, ambivalent or I don't know (see Figure 1). The content variables indicate whether the response refers to for instance, animals, food, medicine or nature, or if fear, progress and moral statements are expressed. (See Ødegaard, 2001.)

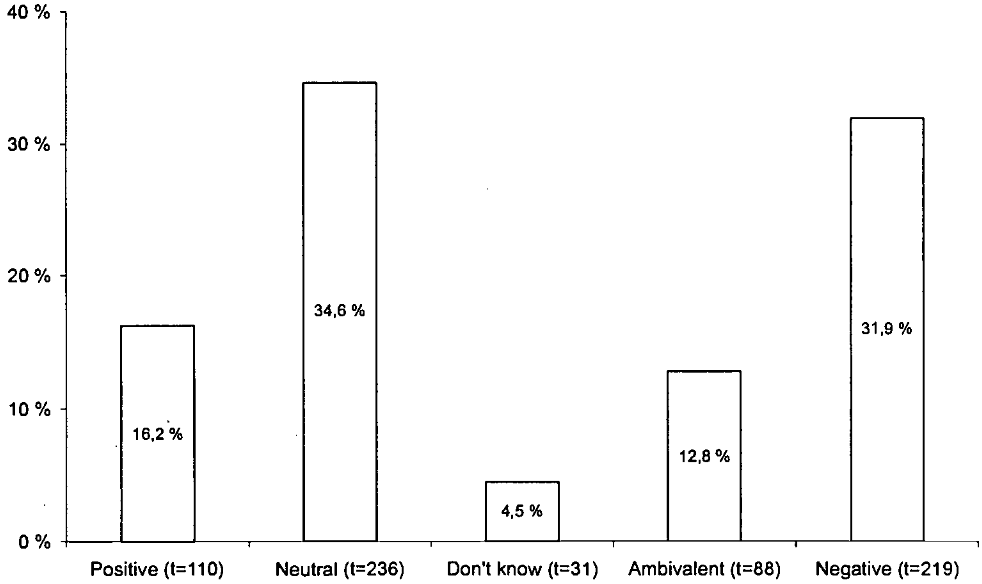


**Figure 1.** Distribution of Norwegian responses according to the evaluation tone in the answers to the open-ended question about biotechnology in the Eurobarometer survey.

The responses were compared to other variables in the same survey, like knowledge and faith in biotechnology, educational background and sex. The results indicate that there are no clear relationships between the way people refer to biotechnology and their educational background or base of knowledge. However, not unexpectedly, increased level of education increases the share of neutral responses. The respondents tend to want to explain what they believe biotechnology to be. More unexpected is the result that the number of positive statements decrease with increasing levels of education (see Ødegaard, 2001).

The data have also been described qualitatively, where the modes of negativity, enthusiasm and so on are portrayed. (See Table 1.) Positive responses express a faith in that this technology might solve many of our problems. The faith may be conveyed in a naive, or a more knowledge-based manner. Negative responses also vary from simple demonstrations of fear of tampering with nature to more well-founded arguments about the risks of biotechnology. Some of the neutral answers leave a 'schooled' impression of wanting to give the right answer, while others tell about different applications. Some responses give synonyms to modern biotechnology, like 'gene manipulation' and 'cloning'. The ambivalent answers indicate an understanding of ethical conflicts involved in this scientific area. The ethical discourses in the material focuse on man's right to tamper with nature, what genetic screening may do to human dignity, and what research does to animal dignity. There are also risk discourses about man loosing control to nature, and man trying to take control instead of God or Mother Nature. Otherwise, the risks are mainly positively estimated, like preserving the quality of food, and fighting diseases with new medicine.

**Table 1.** The Ibsen characters in *Gene-Ghosts*, and the basis on which they were chosen. The relationships to biotechnology are extracted from quantitative and qualitative research on public understanding of biotechnology (Ødegaard, 2001)

| Evaluation tone | Relationship to biotechnology | Ibsen character - chosen by the students |
|---|---|---|
| positive | naive faith in technology, this new technology can solve many of our problems, has confidence in scientists, little education | NORA<br>from *A dolls house* |
| positive | has knowledge about the new technology and sees the positive sides, has faith in the future, the world will be a better place to live in, biotechnology is a good remedy for conquering hunger and diseases, educated | DR. RELLING<br>from *The Wild Duck* |
| neutral | tells about products we can get from biotechnology, and what it may lead to, can have both a negative and a positive attitude, but chooses to tell facts instead of stating own opinion, educated | DR. STOCKMAN<br>from *Enemy of the People* |
| neutral | explains what she thinks biotechnology is, gives 'school-like', boring answers (maybe the ones she thinks are expected?), may or may not have education | HEDVIG<br>from *The Wild Duck* |
| neutral | gives synonyms, alternative words, tries to say biotechnology in a different way, or mentions the organisms used in biotechnology research, little education | REGINE<br>from *Ghosts* |
| negative | dangerous to tamper with nature, nature has a value in itself, nature-mysticism, little education | WOMAN IN GREEN (DEN GRØNNKLEDTE)<br>from *Peer Gynt* |
| negative | afraid of the consequences, has moral objections, what kind of a society will we get? Afraid of knowing too much, we know enough, but not enough of the consequences, nature might hit back on us, like Frankenstein, educated | HEDDA<br>from *Hedda Gabler* |
| negative | like 'playing god', manipulating humans, selecting the people you want, does not trust scientists, educated | BRAND<br>from *Brand* |
| ambivalent | sees both the negative and the positive sides, often at the same time, sees the help it may provide, and imagines possible unfortunate impacts, has moral reservations, has knowledge and education. | OSVALD<br>from *Ghosts* |
| 'I don't know' | has not / will not / can not answer, more negative than positive, indifferent, some education | PEER GYNT<br>from *Peer Gynt* |

The study demonstrates what a complex area biotechnology is in the public sphere, and indicates that the way people think about it, learn about it and make decisions about it, are multifaceted processes that involve their worldview, knowledge, emotions, ethics and moral reflections. This coincides with the studies of Layton et al. (1993), which also are part of my theoretical framework of public understanding of science. It is not only because the area of biotechnology is scientifically and ethically complex, but because the public consists of individuals. It is suggested that science education should take this complicated picture into consideration. By contextualizing biotechnology it is presented in a meaningful way to the students and the cultural and societal bound nature of scientific knowledge is more easily acknowledged. An ethical and moral perspective could be offered to permeate the whole learning and teaching process. Alternative learning methods to contextualize, but also to involve emotional and philosophical elements, are recommended.

Now in what way can these research results relate to drama students in upper secondary school? Well, drama is a manner of contextualizing and involving emotional elements, but how is it possible to do that with a quantitative study of public understanding of science? Statistics are reductionist by nature, and during the action of statistical analysis a lot of information is lost, although nuances and trends are sought captured in a qualitative analysis. Being a drama teacher reading and analyzing this material, immediately made me realize the dramatic potential that is hidden here. The responses that constitute the statistical material could very well be lines in a play! The very first germ of an idea about *Gene-Ghosts* was born.

**Role-play in science education**

Another paper in my doctoral dissertation focuses on the educational value of imagination, collaborative action and critical reflection and how science education can serve the emancipatory interests of learners. The dialogue in a role-play about genetic testing is deconstructed from the perspective of critical theory and educational research. The role-play was conducted in a Norwegian upper secondary school with 18-19 year old students. The material on which this study is based is eight audio-taped role-play dialogues with four roles, conducted in four classes in one upper secondary school outside Oslo, Norway. The students were all in their last year of school and the role-play was not done in a science lesson context. The idea was to explore the students' understanding and handling of a scientific issue they might meet in their future life. How well are they equipped for meeting life's challenges? And in what way does this role-play empower them for the future?

The role-play conflict was an ethical dilemma about whether a young couple that is expecting a baby should take a genetic test of it or not. They are asked by their doctor to participate in a European genetic screening, where they can chose which traits to test. The couple discusses the prospect of participating with her family, and they have to make a quick decision. What nobody knows, except the coming mother's mother, is that one of the testable diseases runs in the family. The dialogues following from this setting are quite engaged and thrilling to follow.

By initiating the role-play the teacher introduces a sosio-scientific topic for setting the scene and providing the students with a shared life experience. The students get information and instruction about their role figures on role cards. (See Text box 1.) The role card provides both personal and scientific information on the situation, but it does not present ready-made opinions. Rather, it offers a personal conflict as a starting-point, which the person in role has to deal with using personal (out of role) experiences together with interaction experiences during the role-play. Roles with different life experiences and life situations offer different perspectives to the same scientific issue. Thus the role-play develops the students feeling of empathy. The actual role-play is improvised, revealing information or antagonisms as desired throughout the progress of the play.

**Text box 1.** An example of a role-card used in the role-play. Notice how it is possible to hide information in role-card and make it up to the student to reveal it. The opening line is given to focus the discussion.

**Role-card:**
Your name is Barbro, 43 years old, divorced and working in a bank. You are looking forward to having a grandchild. Today you are excited about how Gro's visit to the doctor went, so you are looking forward to meeting her and Vegard for dinner. The future seems bright and nice. The only shadow is the knowledge of your own mother's death. She died in her 50's of a heritable disease, Huntington's chorea. You do not know if you have inherited it, because it doesn't break out before you are 45-50 years old. Your doctor suggested a long time ago that you could take a gene-test and find out, but you did not want to, and after that you have almost completely suppressed it. No one else in the family knows how she died. They think she had a brain tumour. Lately, since there has been so much talk about the new baby coming, you have thought a lot about life, getting older, being a grandmother and your own mother. You are frightened when you think of the disease, but even though it is hard to think and talk about, you have decided that you should inform your children about this part of the family history.

Opening line: *How was your visit to the doctor's today?*

The play tends to be a highly cognitive activity where the participants work with ideas and attitudes and test out playfully and with feelings of ease hypotheses about significant science and technology based social issues.

Students are asked to believe in the assigned roles, to think for themselves, and to act on their own initiative based on their own life experiences.

In order to consider how good a basis the role-play is for an empowering education on science-related societal issues, the dialogue was analyzed. The analysis revealed that the students did show ethical competence during the role-play. (See also Figure 2.) The issues that were brought up and discussed in the dialogues were:

- the *duty* to know or not to know (whether it was the parents' duty to know everything about the child so they possibly might prevent future diseases, or if they have a duty not to know so they do not spoil the child's life by being too protective),
- the *right* to know or not to know (whether the children's right to know or not to know about diseases in the family is in conflict with the parents' rights),
- the duty to *inform* or the duty to not inform (whether it is the parents' duty or not to inform the child about possible diseases),
- and medical and moral *risks* influencing the situation (the risks for getting the disease, the moral risk of getting an abortion because of obtained information, and the moral risk of consequences for society when genetic information is outspread).

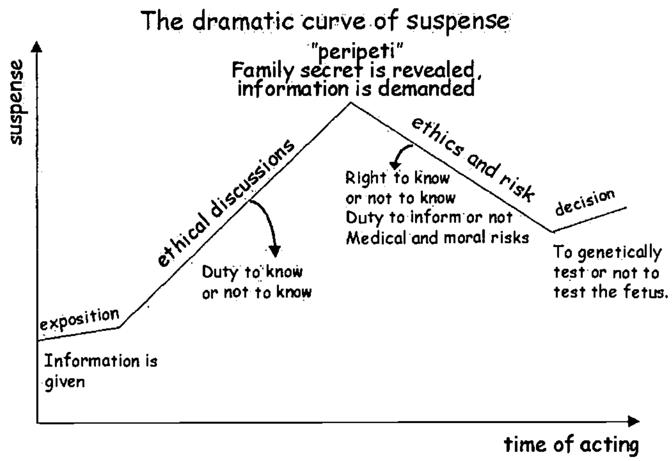


**Figure 2**. A schematic overview of the role-play discussions inspired by a literary curve of suspense and an ethical action guide for doctors and patients.

Figure 2 shows us also one of the other results from the analysis: how the general engagement in the role-play raises when the participants get a personal interest in the results of the gene test. The secret of Huntington's disease being in the family is revealed, and the risk of getting the disease is thus considerably higher than known before. We do not know how the role-play would have proceeded if everybody knew this from the start. But it is a generally known method for engaging the audience (in this case the role-play participants are both actors and each other's audience; see Ødegaard, 2001) to introduce them to the play's environment first, make them comfortable, and later change the focus for emotionally touching them. Our role-play happens during a family dinner, and can resemble a 'real' situation. In his modern contemporary plays, Henrik Ibsen often had a relatively short time of action, perhaps just a couple of days. This can be a means for creating a reality illusion. In Ibsen's dramas he often integrates an analytic exposition of the past. It can be a letter, an old bill of loan, or an old acquaintance that brings up something from the past and contributes to the past being reintroduced. This is the basis for concentration and intensity that distinguishes his realistic plays. There is a big retrospective element in our role-play. The gene test in itself acts as a retrospective remedy that makes the past suddenly become very present for Barbro in our play. It even becomes the future embodied in the little baby to come!

Besides a raised engagement in the role-play, the life lie revelation has another interesting impact with respect to the science education goals. After the participants have had this emotional stir, there seems to be an increased motivation to gain more scientific information. They want to know more about the disease, the course, cures, medicine and so forth. The question of how Huntington's is inherited and the percent risk associated with the disease becomes important, as well as an increased need to understand the scientific expressions in the written information they are provided.

Science education has a history of rationality and emotional neutrality. Science education has emulated the perceived objectivity of science and adorned itself with being unaffected by feelings. Paradoxically, the role-plays reveal that greater student emotional engagement enhances their motivation to acquire scientific knowledge. Studies have shown non-scientists ability to conceptualize science in a short amount of time if the personal motivation is high. Wynne (1991) states, "when people do see a personal or practical use for scientific understanding and are sufficiently motivated, they often show a remarkable capability to learn and to find relevant sources of scientific knowledge" (p. 117).

The deconstruction showed that the students were urged to think critically in the situation, the ethical elements were reflected upon and creatively explored. Most of the groups involved in the study did also manage to make a well-founded decision. The scientific issues that traditionally would be emphasized in this case, like the risk of getting the disease, and how the disease is inherited, were very poorly treated. Did it seem irrelevant to the participants or was it lack of knowledge? The study does not give an answer, but this deficiency seems to be a good starting point for a genetics lesson. It is recommended that role-play is used as a motivating, engaging and empowering way to introduce and work with scientific issues in science education. Because the students reflected critically about how to act, the role-play is a good preparation for citizenry in a democratic society. They might possess a feeling that they are able to transform the world according to their dreams and hopes, find their own voice, and in that way serve their emancipatory interests.

It goes without saying that this paper on role-play has dramatic potential as well. The analysis of the dialogue revealed interesting and stirring ethical conflicts, and as already asserted the genetic test could be used as an Ibsenian retrospective remedy, bringing together the past and future. (If Ibsen had lived today, I am sure he would have used the genetic test in one of his plays!) These research results seemed so rich that a research report did not seem to give justice to it as a mean of mediation. This was when the drama educator was introduced to the idea of a collaborative project, and with *Gene-Ghosts* the research material was to be given an artistic modification and presentation.

## The *Gene-Ghosts* project

My PhD work has two main topics. One is gaining knowledge about public understanding of biotechnology in order to possibly rethink the content of science, the other is exploring how drama can be used in science education to contextualize the science content, engage the students personally and facilitate science to be a meaningful and empowering subject. Both of these themes merge in the *Gene-Ghost* project. The research results from my two papers, on how the public understands science, were used as raw text material for the play. But *Gene-Ghosts* became much more than a 'dramatic' research report. It was to be an explorative journey through modern science, national literature treasures and experimental physical theatre, undertaken by students, teacher and researcher. It became an example of how drama can make science interesting and meaningful to students that are ignorant and have never felt that science was a subject that concerned them.

The drama students were reluctant to the idea of working with biotechnology at first. But after experiencing different role-plays with scientific and ethical themes of biotechnology and following discussions, they got interested. The students also soon realized that they needed a science introductory and update coarse on the areas of genetics and biotechnology. The students themselves gave a group of fellow students specializing in biology, an assignment of providing them information. They were now ready to put together the biotechnology performance.

The public's different attitudes and preferences toward the modern science of biotechnology, quantitatively and qualitatively characterized in my work (see Ødegaard, 2001), was used as a frame for the play. The distribution of the number of roles mentioning biotechnology with respectively negative and positive modes of expression reflected the statistical material. For instance 30 % of the statements from the study were characterized as neutral when talking about biotechnology. Therefore it was decided that 3 out of 10 roles were to express a basically neutral attitude in the play. Through mutual readings and discussions we found 10 role characters that seemed to fit the statistic categories of how biotechnology was expressed, and they also seemed to suit each other in a dramatic setting. See Table 1 and Figure 1.

The ethical dilemmas of genetic testing from my role-play analysis were also used as a basis for developing a dramatic conflict between the chosen Ibsen figures. The group chose to focus on a possible relationship between Regine and Osvald (from *Ghosts* ) and genetic testing of their unborn child. Another conflict the group repeatedly discussed, was the philosophical issue of knowing and not knowing. The students claimed that science is about wanting to know everything, and biotechnology is wanting to know the essence of life itself. Some claimed that science in this way may destroys life's and nature's beauty. The ultimate story about this is Genesis and the Forbidden Fruit from the Bible, so the students decided they also wanted to include the story in the play. The students' own understandings, opinions, attitudes and not least imagination and creativity, were important resources during the project.

## Concluding remarks

Bronowski (1956/1990) reminds us of the likenesses in the creative mind of the artist and the scientist. Bronowski asserts that he "set out to show that there exists a single creative activity, which is displayed alike in the arts and in the sciences" and he "found the act of creation to lie in the discovery of a hidden likeness" (Bronowski, 1956/1990, p. 27).

*Gene-Ghosts* added something new to the drama students' lives. The feeling of empowerment by mastering and mediating the alien knowledge of biotechnology was distinctive. At the same time the students were on a very familiar arena; the theatre stage. What did they do? They searched for 'hidden likenesses'. They had to find bridges between the dramatic world of Ibsen and one of our newest and most modern technologies. Would Brand think that biotechnology was sent by God to give us a truth-seeking tool, or would he think that it is merely a result of humans trying to 'play God'? Do genetic tests find ghosts from our past that come to haunt us? These are true challenges for the students' and our imaginations. We were all exploring new territory and seeing things in new ways. This provided us with magical moments and new insights. New insights not only about biotechnology and Ibsen, but also about teaching and learning.

The dramas of Ibsen are classics because they deal with eternal questions that still concern us. By actively creating links between Ibsen's role figures and biotechnology, the students also saw how modern science may concern every one of us in our modern lives. Suddenly science became meaningful to them.

In my work I hope to have diclosed some of the potential that lies in the use of drama in learning science. Drama involves using both cognitive and affective aspects of learning. It provides a basis for linking students' lived experiences to science. The Brazilian theatre personality Boal (1998) describes his Forum Theatre as a reflection on reality and a rehearsal for future action. "In the present, we re-live the past to create the future" (p. 9). Shouldn't this also be applicable to science education?

## References

Aikenhead, G. (1996). Border crossings into the subculture of science. *Studies in Science Education*, 27, 1-52.

Boal, A. (1998). *Legislative theatre.* London: Routledge.

Bronowski, J. (1956/1975). *Science and human values* (Revised edition). New York: Harper & Row.

Durant, J., Bauer, M.W., & Gaskell, G. (1998). *Biotechnology in the public sphere.* London: Science Museum.

Layton, D., Jenkins, E., Macgill, S., & Davey, A. (1993). *Inarticulate science: Perspectives on the public understanding of science and some implications for science education.* Naffertch, UK: Studies in Education.

Shor, I. (1992). *Empowering education: Critical teaching for social change.* Chicago: University of Chicago Press.

Sjøberg, S. (1998). *Naturfag som allmenndannelse.* Oslo: ad Notam Gyldendal.

Wynne, B. (1991). Knowledges in context. *Science, Technology & Human Values*, 16, 111-121.

Ødegaard, M. (2001). *The Drama of Science Education. How public understanding of biotechnology and drama as a learning activity may enhance a critical and inclusive science education.* Dr.scient. dissertation, University of Oslo, Norway.

Ødegaard, M. & Kyle, W.C. Jr. (2000). Imagination and Critical Reflection: Cultivating a Vision of Scientific Literacy. Paper presented at 73rd annual meeting of NARST, 30.April, 2000, New Orleans, USA.

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# THE ROLE, VALUE, AND THE ACTUAL CIRCUMSTANCES OF SCIENCE MUSEUMS IN JAPAN

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**Abstract**

With rapid progress in science and technology, all citizens need science literacy, including scientific thinking, problem solving ability, and decision making to live a safe, productive, and happy life. But we do not have adequate opportunities to acquire such science literacy. While we can acquire some aspects of science literacy through formal schooling, many of our citizens would benefit by additional learning opportunities. One powerful possibility is to have more informal learning opportunities, such as museums, where we can acquire scientific knowledge, follow the process and achievements of scientists, and develop our scientific and logical thinking. Through these means, we can understand how society and social activities interact with science and technology. This study examined how citizens view the status and value of science museums in Japan. From this survey, we found that although science museums do have their own methods to produce effective exhibits and programs, they are not research-based. And they have difficulty producing programs that develop long-term interest and curiosity.

## Introduction

We live in a tumultuous society. In order to live a rich, safe and happy life we must make good decisions in widely varying situations. Many of these decisions involve critical thinking and other aspects of what has been termed scientific literacy. Daily, we are faced with a multitude of social issues, most of which have some scientific basis. For instance, we routinely must think in terms of ethics, economics, and socially plausible accounts. Many of these accounts require knowledge of science and technology. Yet, many do not have knowledge or skills that are up to this task.

Recent and rapid development of networks and globalization has lead to highly specialized and deepened disciplines, forming a brand-new world, especially problematic for those who lack science literacy. Along with that, we have seen an increase in situations that are impossible to solve simply by an algorithm or simple set of knowledge. This leads to our need for abilities to solve problems by using broad knowledge, scientific thinking, creativity, and collaboration. We need to be educated to participate intelligently and actively in discussions and debates about complicated and important science/technology issues affecting our society. In order to do so, we have to make a correct decision as citizens, selecting needed information, partners, and ways of analysis. In this way science literacy has become inevitable and essential. We must ensure that our citizens obtain this necessary science literacy.

However, children lack opportunity to learn to think scientifically and critically and to be creative. And, unfortunately, this opportunity and their ability seem to decline as the progress through school. Schools and, thus students tend to be too knowledge-centered to discover the significance of true learning. By this we mean understanding and using information and ideas, generating new ideas, and solutions, and communicating effectively with others. This leads, often, to students in Japan who are socially identified as "children who do not like science" or "children who are reluctant to learn science." Yet, most of us share a common goal that states it is essential and valuable to share with not only children but all people the self-expression and excitement that comes from deep understanding of nature.

What can we do? Science museums have a potential to nurture children's science literacy. The flexibility, spontaneity, and informal nature of museums make them potentially powerful sources for enhancing science literacy. This research being reported investigates sources of informal science education and reveals their roles.

In this presentation the role and value of science museums in Japan are considered, including how they should fit into society and relate to schools and schooling.

## What is informal science education and science museum?

In Japan, the difference between science museums and science centers is ambiguous and they do not have concrete definition of informal science education. This study focuses on informal science education facilities for developing children's science literacy, especially the aspect of scientific thinking in a social context. Thus "science museums", in this presentation include not outdoor activity facilities such as zoos, botanical gardens, aquariums, and nature parks, but science museums, science centers, and natural history museums that are hands-on and minds-on and emphasize on scientific thinking. As for informal science education, many researchers have offered definitions of informal science education in the US and the other countries. For example, Wellington (1990) suggests that there are two areas of learning that must be considered in examining science education; the public understanding of science and the advancement of science itself. More simply, he distinguishes formal learning, which takes place in school, from informal learning, which takes place in museums and other non-school settings. Ramey-Gassert *et al.* (1994) proposed some characteristics of formal and informal science learning, by modifying Wellington. Table 1 shows these characteristics.

**Table 1**: Features of Formal and Informal Science Learning. (Ramey-Gassart *et al.* 1994)

| Informal learning | Formal learning |
|---|---|
| Voluntary | Compulsory |
| Unsequenced | Structured |
| Unstructured | Sequenced |
| Nonassessed | Assessed |
| Unevaluated | Evaluated |
| Open-ended | Closed-ended |
| Learner-led | Teacher-led |
| Learner-centered | Teacher-centered |
| Out-of school context | Classroom context |
| Non-curriculum-based | Curriculum-based |
| Many unintended outcomes | Fewer unintended outcomes |
| Less directly measurable | Empirically measured outcomes |
| Social intercourse | Solitary work |
| Nondirectedor Learner directed | Teacher directed |

## What can informal science education contribute to students?

Informal science education enhances students' positive attitudes toward learning, nature, and science in general. Students naturally show much interest in unknown things and informal science education meets such needs and nurtures them further, while developing the curiosity in each student. Museums foster this by being different and by allowing more activity than is usually allowed in classrooms. The more active a subject is, the more successful the subject's learning is likely to be (Inhelder, *et al.*, 1974). At the same time, as learners come to find out about new and interesting phenomena they become more active (Thier, *et al.*, 1976). Birney (1988) states that acquiring new information satisfies human emotional needs and that learning is inherently enjoyable. Learners appear to associate new knowledge with an increase in their own social value. Meaningful learning occurred when the students were engaged in hands-on activities with interactive exhibits (Hofstein, *et al.*, 1997).

## Why is informal science education important?

Screvan (1986) defines informal learning as "non-linear, self-paced, voluntary, and exploratory." Thier *et al.* (1976) and Birney (1988) described science museums as a place where visitors come by choice, and where the learners have control over what they examine and learn. Korn (1995) states that explainers in museums provide a non-threatening and easy way for visitors to satisfy their curiosity. And informal learning is not evaluated or assessed according to standard methods such as a letter grade or number, and it occurs without preplanning (Birney, 1988). These aspects greatly contribute to visitors' learning and enjoyment at science museums.

Normally the curiosity or interest that individual visitors have is diverse according to their character and living environment; so is their learning style. In school science students seldom experience free inquiry of science topics because of the curriculum. In museums, they can consider or examine their own thinking by taking as much time as they want and by participating in workshops where a science specialist advises them effectively. As Wellington (1990) states,..."hands-on science centers, alongside newspapers, magazines, television, radio and museums, play an important part in the broader science education, whether or not they can contribute to a more scientifically literate public depends largely on one's definition of scientific "literacy."

Two special dimensions of learning in science museums can be mentioned. One is that they have strong links to social context. This includes two further categories. For the first, the visitors, especially children who do not have enough experience to discuss their own opinions with the other peers, can communicate. The educational strength of informal science education facilities is its ability to communicate science through the presentation of concrete, relevant examples (Rix *et al.*, 1999). Secondly, visitors learn something in a social context such as trend technology, local or global environment, and industry. Birney (1988) describes this as ".informal learning reflects a dynamic interaction between socialization processes and concrete experiences." Rix *et al.* (1999) mention that one of the key roles of interactive centers is to develop public awareness of science. But we need to know what sorts of awareness and understanding are possible in this context. Concerning this, La Follette (1983) proposes a brand-new perspective that science and technology museums are potent venues for presenting ethics and values issues in general, with connecting with government and industry. In order to achieve such museums, La Follette feels we must shape the exhibits and decide on where and what to focus; which policy issues or contemporary events to include.

Science museums offer learning with entertainment. Rix *et al.* (1999) point out that science can actually be entertaining and enjoyable, leading to a dispute over whether such centers should be used as resources for schools. Some (Birney, 1988) say entertainment is critical and essential for learning, because acquiring new information satisfies human emotional needs. And he notes, children do not appear to separate learning from enjoyment and find that seeing something new, different, or interesting is inherently enjoyable. As we get accustomed to learning at schools, we often alternate the primary interest and eagerness toward learning and success in class, because it tends to be competitive with the other peers, and they have to follow the curriculum and the lesson plans. Bierbaum (1988) states the educators are somewhat willing to include visitor enjoyment as a goal, both within the museum as a whole and in the area of extra-exhibit educational programming. If the dimension of entertainment is successfully included into informal learning at science museums, student learning would increase at a geometric rate.

The value and roles of science museums are not identical, and science museums have to be managed by using and maximizing those peculiar values. In this presentation, we focus on the value that directly emphasizes students' benefits to learning or their cognitive outcomes. They are shown by voluntary, open-ended, learner-led, learner-centered, and social intercourse (the categories used from Ramey-Gassert *et al.*, 1994, Table 1).

## The status of informal science education in the US and the other countries

In the National Science Education Standards (1996), statements about informal science education can be found in Chapter 3 (Teaching Standards), Chapter 4 (Professional Development Standards), Chapter 7 (Program Standards), and Chapter 8 (System Standards). They clearly mention the role and importance of science museums, nature centers and so on as extension tools for broad school science learning, showing a large picture of partnership with school science in the society. Hofstein *et al.* (1997) propose to link informal science education to the section "Science as Inquiry" in Chapter 6 of the National Science Education Standards. And there are much action research in the US, Britain, and the other countries that seeks the benefit and role of science museums or to challenge of partnership between them and school sciences. (For example, Falk (1993), Honeyman (1996), Orion *et al.* (1994), and Kubota *et al.* (1991)).

### Discussion 1: The status of informal science education in Japan

In Japan there is some research on informal science education, but it cannot be said to be either academic or systemic, and most such research merely reports on certain projects. For example, Kumano (1998a, 1998b) reports on the Youngsters' Science Festival (YSF) as informal education research. YSF, organized by the Japan Science Foundation, is a sort of science fair with many booths, stages, and workshops, and which is held in many cities in Japan every year. YSF promotes a movement to establish a hands-on environment so that children become more familiar with science and technology. At YSF, the main demonstrators are high school science clubs and university laboratories, industries, and volunteers from science museums. Research about informal science education, from Kumano and others, however, is not usually theory-based, nor are there any other examples of research that focuses on science museums in daily service, such as exhibitions, programs, partnerships, and curatorships.

Also, the Japanese government does not routinely see or use science museums as informal sources to support school science. In Japan there exist *Courses of Study* (Ministry of Education, Science, Sports, and Culture, 1999), which are revised every ten years based on the National Commission on Education Reform. These differ from the *National Science Education Standards* in the US in that *Courses of Study* in Japan have legal restriction and implications so that curriculum developers and school teachers have to observe it when building curriculum and planning lessons. The only statements about utilizing science museums in *Courses of Study* is as follows:

In planning the lessons, science teachers should positively include the activities at science museums or science centers.

In order to help students understand through concrete experience, science museums could be included. It seems obvious that we could help student learning by using the facilities of science/natural environment museums, science centers, botanical gardens, zoos, and aquariums in the local environment. These facilities are rich resources of local natural environments each area, and it would be useful for the students' learning to include these resources in lesson plans (Ministry of Education, Science, Sports, and Culture, 1999).

Though there are some other statements about informal science education in *Courses of Study*, all of them focus on outdoor activities or field trips. These facts show that research on informal science education is still on its way to being developed in Japan, and we need more academic and systemic research. Several concrete problems need to be solved, as Suzuki (2000) points out from her investigation that both primary school and junior high school students in Japan regard science as requiring great effort for learning. They think that it is not possible to learn science while enjoying it. Further, the students regard science as very hard work. They think it is impossible, either, to extend every dimension of scientific skill while enjoying science learning or to have any leisure time that includes scientific inquiry. Also, she found out that only a few students in Japan could solve a series of problems with scientific, logical, and creative thinking. These results could owe to the current emphasis of school science in Japan, where they tend to think of science apart from daily incidents, and do not feel responsibility to make a commitment to society. Thus, it should be that informal science education, including science museums, support or make partnerships with school science in order to help the students call for hands-on and minds-on science, offer them various scientific and technological topics to consider, and ultimately grow them into scientifically literate citizens who can make better decisions for society.

### Discussion 2: The status of goals and activities of science museum in Japan

As a first and essential step for this research, a questionnaire was developed to survey science museums in Japan. This questionnaire investigates their goals, activities, and the condition of their partnerships with school and school sciences. Appendix 1 shows the content of the questionnaire (translated from Japanese). The pilot test is sent to the science museums in Japan in November, and we are waiting for the responds from the other fifty science museums. The total results will be reported in the presentation. During analysis each item is categorized according to the viewpoints such as research-based, social interaction, education-centered, science-centered, curatorship, the frequency of the partnership with school science, science literacy, and so on.

Some interesting features are found through their responds. It turns out that most science museums in Japan have a financial problem to renew and obtain the exhibits and to run the facilities. Personnel problems are serious, as the curators move to new facilities every three years. They must then learn the existing method of management. Museums must consider well the partnership with school science and consider educational effects. In some science museums in Japan, most of which are categorized as science centers in the US, specialists from public schools arrange and plan various programs according to the children's needs. The specialists are usually science teachers, on loan by the local divisions of public education to those informal educational facilities. They make great efforts to take the curriculum into account. While emphasizing partnerships with school science, they also call for authentic science learning. Since they are informal science education facilities, they can plan the activities as free choices without any restriction. But on the other hand, they raise a problem that it would be doubtful whether that authentic activity is on behalf of children, or of science museums themselves. For, since they cannot help being interested in how many visitors may come to the program they plan, their programs tend to be like hands-on science activities that just bring out the visitors' interest and enjoyment. And that interest does not last long, so their exhibits and programs focus on showy and qualitative experiments so that the visitor can easily figure out what is going on and easily understand the theory or knowledge behind the experiments. On the other hand they do feel the necessity of quantitative approach that are also included in authentic science learning. But it is very difficult to hold them in the program of informal science education facilities because it is sometimes time consuming to reach a certain result. Thus they need to develop a new framework for long-term programs that includes quantitative approaches.

## Conclusion

This study reveals several values and problems with science museums as informal science education facilities. The goals and purposes of their facilities are clear and they plan many activities and exhibits in order to show their own originality, but most of them are not supported by research. And it would work more effectively if public school teachers who are familiar with the school curriculum and children themselves worked as a staff. But on the other hand the informal science education system in Japan has a wide range of problems such as budget, cost and personnel, and they lack rationale, such as research based and authentic learning. It needs to add systemic improvement and academic consideration mainly at these four points.

This presentation is done focusing on the role and value of science museums as the first step of a systemic research on informal science education in Japan. We will analyze more details of the actual circumstances of science museums in Japan from the viewpoints of program, exhibits, curatorship, self-assessment, and so on. And through the comparison of advanced countries with informal science education such as the US, Britain, and Sweden, we will offer a wide-range framework of science museums that makes them more than entertainment and that enables the children to commune with science and technology, to do authentic learning in social context, and ultimately, to produce as many as scientifically literate citizens. In order to do so, we will seek what role science museums in Japan should play and what value they can utilize in order to coordinate high quality with the needs of the children, the staffs there, and society.

## References

Bierbaum, E. G.. (1988), Teaching Science in Science Museums. *Curator*, **31**(1) 26-35.

Birney, B. A. (1988), Criteria for successful Museum and Zoo Visits: Children Offer Guidance. *Curator*, **31**(4) 292-316.

Falk, J. H. (1993), Assessing the Impact of Exhibit Arrangement on Visitor Behavior and Learning. *Curator*, **36**(2) 133-146.

Hofstein, A., Bybee, R. W., and Legro, P. L. (1997), Non-formal and In-formal Science Education: Linking Formal and Informal Science Education through Science Education Standards. *Science Education International*, **8**(3) 31-37.

Honeyman, B. N. (1996), Non-formal and In-formal Science Education: Science Centers: Building Bridges with Teachers. *Science Education International*, **7**(3) 30-34.

Inhelder, B., Sinclair, H., and Bovet, M. (1974), *Learning and Development of Cognition.* London: Routledge & Kegan Paul. Ltd., pp. 25.

Korn, R. (1995), An Analysis of Differences between Visitors at Natural History Museums and Science Centers. *Curator*, **38**(3) 150-160.

Kubota, C. A., and Olstad, R. G., (1991), Effects Novelty-Reducing Preparation on Exploratory Behavior Cognitive Learning in a Science Museum Setting. *Journal of Research in Science Teaching*, **28**(3) 225-234.

Kumano, Y. (1998a), A research on Science Education in Lifelong Learning Society- A report from the Data on Youngsters' Science Festival in Shizuoka. The Proceeding of the 22nd Annual Meeting of Japan Society of Science Education, pp. 191-192.

Kumano, Y. (1998b), A research on Science Education in Lifelong Learning Society- A Report from the Conference of Internationalization of Science Education held in Seoul. The proceeding of the 48th Annual Meeting of Japan Society of Science Teaching, pp. 138.

La Follette, M. C. (1983) Science and Technology Museums as Policy Tools- An Overview of the Issues. *Science, Technology, and Human Values*, **8**(3) 41-46.

Ministry of Education, Science, Sports, and Culture. (1999), Courses of Study for Elementary School.

National Research Council. (1996), The National Science Education Standards.

Orion, N., and Hofstein, A. (1994), Factors That Influence during a Scientific Field Trip in a Natural Environment. *Jornal of Research in Science Teaching*, **31**(10) 1097-1119.

Ramey-Gassert, L., Walberg III, H. J., and Walberg, H. J. (1994), Reexamining Connections: Museums as Science Learning Environments. *Science Education*, **78**(4) 345-363.

Rix, C., and McSorley, J. (1999), An Investigation in to the Rile That School-based Interactive Science Centers May Play in the Education of Primary-aged Children. *International Journal of Science Education*, **21**(6) 577-593.

Screven, C. G.. (1986), Educational Exhibitions. Some Areas for Controlled Research. *The Journal of Museum Education: Roundtable Reports*, **11**(1) 7-11.

Suzuki, M. (2000), Assessing Science Literacy of the Students; Modeling upon "Six Domains of Science". *Journal of Science Education in Japan*. **24**(3) 139-150.

Thier, H. D., and Linn, M.. (1976), The Value of Interactive Learning Experiences. *Curator*, **19**(3) 233-245.

Wellington, J. (1990), Formal and Informal Learning in Science: the Role of the Interactive Science Centers. *Physics Education*, **25** 247-252.

**Appendix 1. The questionnaire "The external and internal conditions of science museums in Japan" (Translated from Japanese)**

1. The purpose, goal, and aim of the museum (not necessarily if given a reference or a brochure)
2. The history (or antecedents if applicable) (not necessarily if given a reference or a brochure)
3. Target audiences and the actual visitor stratum
4. What program do you offer to visitors? (Concretely, if you have various programs according to visitor stratum, please describe all.) What do you wish them to perceive or to learn?
5. What discipline of science do you focus on? And what is the popular exhibits and programs in your museum?
6. What point of the museum are you proud of? (e.g.: exhibit, visual design, staffs, programs, professional development or research activities, or whatever)
7. What do you think the strong point of the museum? (You can assume general science museum or your museum.)
8. What effort do you take in order to maintain or to develop more of the museum's quality?
9. What kind of staffs do you need in your museum?
10. What kind of program do you have as an in-service training in your museum? What do you have on mind in doing the training?
11. Do you have a self-assessment system? If it is open to public, please describe how and in what point you self-evaluate. (If you do not have the system, are you planning to introduce one to your museum?
12. How often do you accept group visitors from schools? What ratio is the group of visitors in the total?
13. Do you act or inquire into the partnership with school science? If Yes, please describe the detail, if No, are you willing to do that? And do you need cooperation from national or local government agencies?
14. Do you try to make a partnership if the schools offer you to do? Or, do you have some idea of partnership to school science?
15. Do you think you need to make your museum with support of academic theories in order to manage it from now on? If you do not, please describe what is your basis to manage it?
16. What are the current topics in your field? (e.g.: the management style, the boom of exhibit, personnel, and so on)
17. Do you mind my further contact if I need to ask your advice about your museum? If you don't, please inform me of the name of person in charge.

**Keywords:** science museums, informal science education, social context, scientific thinking, science literacy

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# APPROACHES USING ANALOGIES IN INTERACTIONIST ENVIRONMENTS IN EDUCATION

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**Abstract**

This paper discusses some studies conducted concerning the use of analogies and metaphors in education, and the continuous use of these linguistic resources in conveying scientific concepts. The term *analogy* bears two fundamental meanings: first, its proper and restricted sense which was extracted from its use in mathematics (equivalent to *proportion*) as *equality of relations*; its second meaning features as a *likely* extension of the concept, based on the use of generic resemblances that may be adduced in a variety of situations. In this paper, the term is equitable to the latter meaning, and the words *vehicles, bridges or models* are to be regarded as being synonymous to the word analogy. This work not only reflects upon the employment of those devices as both teaching and learning tools but also points out several different points of view concerning the possible actual contributions analogies and metaphors are able to make to a process of conceptual changes. The fact that the utilization of these resources may contribute to the creation of interactionist environments in schools is also highlighted, as it employs the students' background experience

It presents the Teaching with Analogies Methodology - MECA developed by the authors, and it comments the stages proposed. In practice part works out the biological concept of *Blood Incompatibility* based upon the model. This paper demonstrates some of the differences and similarities between the target (the concept) and the vehicle (the analogy). It proposes reflections on the methodology and details the main of the an interaction between teacher and the text produced by means of not establishing answers or single observations. The student / teacher interaction in the teaching environment is important factor as favoring the process of understanding and the comprehension of concepts. The study proposes that the student's ability to work out analogies and the teacher's skill in assessing that ability may constitute a learning assessment tool, insofar as the understanding and the comprehension of the concept.

The process of the construction of analogies based upon those they already understand and comprehend and similar to those proposed by the teacher, is seen as constituting the first step towards an effective conceptual change. The learning of new concepts and changes in behavior must be studied in order to verify the effectiveness, durability, consistency, timing and the new actions subsequent to the comprehension and understanding of the concepts that have been dealt with.

## I- Introduction

The search for alternatives that help clarify, favor and facilitate both the teaching and learning processes has been a constant preoccupation of pedagogues, teachers and other professionals involved in teaching processes. The use of analogies in this process, in addition to constituting an element of innovation, has become both an impetus and a challenging theme.

The use of analogies not only represents a pedagogical innovation in its dynamic and adaptive means of working out the structure of concepts with the student, but also features a growing acceptance as a resource of basic intuition, as approached by epistemological reflections over both vital and cognitive processes.

In a view centered on the collective self, the importance of context and culture is focused upon. Hence, the emphasis on the development of the apprentice's mental structure and on the evolution of intellectual competences contextualized either in groups or individually, through innovative language.

This is pointed out by ASSMANN (1998: 135), when he refers to the personal experience of *"I am enjoying" or "I'm discovering" a new form of thinking, which usually requires supporting concepts and supporting languages for one to experience changes"*. This helps us understand what the construction of knowledge means, in terms of individual experience. In an innovative concept of learning, that leads to consistent conceptual changes as well as practical attitudes, which can be found in the use of new methodologies providing innovative languages in the construction of concepts for the construction of analogies.

We start with the assumption that motivation, experience, background and language play a significant role in knowledge construction, transfer and learning. That's where analogies apply, as they are, according to DUIT (1991: 649), "*...that analogies may be valuable tools in conceptual change learning if their "metaphorical" aspects are regarded. The paper deliberately takes a constructivistic position. The role of analogies in the learning process is mainly analyzed from this perspective.*"

This paper reinforces NAGEM, CARVALHAES & DIAS (2001) in proposal on the Teaching with Analogies Methodology - MECA for the exploration of abstract concepts in a variety of subject matters with the use of analogies. Also included herein is an analysis of their work, as a means to observe the capabilities and the limits that analogies feature as a resource.

## II- Objectives

This present work is intended to provide an example, with the use of a biological concept, the Teaching with Analogies Methodology - MECA; to foster the establishment of links between analogies and conceptual changes and contribute to the enrichment of interactive learning where the apprehension of significant concepts and contents is produced.

## III- Theoretical References

Literature has shown that the use of analogies and metaphors are present in every human discourse. Discussions on the use of these resources as facilitators of the study and the comprehension of complex matters date back to Aristotle. ABBAGNANO (1999), in his philosophy dictionary, registers the term *analogy* bearing two fundamental meanings: first, its proper and restricted sense which was extracted from its use in mathematics (equivalent to *proportion*) as *equality of relations*; its second meaning features as a *likely* extension of the concept, based on the use of generic resemblances that may be adduced in a variety of situations. In this paper, the term is equitable to the latter meaning, and the words *vehicles, bridges or models* are to be regarded as being synonymous to the word analogy. In this paper, the term is equitable to the latter meaning, and the words *vehicles, bridges or models* are to be regarded as being synonymous to the word *analogy*.

The intrinsic intentionality constitutes, according to studies conducted by SEARLE (1980: 308) *"the necessary condition for a symbolic system to acquire a semantic dimension"*. In fact, comprehension cannot be discussed outside of a semantic dimension. Mental representations or intentional contents are related to linguistic representations. The comprehension of a text or concept runs through linguistic comprehension.

A relevant role has been attributed to the semantic dimension of comprehension in methodological discussions: To analyze, interpret and apply the expressive resources of languages, relating texts to contexts, in the face of nature, function and organization of the statements produced by the learners. It is of paramount importance that the students know how to analyze specific texts and concepts while keeping in sight the whole environment in which they are inserted, and realize that specificities contain a socially constructed sense.

For that reason, the construction of analogies requires systematization and demands that effort be directed towards the construction of the analogous concept to reach an understanding of the target. On the other hand, in discussions about strategies for knowledge exploitation and amplification, it is especially useful to cite BACHELARD (1999), when he refers to the evolution of scientific thinking, he enlists a series of pre- or non-scientific rationales which constitute several epistemological obstacles: animism, anthropomorphism, finalism, realism, substancialism, artificialism, libido, images, *analogies and metaphors*[1], among others.

This position finds opposition in CACHAPUZ (1989), who provides another focus on the use of analogies, as an alternative which aids the apprentice in the acquisition of knowledge when working out complex concepts in several different matters. In the search for a means of promoting improvements in the pedagogical field of work, it is convenient to study the thematic analogy focusing on the rationale forms that may come to help students in the act of learning, by aiding them to better understand and develop their thinking in relation to the construction of scientific concepts.

Analogies stand out as being worthy of study and analysis as teachers' tools to be employed in the classroom's everyday pedagogical practice. Studied from the linguistic point of view, they've come to merit special attention from other fields of knowledge, as is the case of the other cognitive sciences. *"Teachers and students in association must utilize the languages as a means of expression, information and communication in inter-subjective situations that require a degree of distance and reflection upon the interlocutors' contexts and statutes and one must place oneself as protagonist in the process of production/reception" BRASIL (1999:107)*

VYGOTSKY (1934: 149), said, *"the influence of scientific concepts on the student's mental development is analogous to the effect of a foreign language."*. In fact, we may see that, the learning of a foreign language is supported by the control one has of one's own mother tongue. The same should happen to concepts, since he presupposes that "*every learning has its pre-history*" VYGOTSKY (1934: 149) . Thus, spontaneous concepts are exercised from the early stages of language development. Moreover, he observes that *"by constructing its way slowly, an everyday concept unblocks the path to the scientific concept and its ascending development"* VYGOTSKY (1934: 148). The structuring of this inter-relational network is supported by the apprentice's performed readings, which provide reference to develop integrated spontaneous and scientific concept models when instruction is an interactionist process that is realized between teacher and student in the act of learning.

From this perspective, *"Instructional analogies refer to those instances in which some less familiar domain is made comprehensible by appealing to similarity relations with a more familiar domain*" DAGHER (1995: 295). Therefore, these tools provide a bridge from the student's previous knowledge to new concepts. DUIT (1991: 652) relates it to the constructivist approach in the employment of familiar concepts for the understanding of unfamiliar domains, based on two ideas: "(1) *learning is an active construction process; and (2) learning is possible only on the basis of previously acquired knowledge.*"

It is understood that when the intention is to relay a message by means of an analogy, it is fundamental to have it followed by an explanation, including those most commonly known analogies. An analogy which brings no complementary explanation about its real target meaning or comparison may generate doubts and confusions if its interpretation is solely the responsibility of the receptor. This interpretation will rely on his/her expectations, age, customs and other individual characteristics, as well as on the historical timing of the analogy.

CACHAPUZ (1989) distinguishes two kinds of strategies employed in the teaching models utilizing analogies. He classifies them as either a student-centered strategy, if the student selects the vehicle, or a teacher-centered strategy, as is the case when the teacher produces the vehicle. The author emphasizes the real need for an interactive exploitation of the analogy.

During this interactive exploitation, one seeks to demonstrate the attributes or the established relations, otherwise *"there's still the chance that students may not select relevant aspects of the familiar domain, or even*

[1] authors' highlight

*worse, that they may select the irrelevant ones. Finally, the need to clearly determine the limits of the analogy is consensual, that is, not only what is comparable, but also what is not, since not all aspects of the familiar domain are transferable to the studied domain*" CACHAPUZ (1989: 123).

It is important to try and develop in the apprentices´ mind an observational attitude, so that constructive images will be the first ones to form in their minds as a clear means of expression of their thinking, thus providing incentives to a reflective activity in the establishment of significant relationships and conception / action.

Once again, it is important to highlight a key point in the construction of analogies: the vehicle must be within the material previously read by the student, so as to insure the student's mastery of that abstraction level. CURTIS & REIGELUTH (1984: 100) add: "*The careful construction of analogies and their inclusion in instruction must insure that the analogy is not carried too far and that the vehicle is within the knowledge of the learner*".

In the same vein and also agreeing with CACHAPUZ (1989: 125) who draws our attention to the age brackets of the target audience in question, as "*younger students tend to form comparisons based upon a logic of attributes while adults prefer to employ a logic of relationships*".

Another point of consideration is the importance of the teacher's actions towards "*helping the students to be spared the use of analogies which are no longer adequate*" CACHAPUZ (1989: 126) as, for instance, occurs in the scientific realm in which the changing of a vehicle is a consequence of a change in concepts, once the analogy used is no longer capable of illustrating the desired concept.

The organization of the steps in the structuring of the exploitation of an analogy, as a learning strategy, is clarified by CURTIS & REIGELUTH (1984: 115), who recommend that "*The vehicle should usually be explained or described before presenting the new content to help insure that the analogy is understood by the learner. If this explanation is provided, the learner is forced to use the cognitive strategy and, therefore, it may be unnecessary to identify or explain the strategy itself.*"

With the adoption of this form of instruction, the analogy is classified as a organizer, informant and *it allows the writer to refer back, and the learner to think back, to the analogy at various points in the instruction*" CURTIS & REIGELUTH (1984: 108).

The employment of analogies, supported by these guiding points of construction, has more significance when it supplies clues that focus on familiar content, in this manner collaborating towards more complex advancements.

The methodology *MECA* proposed by NAGEM, CARVALHAES & DIAS (2001) was based on what GLYNN (1991) proposed in *Teaching with Analogies* - TWA.

## IV- The Methodology Of Teaching With Analogies - MECA

The development of this methodology, which resulted from studies undertaken by the GEMA - TEC[2] group, has followed various criteria as it considers that "on the one hand, analogies promote changes, provide new perspectives and motivation and clarify the abstract, while on the other hand they may not have the desired effect and may come to constitute a "*double-edged sword*" (DUIT, 1991: 666).

This educational support model for teachers and educators envisions the systemization of the methodology employed in the use of analogies as teaching tools, following the format below:

[2] Metaphors and Analogies in Technology, Education and Science Study Group.

| | |
|---|---|
| 01 | Field of Knowledge |
| 02 | Subject Matter |
| 03 | Target Audience |
| 04 | Vehicle |
| 05 | Target |
| 06 | Description of Analogy |
| 07 | Similarities and differences |
| 08 | Reflections |
| 09 | Assessment |

Within this methodology, **Field of Knowledge** refers to the definition of the area specifically comprised of by certain knowledge to be worked with in the various courses of the programs such as mathematics, physics, biology, chemistry, etc.

The term **Subject Matter** refers to the content to be dealt with within the field of knowledge such as the study of blood types in the Sciences.

By **Target Audience** we mean the person at whom the analogy is targeted through the detailing of their profile. This step clearly illustrates our concern with the use of suitable vehicles which take into consideration factors such as age, previous experience and knowledge. For instance, when regarding their relationship with the consensual knowledge and historical context in question.

In using **Vehicle** we are referring to the *"familiar content"* as defined by CURTIS & REIGELUTH (1984:100). It is the analogy itself which provides the understanding of the object of study. This term is preferable to others such as "*analogue*" THIELE & TREAGUST (1995: 784) or *"bridge"* DAGHER (1995: 601), due to its intuitive notion of movement that facilitates the role analogies play in instruction regarding the act of "*leading the student to the target concept*". **Target**, on the other hand, is defined as "*... the domain that is explained or learned*" DUIT (1991: 650) .

In the **Description of Analogy** stage the vehicle is first presented and explained, and it is only then that the target is dealt with. This procedure seeks to make the analogy available to the students at any stage of their studies, and to function as a motivational element as well.

In dealing with **Similarities and Differences,** the aim is to show, in an objective manner, the points relevant to the understanding of the target. In exploring the analogy, it is important to call attention to the necessity of re-enforcing the similarities, which should outnumber the differences. Care must be taken not to focus heavily on the differences between the vehicle and the target. This procedure must not stray from the objective of the analogy, which is to illustrate the similarities, being aware of the fact that it is more difficult to access them than the differences, as well as the fact that in re-enforcing the differences, the analogy loses its meaning.

In this interactive activity, it is necessary for the teacher to remain oriented towards constituting the central focus from the relevant similarities between the vehicle and target, in a manner in which the likely irrelevant similarities are duly analyzed and dismissed. It is worth noting that the relevant differences must be explored so as to prevent the transfer of undesirable characteristics from the vehicle to the target in question.

Under the topic **Reflections,** a joint analysis with the students of the validity and the limitations of the analogy, determining the areas in which it may fail, as well its adequacy in the intended content, is sought after. At this moment, the purpose of the methodology is made clear, that is, to foster not only an understanding of the content but a critical and reflexive attitude as well.

Attention should also be paid to the fact that the methodology of teaching with analogies – **MECA,** provides teachers and educators with a suggested strategy that promotes the qualitative assessment of the assimilation, based upon the degree of understanding achieved. It's with this that the final term, **Assessment**, deals with. In this stage, it of paramount importance that the student be encouraged to develop his own analogy and propose a vehicle more familiar to his own experiences, realizing the similarities and differences and thereby making explicit his understanding of the object of study.

At this time, the differences in the individual students' learning processes should be considered. It is possible that difficulties may arise as some students may very likely be capable of forming instantaneous analogies, while others may require more time. It is the role of the educator to step in and make it possible to apprentices to perform extra class activities. Time must be allotted for the student to internalize, reflect upon and deliver his responses to the questions proposed.

**V- Example**

1. Field of Knowledge: Sciences[3]
2. Subject Matter: Blood Types A, B, AB e O
3. Target Audience: Students in Grade School and Laymen.
4. Vehicle: Water, coffee and cream
5. Target: Compatibility or incompatibility of blood types
6. Description of Analogy

Imagine four cups: one filled with **water,** one with **coffee**, and one with **cream** and one with **coffee with cream**, as is shown below:

Cup of water   Cup of coffee   Cup of cream   Cup of coffee with cream

If experiments are made mixing the contents of the cups, the following changes in colors will be observed:
1. If a bit of the **water** were poured into the cups of **coffee, cream** or **coffee with cream**, the mixtures would not be significantly altered. Hence, it can be stated that it is possible to mix the **water** with the contents of the other cups without altering them greatly.
2. If a bit of the **coffee** were poured into the cups of **water** or **cream**, the mixtures would be significantly altered. Hence, it is possible to state that mixing **coffee** with the other two liquids, they would be significantly altered.
3. The same would happen if a bit of **cream** were poured into the cups of **water** or **coffee**. Hence, it can be stated that it is not possible to mix the **cream** with the other two liquids as they would be altered.

[3] Analogy structured by Ronaldo Luiz Nagem utilizing the MECA methodology.

4. If a bit of the **coffee with cream** were poured into the cups of **water, cream** or **coffee,** the mixtures would be altered. Hence, it would be possible to state that mixing **coffee with cream** with the other liquids, they would be altered.
5. If a bit of **coffee, cream** or **water** were poured into the cup of **coffee with cream**, the mixtures would not be altered. Hence, it would be possible to state that mixing **coffee, cream** or **water** with the **coffee with cream**, it would not be altered. Through the previous observations, it can be verified that the cup with the **coffee with cream** mixture may receive small quantities of all the other liquids without having the original mixture modified as it already contains all of them[4].

In the transfusion of blood something similar occurs. The blood typing system **A, B, AB** and **O** indicates that some people have blood type **A**, others have blood type **B**, and others have blood type **AB,** while others have type **O**.

Think of blood type **O** as if it were the cup of **water,** type **A** as if it were the cup of **coffee**, type **B** as if it were the cup of **cream** and type **AB** as if it were he cup of **coffee with cream** as is shown below:

| Water | Coffee | Cream | Coffee with cream |
|---|---|---|---|
| Type **O** | Type **A** | Type **B** | Type **AB** |

By comparing the results observed, it may be concluded that:

1. As it is possible to mix the **water** with the cup of **coffee**, the cup of **cream** and the cup of **coffee with cream**, producing barely perceptible alterations, blood type **O** may donate blood to the other blood types A, B, AB e O. For that reason, type **O** is called a universal donor.
2. As it is **not** possible to add the **coffee with cream** to the other types of liquids, **water**, **coffee** and **cream**, without producing several alterations, type **AB cannot** be a donor to all other blood types. For that reason, type **AB** is called a selfish type.
3. As it is **not** possible to mix a bit of the **coffee** either in the cup of **water** or in the cup of **cream** without producing alterations, type **A** cannot donate blood to types **O** and **B**. On the other hand, as it is possible to mix a bit of the **coffee** with the cup of **coffee with cream**, type **A** can donate blood to type **AB**.
4. As it is not possible to mix a bit of **cream** with the cup of **water** nor with the cup of **coffee**, as it produces significant alterations, type **B** cannot donate blood to types **O** and **A**. As it is possible to add a bit of the **cream** to the cup of **coffee with cream**, type **B** can donate blood to type **AB**.
5. As it is possible to mix small quantities of all other liquids into the cup of coffee with milk, producing almost no alterations, type AB may receive donations from all blood types, and is thus called a universal receptor[5].

[4] Note: Both the scenario and the sequence may be altered according personal preferences

[5] Note: the sequence of explanations may be altered also

6. Similarities and differences in the analogy:

| Similarities | Differences |
|---|---|
| Number: four blood types corresponding to four different substances. | Blood types A, B, AB and O do not have different colors as in the case of the liquids used: water, coffee, cream and coffee with cream. |
| Water is a substance with a simple composition and can be mixed with other kinds of liquids. Type O can donate blood to other blood types. | Blood is a very complex system as it contains a variety of substances. All types can receive type O blood. |
| The coffee with milk type can receive all other kinds of liquid. Type AB can receive blood from all other types. | Type O, for instance, does not receive blood of types A, B or AB. The same occurs with the water. |
| Coffee can not be mixed with milk and vice-versa as it produces a completely different mixture. Type A cannot donate blood to type B and vice-versa... | However, in the case of mixing liquids, alteration does not lead to any harmful results. In the case of blood, the alteration could be fatal. |
| Water can not be mixed with milk as it will be significantly altered. Type O blood can not receive other types of blood different from his own. | The alteration occurring in the blood is not a change of color as in coffee with milk, but an alteration of the blood cells. |
| Donated blood is inserted directly into the vein with a syringe. | Coffee with cream is drunk. |

8. Reflections:
When mixing one blood type with another, there are no color alterations as is the case with the mixture of coffee with cream, but there is an alteration in the chemical-physical composition resulting in the agglutination of blood cells. The analogy has limitations such as, for instance, it does not draw attention to that. It tends to focus on the compatibility and incompatibility of blood types. Different similarities or differences as well as other ideas may be brought up during the discussion of the analogy with the students.
9. Assessment:
At this stage, students are asked to produce their own analogies and to point out the differences and similarities observed between the analogy they produced and the target concept. It is interesting to note that the production of the other analogy by the students for the target concept may make evident the understanding and comprehension of the concept.

## VI- Final Considerations

In producing an analogy, it is important to pay close attention to and realize the nature of its contribution on a conceptual level, as it will be the means through which those changes expected by the students when working with arid concepts in various contents will be achieved.

An attempt must be made to set up the epistemological scenario jointly with the students even before they start producing their own sketches of the concepts, in order to explore the vocabulary inherent to the semantic field in question, thus facilitating both association and identification amongst mental domains. Within an interactionist practice, the teacher may follow up student's understanding in the restructuring a concept, seeking the realization of a new meaning for that concept by means of exploiting the analogy.

Finally, in the employment of this learning strategy it is fundamental that it is not limited to the construction of a model or recipe. It requires additional changes in the educator's practice regarding the ways contents and cognitive changes are dealt with, which demands deeper reflections upon their pedagogical actions and performance.

The present study is a contribution, a fundament, both theoretical and practical, to be utilized as tool to assist the teacher in introducing and elaborating upon concepts and in the definition of contents and methodologies. It is believed that this may constitute a useful reference because the employment of this resource for the development of complex and abstract contents is still incipient in the Brazilian educational system, and it may aid in popularizing knowledge.

In this sense, we, teachers, must make the decision making processes inside the classrooms viable, by making room for comparisons, questioning, summarization, text production and other means of having the students' participate. Students are to be responsible for the changes; and teachers for the fostering of enriching experiences that allow for a diversity of processes in which comprehension is required. In this manner, we, educators, are recognizing the importance of assessing the effectiveness of the focus allotted to information in the communication between student and teacher.

The proposed employment of Analogies within a specific methodology allows for a new dimensioning of the role played by memory in the understanding and apprehension of concepts, to the extent that observation, reflection and rationale may in part replace memorization activities.

## VII – References


ABBAGNANO, N. (1999) *Dicionário de Filosofia.* Ed. Martins Fontes. São Paulo.

ASSMANN, H. (1998) *Metáforas novas para reencantar a Educação. Epistemologia e Didática.* 2. ed. Piracicaba: Ed. UNIMEP.

BACHELARD, G. (1999) *La Formation de L'esprit Scientifique.* Seizième tirage – Paris. Librairie Philosophique J. Vrin 6, Place de La Sorbone, Ve. 1999.

BRASIL. (1999) *Parâmetros Curriculares Nacionais do Ensino Médio.* Ministério da Educação e Desporto. Secretaria de Educação Média e Tecnológica. Brasília.

CACHAPUZ, A. (1989) *Linguagem metafórica e o ensino das ciências.* Revista Portuguesa de Educação. *2,* (3), 117-129.

CURTIS, R. V. & REIGELUTH, C. M. (1984) *The use of analogies in written text.* Instructional Science, *13,* 99-117.

DAGHER, Z. R. (1995) *Review of Studies on the Effectiveness of Instructional Analogies in Science Education.* Science Education, *79,* (3) 295 – 312.

DUIT, R. (1991) *On the role of analogies and metaphors in learning science.* Science Education, *75* (6), 649-672.

GLYNN, S.M. (1991) *Explaning science concepts. A teachining with analogies (TWA) model.* In Glynn, S. R. Yeany, & B. Britton (Eds). *The psychology of learning science.* Hillsdale. NJ. Erbaum. Pp. 219-240.

NAGEM, R. L., CARVALHAES, D. O. & DIAS, J. A. Y. (2001) *Uma proposta de metodologia de ensino com analogia.* Revista Portuguesa de Educação, (2). 14.

SEARLE, J. (1980) *Intrinsec Intentionality.* Behavioral and Brain Sciences. vol.3, 307-309.

THIELE, R.B. & TREAGUST, D. F. (1995) *Analogies in Chemistry textbooks.* International Journal of Science Education. Vol. 17 (6): 783-95.

VYGOTSKY, L. S. (1934) *Myshlenie i rech.* Trad. cast. de la ed. inglesa de M.M. Rotger (1977). *Pensamiento y lenguage.* Buenos Aires: La Pléyade. In Pozo, J.I (1998). *Teorias cognitivas da aprendizagem.* Trad. Juan Acuña Llorens. 3a. Ed. Porto Alegre: Artes Médicas.


**Key words:** Analogies, Interactionist, Learning and Teaching Methodology, Scientific Concepts. (This research was supported by CNPq, Brazil)

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# A STUDY ON SEASONS REPRESENTATIONS IN SCIENCE TEXTBOOKS FROM THE PERSPECTIVE OF HISTORICAL-CULTURAL INFLUENCES

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**Resumo**

O estudo analisa o conhecimento escolar em ciências expresso em livros didáticos brasileiros, focalizando especialmente as ilustrações sobre o tema estações do ano. Essa investigação surge a partir da constatação dos inúmeros problemas que envolvem as usuais abordagens dessa temática nos livros voltados para o ensino fundamental, podendo situá-los em pelo menos duas dimensões principais: (i) a existência de inúmeros erros conceituais em relação à explicação do que ocasiona as estações do ano e (ii) as formas de representar essas estações. Partindo do entendimento de que os livros didáticos são um testemunho público e visível dos conflitos que envolvem as decisões e ações curriculares, concordamos com Ivor Goodson quando defende a importância de estudos sobre o currículo escrito. Além disso, os livros didáticos brasileiros têm tido um importante papel na formação dos professores da educação básica. Partindo do trabalho de Oliveira (1997), investigamos quinze livros didáticos voltados para as séries iniciais do ensino fundamental. Esta fase do estudo foi realizada durante um curso de formação inicial de professores realizado na Universidade Federal Fluminense, estado do Rio de Janeiro. Grande parte das representações encontradas nesses materiais contrasta com o que observamos no hemisfério sul e, mais especificamente, nas diversas regiões do Brasil. Reconhecemos as dificuldades envolvidas na transformação dos conhecimentos científicos sobre as estações do ano em objeto de ensino. Apesar disso, argumentamos que boa parte dos problemas encontrados na forma como os livros didáticos vêm representando as estações do ano é fruto de uma importação acrítica de representações didáticas elaboradas no hemisfério norte. Tal importação não se deu de forma isolada, possuindo raízes históricas que remontam ao próprio processo de escolarização do Brasil. De lá para cá, viemos perdendo esses vínculos históricos, naturalizando os conteúdos encontrados nos livros didáticos como se fossem os mais corretos e pertinentes a serem ensinados. No caso específico desse estudo, podemos dizer que essa importação de modelos esvaziou as estações do ano de seu conteúdo histórico. Assim, ilustrações que teriam sentido se explicadas como pertencentes ao hemisfério norte passaram a ser utilizadas para explicar uma realidade distinta e que não se encaixa nos modelos propostos.

## Introduction

This work aims at to analyse Science school knowledge as it is expressed in Brazilian textbooks, particularly in terms of how their illustrations show the seasons. This investigation arises from the fact that there is a number of problems related to ordinary approaches concerning the topic in Elementary Schools[3]. We can place these problems at two main dimensions: (i) the conceptual mistakes meant to explained *why are there seasons?*; (ii) the ways the seasons are represented. There are plenty of literature dealing with students' alternative conceptions of the scientific explanations of seasons.[4] Local authors, like Caniato (1989, 1992), Canalle *et al*

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[3] In the Brazilian educational system, elementary school comprehends eight years of teaching, beginning at seven and finishing at fourteen years old.

(1997) and Trevisan *et al* (1997) also have contributed with accurate analysis about the major uncorrected definitions present in textbooks, and, at the same time, they have proposed a number of school activities to face the difficulties. However, there is a lack of studies examining, specifically, the pictorial misrepresentations of seasons in textbooks.

Since 1996, Brazilian Ministry of Education has undertaken a programme to assess all textbooks distributed to state schools. During the course of this kind of evaluation the theme *seasons* has been pointed out as one of the most critical, not only in terms of their accuracy, but also in terms of their misrepresentations. Such representations can be identified by verbal expressions – *Spring is the season of flowers* – and by the accompanied illustrations such as *snowman representing Winter* or *leaves falling from the trees in Autumn*.

The examples highlight the fact that seasons representations in Brazilian textbooks do not portrait the regional characteristics. As it is known, Brazil is a large country with the majority of the territory located within the tropical area. It means that there is no temperate climate and, therefore, the four seasons occur in a different pattern from the northern countries. Besides, within the country there are several differences among the seasons. Considering the geographic regions in Brasil, it is possible to recognise only two seasons, wet or dry (in places where this happens it is said that, respectively, Summer is the dry one and Winter, the wet one) in the northern parts, and four seasons in the south, mainly identifiable by differences in temperature and daylight length.

In this work we argue that there are historical reasons which underline the discrepancies between textbooks seasons pictorial representations, and Brazilian physical context. Therefore, our focus will be looking at these kind of problems, not only regarding them as "mistakes" but, ultimately, as a result of a process built alongside socio-historical influences which ended up naturalising the content. In order to do that, we shall be looking at how textbooks have become an explicit example of this process.

**Textbooks as a genuine study object**

Traditionally, textbooks have been a powerful tool to select and organize both teaching contents and methods. Since the first attempts to organize a Brazilian schooling system – marked by the opening of the Colégio Pedro II[5] in 1837 –, these teaching materials have been present in our curricula, in a meaningful way. By using original French books or translated ones, the produced curriculum in this institution was, for a long period of time, the model followed throughout the country.

Especially from 1970 onwards, the importance of such curriculum materials grew considerably. This can be seen as a result of a social-historical context in which teachers' devaluation occurred not only regarding their initial education[6], but also regarding their incomes. The fact that Science as a Primary school subject became compulsory aggravated the dependence on textbooks. A growing number of teachers found in these materials a silent ally, which defines the selection of contents and organization of school activity.

[4] Barrabín, De M. (1995), in his article – Por que hay veranos y invernienos? Representaciones de estudiantes (12-18) y de futuros maestros sobre algunos aspectos del modelo Sol-Tierra. *Enseñanza de las ciencias. 13 (2), 227-23* – gives an overview of studies published in different countries: Giordan & de Vecchi (1987); Jones, Lynch & Reesinch (1987); Kapterer & Dubois (1981); Klein (1982); Nussbaum & Novak (1976); and Schoon (1992) Another good example can be found in: Camino, N. (1995). Ideas previas e cambio conceptual en Astronomía. Un estudio con maestros de primaria sobre el día y la noche, las estaciones y las fases de la luna. *Enseñanza de las ciencias. 13 (1), 81-96*

[5] The opening of the Colégio Pedro II aimed at giving unit to Brazilian secondary school. Since the ban of Jesuits from the Brazilian territory in 1759, secondary school teaching was mainly given by avulse lessons. Therefore, since its beginning, this school was proposed as a model to secondary teaching to be followed throughout the country.

[6] In this article we prefer to use *Initial Teacher Education* instead of *Initial Teacher Training*.

Considering textbooks as a public and living witness of the conflicts surrounding curricula decisions and actions, we agree with Goodson (1988) when he defends the importance of the study of written curriculum. To this author, the relationship between "written curriculum" and "curriculum in action" depends on two factors: (i) the social-historical nature of the pre-active curriculum construction; (ii) and the interactive curriculum development within the school. These aspects do not mean the establishment of a straight bond between pre-active and interactive phases. Not also does it mean that the former overrules the latter. As a matter of fact, Goodson understands that it is dangerous to abandon 'pre-active' definitions, for we might accept them as an assumption. By doing that, these definitions become naturalized and, therefore, they prevent questioning the social and historical roots of the several conflicts which have created them.

The considerations made above allow us to place textbooks within three main dimensions, *curriculum*; *teaching action*[7]; and *initial teacher education*. In the first of them, textbooks formalize the intentions originated both from subject knowledge communities and educational authorities. These different social groups have selected and organized, throughout a process of dispute, aspects of a wider culture. In the specific example of Brazilian textbooks, we can say that they have taken not only the scientific and educational discourses, but also the "official" discourse from the government. Since the Ministry of Education is responsible for the acquisition of textbooks to all state schools – in a program to assess these materials – consequently, teachers' choice is directed by the institution.

According to Chevallard (1985), textbooks are placed at the end of a transformation chain in which scientific knowledge becomes scientific school knowledge. To this author, this kind of transformation is mediated by a group of social and political factors. As a result, scientific school knowledge becomes a unique kind of knowledge and it overrules the scientific knowledge to the social aims of schooling. As stated by Forquin (1992) within the process of organizing school knowledge, there are dominant values involved like presentation, clarification and gradual development. For that, redundancies and explanatory comments are commonly employed. Besides, the school knowledge is also a result of condensation techniques and, at the same time, concretization attempts like diagrams and illustrations.

All these characteristics of scientific school knowledge expressed in textbooks allow one to think of them in their teaching dimension, since they give parameters to select and organizing contents. More than that, in the school routine, teachers find in the textbooks contents to be taught and a teaching proposal, which positively guides their work in classroom.

Finally, textbooks are in the middle of a pathway, which goes from University to schools. They are strategically and uncritically accepted as substitutes of a more robust model of initial teacher education. Textbooks and initial teacher education courses are historically linked together since early colonization times. Due to the relationships between Portugal and hegemonic cultures, particularly the French one, the Brazilian educational history exemplifies this attachment to European scientific production. At the end of the XIX century and at the beginning of the XX , Brazilian teachers have mainly used French textbooks – originals or translations –, or even English ones (Lorenz, 1986). This context required better qualified teachers which contrasts to what have been witness during the last decades. This can be seen as a result of educational policies which have neglected both the initial teacher education and the professional conditions. We might consider that teachers' economical and cultural empowerment runs in parallel to a growing dependence on textbooks. This reveals a relevant aspect of the problem that deserves a deeper study, but it is beyond the scope of this article.

The three dimensions in which the textbooks are involved stress the importance of analyzing these kind of school materials from different perspectives. Considering textbooks as a mediating component among several knowledge that circulates within school contexts, we will be presenting how seasons have been illustrated in these materials.

[7] By teaching action we mean all teaching activities performed by teachers, including the use of resources, to allow pupils to grasp the meaning of school contents.

### Looking at seasons illustrations in Brazilian Science textbooks

Oliveira (1997) investigating connections between pupils' and teachers' representations of the seasons found similarities between them and the ones of the textbooks. For instance, most teachers and pupils, had drawn snowman, snow, heavy rains, storms and thunders to represent Winter; flowers, butterflies, rainbows to represent Spring; sun and beach to represent Summer; and trees full of fruits and leaves falling from trees to represent Autumn.

These categories of representations were also found in all 15 textbooks investigated during a course given to prospective teachers at the Universidade Federal Fluminense, in the State of Rio de Janeiro. The majority of the pictorial representations (see Fig. 1) contrast with what can be observed in Brazil. The Brazilian seasons landscape[8] variations such as the ones observed in northern hemisphere do not occur throughout the country. For instance, there is a number of species of plants (especially trees) with deciduous leaves. However, their falling span time does not follow northern hemisphere seasons' pattern[9], and therefore, cannot be associated to Autumn. Also, in the books illustrations, a typical northern country winter is represented with no resemblance to the Brazilian winter. Along the months of the year Brazilian flowered plants[10] are active as much as fruitful trees, so that there are flowers and fruits without interruption or, in other words, there is no a typical Spring or Autumn time. Consequently, a Brazilian student using a book with these kind of illustrations will find it difficult to match this seasons characterization with what he or she finds in his or her own place.

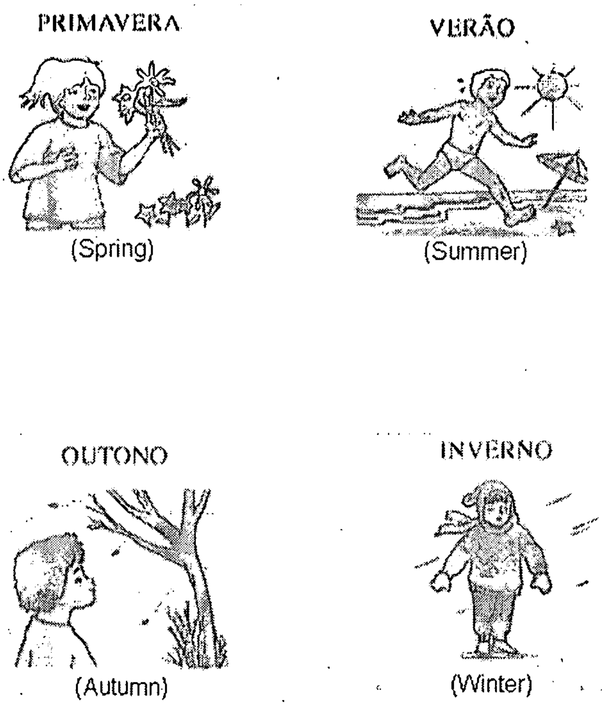


**Fig. 1** – A typical seasons pictorial representation in a Brazilian science textbook

As it is widely known, in northern hemisphere countries the seasons occur in number of four, clearly marked. Seasons changes also can be observed on the behaviour of living things – migration of birds, hibernation, distinct time for fruiting and flowering plants etc. Landscape changes in each season are thus, associated to temperate climates. In a country, like Brazil, in which the majority of the territory is placed between the Equator and the Capricorn Tropic,

[8] In this article we use landscape to mean the patterns of the environment during seasons, especially aspects of trees.

[9] One of the examples is Amendoeira da Praia ou Chapéu de Sol (*Terminalia catappa*), originally from Africa (Joly, A. B. *Botânica: Introdução à Taxonomia Vegetal.* São: Nacional, 1985). This popular tree has deciduous leaves that can be observed throughout the Brazilian coast. The leaves, however, do not fall in the Brazilian Autumn. Also, in a region known as "Brazilian Savanna" or even in the inner parts of the East Brazilian Tropical Rain Forest (Mata Atlantica) – in the states of Minas and Sao Paulo –, the arboreal plants have deciduous leaves, but they fall during the dry season.

[10] By Brazilian plants we do not mean only native ones.

there are three modes of climates: *equatorial, tropical* and *subtropical*[11]. In the Brazilian climates, seasons variations are more related to rain than to temperature. Because of the location of this country, the occurrence of different types of seasons becomes particular according to the geographical area. Therefore, it is not possible to compare the landscape contrasts seen in temperate climates areas with the Brazilian ones. As said before, in some places, there are only two seasons – dry one and wet one. The more a region is situated to the southern parts, the more contrasting the seasons become.

In scientific terms seasons can be explained by a combination of factors during the course in which the Earth orbits the Sun. Altogether, the Earth's axis inclination and the position of the Earth at the orbit are the main explanations for the periodicity observed during the seasons. In cartographical terms, the occurrence of seasons also depends on the latitude in which the geographical place is located. Seasons are produced as a consequence of the angle of sunlight incidence throughout a curved Earth surface. For instance, around the Equator this angle is quite straight and means that places located at this area receive, practically, the same amount of sunlight radiation throughout the year. The same cannot be said about southern or northern latitudes. Towards the south of Brazil, what becomes marked, during the course of the seasons, are the daylight length variations. Therefore, in the southern parts, the daylight length variation is what can provide a better characterization of the season, *not* the landscape transformations.

To sum up, there are three important features to be considered when seasons in Brazil are to be understood: differences between wet season and dry season in the northern places; temperature variations between Summer and Winter in southern areas; and daylight length variations. In the regions closer to the Equator daylight length does not vary much all over the year. Consequently, temperature variation in this area is timid[12]. Towards the south of the country, the seasons get more defined, occurring clear variation of the daylight length. Finally, in the southern states, temperature drops in the Winter, but just in a few places – in high altitudes – it snows.

Based on the data available in this study, we can stress that the differences between temperate climate seasons and sub-tropical seasons were not represented. It seems that peoples' ordinary perceptions were underestimated by northern hemisphere contexts imported representations. In the next section we will analyse this question in a more detailed way.

## Science textbooks and historical-cultural influences

As explained, seasons have been approached in textbooks in a problematic way. In the initial years of schooling, there has been pointed out that both the misinformation and books illustrations are not clearly related to Brazilian physical context. This certainly makes the learning process difficult and distant from pupils' everyday life.

Looking at how seasons have been mentioned by Brazilian naturalists show a different view from what has been pictured in the textbooks analyzed. For instance, at the end of the XVIII century, Manuel Arruda da Câmara[13] – a Brazilian naturalist working for the Portuguese Crown – has registered the contrasts between seasons in the two hemispheres:

> *In this country it is not possible to make distinction, as in Europe, of the four constant seasons: here there are only two of them – Summer and Winter – [.].besides, I can see two marked*

[11] By definition temperate climates are the ones of the areas between the Artic and Antarctic Circles – and , respectively the Tropics – either Cancer, to the North, or Capricorn to the South. However, in Brazil there is no temperate climate in the region placed from the Capricorn Tropic southwards. In this region, the climate is known as *subtropical.*

[12] It is known as isotherm.

[13] During this period, Manuel Arruda da Câmara has undertaken several expeditions throughout Brazilian states of Piauí, Paraíba, Ceará and Maranhão. His studies – dated from 1752 to 1811 – were only published in Recife, 1982.

*climates, due to the physical features of the land surface.* [14] (Câmara, 1982: 127-8, apud Prestes, 2000)

What the text suggests is that the misrepresentation of seasons found in the textbooks are not the result of lack of knowledge of old naturalists about the differences between Europe and Brazil. More than that, Câmara's register shows a particular mode of seasons in northern parts of Brazil. If the misrepresentations found in current science textbooks cannot be explained by wrong observations from the past, what would have caused them?

We recognize that there is a reasonable number of obstacles to transform the scientific knowledge about seasons into a teaching object. The scientific explanation model is complex and requires wider cognitive elaborations. The understanding of the concept, also, does not occur as a result of a direct phenomenon observation. On the contrary, it demands a great abstractive ability. Besides, seasons occur in a time span long enough to be observable on a course of a school year. Specially in great urban areas it is difficult to visualize the sky and this brings other problems to observe the phenomenon. Also, pupils, most commonly, mistake climate with seasons.

Despite all these conceptual difficulties, we argue that most of the textbooks problematic representations are the result of an uncritically importation of northern hemisphere patterns. It is relevant to recall that many of the Colégio Pedro II teachers have also translated foreign books, especially the French ones. Afterwards they have become authors of their own textbooks. Thus, we suppose that their references sources, more specifically, their sources of illustrations about seasons were those from foreign books which had typical European countries pictorial representations.

The French influence had been gradually overtaken by the English speaker countries. Particularly after the Second World War, the American influence grew considerably. During military dictatorship government[15] this presence became stronger by a number of agreements established with the United States, such as the one between the Brazilian Ministry of Education and the United States Agency for International Development (Agreements MEC/USAID). Besides, several projects received financial support from UNESCO, Ford Foundation and Rockefeller Foundation. The priority of such founds was to translate foreign projects – e.g. BSCS, PSSC, CBA and Nuffield – and afterwards, to produce local textbooks and other teaching materials (Barra & Lorenz, 1986).

As stated previously, all of these foreign influences grew exactly in a disturbed political moment. The outcomes on the Educational legislation have brought about changes in the curriculum structure, making Science a compulsory school subject in first years of schooling. The rapid burst of several textbooks titles emerged at the core of the reforms. Within this context, textbooks matched teachers' demands and helped them to work with a school subject to which they felt unprepared.

Thus, the mentioned influence from English speaker countries is attached not only to teachers' needs, but also to book market demands. We suppose that Brazilian textbooks authors, facing this expanding consumer market, have searched, once more, inspiration from foreign books. Such fact has contributed to reinforce seasons patterns, typically from the north hemisphere.

It is important to stress that we do not regard textbooks as the only responsible for the diffusion of the imported representations of the seasons. The northern countries seasons patterns are exposed as Brazilian patterns in museum exhibitions, books, journals, advertisements, newspapers and television programmes. The popular imaginary has been fostered by European and, especially North American contexts through various ways. Despite that, we consider that the school and, especially the textbooks, play a fundamental role in the building

[14] Translated by authors, from the original: *Neste país, não se distingue, como na Europa, as quatro estações constantes: apenas se marcam duas, verão e inverno* [...], *mas, além disto, eu distingo dois climas bem diferentes, por causa da construção física da superfície do terreno.*
[15] Brazil was ruled by a military dictatorship between 1964 to 1985.

and maintaining of these patterns. This interpretation seems to be coherent to what we have just exposed and can be fruitful to explain the empirical data such the ones we have focused in this article.

## Final comments

All illustrations found in the fifteen books analyzed express a teaching model to the seasons which has not been produced from the Brazilian context. Throughout the schooling process, we have lost the historical links which placed such illustrations in our textbooks. We can view that, this exemplify a form of naturalization of the written curriculum. The representations of the seasons produced in the north hemisphere have been accepted as the most correct and appropriate to be taught in Brazilian schools.

We argue that such importation is not an isolated fact within the process of Brazilian schooling. As stated earlier, it has been historically originated alongside the foreign influences over the long term construction of our school system. We believe that the strength of the influences was not only based on the domain of the ideas which underline the science education, but it was mainly based on the significant financial resources support.

Particularly, what this study reveals is that the imported model from a foreign context has emptied the content from its historical roots. Textbook illustrations showing the occurrence of seasons in northern hemisphere could become meaningful if they were properly explained according to its own context. Thus, the northern hemisphere illustrations in Brazilian textbooks have become meaningless because they have been employed to explain a totally different context. Under this perspective, the imported model does not fit into the real world.

## References

BARRA, V. M. & LORENZ, K.M. (1986) Produção de materiais didáticos de Ciências no Brasil, período: 1950 a 1980. *Ciência e Cultura*, 38(12): 1970-1983.

CANNALE, J. B. G., TREVISAN, R. H. e LATTARI, C. J. B. (1997) Análise do conteúdo de astronomia de livros de geografia de primeiro grau. *Caderno Catarinense de Ensino de Física*, 14(3): 254-263.

CANIATO, R. (1989) *Projeto de Ciência Integrada.* Campinas: Papirus.

CANIATO, R. (1992) *Com Ciência na Educação.* Campinas: Papirus.

CHEVALLARD, Y. (1985) *La Transposition Didactique.* Du Savoir Savant au Savoir Enseigné. Grenoble: La Pensée Sauvage.

FORQUIN (1992) J.C. Saberes escolares, imperativos didáticos e dinâmicas sociais. *Teoria e educação*, nº 5, pp. 28-49.

GOODSON, I. F. (1988) *The Making of Curriculum: Collected Essays.* Londres: Falmer Press.

LORENZ, K. M. (1986) Os livros didáticos e o ensino de Ciências na escola secundária brasileira no século XIX. *Ciência e Cultura*, 38(3): 426-435.

OLIVEIRA, D. C. (1997) *Representações dos Alunos, Professores e Livros Didáticos sobre as Estações do Ano: Um Olhar Crítico no Ensino de Ciências Naturais nas Séries Iniciais.* Niterói: FE/UFF (monografia).

PRESTES (2000) M.E.B. *A investigação da natureza no Brasil Colônia.* São Paulo: Annablume Ed. e Fapesp.

TREVISAN, R. H., LATTARI, C. J. B. e CANALLE, J. B. G. (1997) Assessoria na avaliação do conteúdo de astronomia dos livros de ciências do primeiro grau. *Caderno Catarinense de Ensino de Física*, 14(1): 7-16.

**Palavras-chave:** currículo, ensino de ciências, ensino fundamental, estações do ano, livros didáticos.

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# THE CONCEPTION OF SCIENCE, ALTERNATIVE CONCEPTIONS AND THE STS APPROACH IN THE TEACHING-LEARNING PROCESS OF THE CONCEPTS OF ACIDITY AND BASICITY

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## Abstract

La enseñanza de las ciencias en México ha cambiado considerablemente en la última década del siglo XX. Los curricula del bachillerato han incorporado de manera sistemática el enfoque de la ciencia, tecnología y sociedad (CTS). Sin embargo, en los cambios realizados se ha dado relativamente poca importancia a la incorporación de las ideas previas o concepciones alternativas de los estudiantes.

Si queremos que los egresados del sistema escolarizado se conviertan en ciudadanos alfabetizados en el ámbito científico, es necesario que orientemos la planeación de la educación hacia el logro de aprendizajes significativos, correctos desde el punto de vista científico y tecnológico. Esto no se puede alcanzar si no se parte del conocimiento de las ideas previas de los estudiantes, en el ámbito específico de la disciplina a enseñar.

En este trabajo se presentan los resultados de una investigación bibliográfica que, sobre las concepciones alternativas de los estudiantes relacionadas con el tema de ácidos y bases, abarcó artículos publicados en revistas internacionales, arbitradas, de 1975 a 2001. Asimismo se revisó el tema en Internet. Se encontraron ideas previas de los estudiantes en los niveles de secundaria, bachillerato y universidad que han sido observadas como resultado de diferentes investigaciones y estudios. Se realizó una clasificación de las ideas previas halladas y se hace una serie de recomendaciones para la enseñanza, tendientes a promover el cambio conceptual en los estudiantes.

Se considera que la concepción de ciencia que tengan los profesores, y se maneje en los libros de texto que utilicen, es un factor determinante para lograr el objetivo de la alfabetización científica de los futuros ciudadanos.

## Antecedents

Science teaching in Mexico has changed considerably in the last decade of the XX century. High school curricula have incorporated de STS approach systematically. Yet, the changes overtaken have given relatively little importance to the students' alternative conceptions.

If we want our students to become literate citizens in the science and technology field, it is imperative to orient the scholar education towards a truly meaningful learning, valid in the scientific and technological domain. This cannot be achieved without taking into account the students' alternative conceptions in the specific discipline to be taught.

The science conception held by teachers and textbooks could be, as well, a serious limitation in the acquirement of the objective of scientific literacy of the former students.

## Science conception

Within the last decades, science teaching has evolved from the traditional passive learning –in which the students are passive recipients of the knowledge transmitted by teachers- through discovery learning, all the way

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up to the approach of meaningful learning based upon the alternative conceptions. In the latter, the students' build their knowledge from their very own conceptions.

This approach is based in constructivism, which basically establishes that each individual builds up his/her own knowledge. In the process there may arise some ideas or conceptions alternative to the scientific ones that might be completely different, incomplete or confuse. These ideas may influence or become an obstacle in learning scientific concepts and avoiding to take them into account might be one of the main difficulties for succeeding in the teaching learning process.

In our everyday knowledge, we often assume a "realistic" viewpoint; so, we believe that the world is just as we perceive it; what we don't see or don't perceive does not exist or, at least, it is very hard to conceive.

This "realistic" trend is quite dominant and tough to overcome, especially in the scientific domain, due to the fact that a positivist conception has prevailed among scientists, for a long time. This conception held that science aim was to discover the structure and function of nature, instead of building models to interpret it. In overcoming this positivist viewpoint, we could adopt a position within relativism or constructivism. This position holds that there are several ways to know reality and none of them is necessarily true. Each way is enclosed in a theoretical frame and depends upon the practical necessities it faces.

Constructivism is an epistemology -a theory of knowledge- used to explain how do we know what we know. Knowledge does not reflect an objective, ontological reality, but exclusively an ordering and organization of the world, made up from our experience. Constructivism is, as well, a way of thinking about knowledge; a referent from which models for teaching, learning and curriculum are built.

Within this perspective, scientific knowledge isn't ever extracted from reality itself, instead it comes out of the scientists minds who make models and theories, in an attempt to give meaning to that reality. Scientific theories are not absolute or positive knowledge, but relative approaches that, far from discovering the structure of the world or nature, build or model it.

Science is a process, not only an accumulated product of theories and models. It is necessary that the students understand this dynamic and non-permanent character of scientific knowledge, succeeding in making them to perceive its temporality, its cultural and historical nature. The pupils, as well, must be aware of the relationship between science development with the technological production and social organization and, therefore, of the commitment of science and society.

Within constructivism science is seen as systems of models that describe how the world can be, instead of how it is. These models don't get their validity in the precision with which they describe the world, but in the precision of the predictions that might be based upon them. Science is no longer the search for truth, but it is a process that helps us to explain the world. To teach science, then, becomes an active and social process, used to explain our experience. Science does not ever reach true knowledge, since it does not reproduce exactly the real world. We have models increasingly more and more complex and potent to predict, explain and simulate the world's structure.

If teachers are not aware of this conception of science and textbooks don't reflect it, education will not succeed in making the future citizens able to assume a critical position towards the results of scientific research. The former students will not be able to be skeptic about the supposedly scientifically developed products, which are everyday, found in the counters.

### Alternative conceptions and difficulties in learning Chemistry

One of the basic ideas of constructivism is that the student's learning starts from his/her previous knowledge. Therefore, it is imperative to know how it is constituted, how it is organized and represented.

Persons don't know the world directly, but through the filter imposed by their ideas and expectations. We have ideas that allow us to predict and control events in every domain relevant to us, increasing our adaptation to it. Students' ideas are a construction or cognitive elaboration developed by them, that hinder the acquisition of new learning.

These alternative conceptions are personal constructions, in most cases a product of a non formal or implicit learning, whose aim is to establish regularities in the world, making it more predictable and controllable. Whenever someone tries to understand something must activate an idea or previous knowledge useful to organize and make sense in that situation.

Learning processes, as well as the growing of scientific knowledge, are based in the same mechanism of evolution, or substitution, of old ideas by the new ones. Scientific learning and cognitive development in general are conceived as processes in which ideas, concepts and old meanings are replaced by new ones.

Learning science is a conceptual change process of transformation of alternative conceptions into scientifically accepted ideas. In science teaching, models of conceptual change often assume the need of activation of the student's conceptions, to put them under conflict and later on replace or transform them into scientifically accepted ideas.

The underlying message of research regarding the students' ideas is that if we don't know their thought and why they are committed to that believe, teaching of science will have very scarce possibilities of having an impact.

Some of the difficulties in learning Chemistry are,

1. Existence of different levels of description of matter (macroscopic, microscopic and symbolic)
2. Diversity in the use of successive versions of models and theories along teaching
3. Unavoidable need of understanding the nature of models, being able to get involved in their elaboration and proper use, and to be aware of their instrumental and evolutionary character.

These difficulties are also related to the organization of the student's knowledge, beginning since their implicit theories (previous ideas). Understanding scientific theories implies overcoming the hindrance imposed by his/her alternative conceptions. The way from the early student's intuitive theories to a scientific vision of the world, is known as conceptual change. It involves to overcome organized conceptions in which the world's vision is centered in perceptive aspects (things are just as we see them) to arrive to constructivism. The latter is featured by an interpretation of reality through models.

To fulfill efficacy in scientific education, i.e., in chemical education, it is necessary to guide students towards conceptual change. This implies that the goals, content and methods of teaching take into account the features of the target students and the social and educative demands that frame them.

## The acid base concepts

The subject of acids and bases is particularly challenging in Chemistry. The student must possess a deep understanding of the structure of matter -atoms, molecules and ions- as well as of the chemical reaction and of chemical equilibrium. A deep understanding means a hierarchically organized net of interrelated concepts. The student must be able to represent this net of information –that we call knowledge- within the three Chemistry levels of thought (macroscopic, microscopic and symbolic). When the student is entering the acid and base field, must be able to move constantly among these systems of matter representation and to use each one in the appropriate opportunity.

There are several acid-base concepts and, since all of them are still standing (Arrhenius, Brönsted-Lowry, Lewis, etceteras), they confuse students. This, together with strategies that do not consider the pupils' previous ideas, neither their "natural" learning way, ends in failure of the students learning of the attempted subject.

Acids and bases constitute a central subject in the chemistry curriculum; both in junior and senior high school and in the first semesters of the university. Yet, very little is known about the alternative conceptions in this area. Apparently, textbooks, curricula and teaching practice function without considering the students' related thought.

When a student has problems understanding the concepts related to these substances (acids and bases) it might be safely deduced that he or she will also have difficulties understanding other chemical subjects, since they are so deeply connected.

**Alternative conceptions related to acid base concepts**

This paper accounts for a bibliographic research that covered published papers in international, refereed journals, from 1975 to 2001, related to the students' alternative conceptions, regarding the acid-base subject. These alternative conceptions were also revised in Internet, applying the same criteria of reliance.

Alternative conceptions of the students were found in junior and senior high school, as well as in the university level. These have been reported as a result of research, published in international education journals. It can be observed that there is a lack of research in the subject of acid-base chemistry, since there are not as many papers published in this subject as there are in the structure of matter or chemical equilibrium. The alternative conceptions reported are very similar and focus only in some aspects.

The alternative conceptions of the students may cover different levels (macroscopic, microscopic or symbolic). The little awareness of their own conceptions shows the lack of integration of the conceptions held by the students.

The ideas were classified following specific topics, within the acid base subject, i.e.

1. Macroscopic properties.
2. Reactions and substances behavior
3. Strength and concentration
4. Neutralization and pH
5. Molecular and electric structure
6. Symbolic representations

Table I shows some examples of the ideas found in the literature, that belong to the previously mentioned categories.

**Table I.** Classification and examples of the alternative conceptions of students, found in the literature, relating to the acid-base subject

| Category | Examples |
|---|---|
| Macroscopic properties | • All substances with sharp or pungent odor are acids.<br>• Acidic substances are not to be ingested.<br>• All acids are poisonous.<br>• Fruits are basic. |
| Reactions and substances behavior | • An acid is a substance that does not react with antiacids.<br>• Acids and bases do not react, they simply form physical mixtures. |
| Strength and concentration | • ...the more concentrated the more acidic.<br>• Concentrated acids are more dangerous than concentrated bases.<br>• The difference between a strong and a weak acid is that the latter corrodes materials more quickly.<br>• The product of a reaction between an acid and a base is a salt (Partially correct) |

| | |
|---|---|
| Neutralization and pH | • Neutralization is an irreversible reaction.<br>• pH is a measure of acidity but not of basicity.<br>• In the reaction between an acid and a base, there is no heat released. |
| Molecular and electric structure | • Acids and bases react by sticking together to form one particle.<br>• Bases do not contain hydrogen. |
| Symbolic representations | • HNaO is an acid. |

Several kinds of relations may be established between the students' alternative conceptions and the history of these scientific concepts. The genesis of the relation could be found in an ancient definition, no longer accepted, or in confusion related to the several concepts in use nowadays.

Today's acid base concepts cannot be considered right or wrong, they simply are useful or not. They satisfy the creative function of suggesting parallel factors that had not been related previously. These concepts must expand and change because the chemical facts that they attempt to organize also expand and change.

## General recommendations to achieve meaningful learning, based on the alternative conceptions

**Historical development of concepts and its teaching.**
History has played an important role in the last decades in the teaching of science. Introducing the human factor, to be aware of the process of construction of scientific knowledge and to witness how it became what it is today, is a very useful tool.

The historical development of acid base concepts is especially interesting and helps to clear up some confusions and ideas held by the students. Many of the students' ideas may be related to the way some ancient scientists approached chemical facts. Adding a historical component to this issue and involvement of teaching strategies based upon constructivism –that take into account the alternative conceptions- may considerably help the conceptual change, achieving meaningful and lasting learning.

**Cooperative learning, laboratory and electronic media**
Cooperative learning may be a useful way to make alternative conceptions arise, as well as helping in the conceptual change of the group.

Chemistry teachers have precious opportunities in the laboratory work, but it has to change to be adapted to constructivism and become a true learning experience for the students.

Of course, we cannot avoid mentioning the electronic media (multimedia, simulations, the web, and so forth) which are also a very relevant means of learning.

Constructivism shows us science as a very important tool to understand the world. Within this approach the alternative conceptions play an essential role. We all start our learning from our previous knowledge; so, it is unavoidable to know it and see how close it is to the scientific knowledge. If the scientific knowledge is built upon erroneous, deformed or incomplete basis, it will not be assimilated properly and soon will be forgotten.

## Conclusions

If we want our students to become literate citizens, as far as science and technology are concerned, we must plan the whole curriculum accordingly:

- To start with, the students' previous ideas must play a central role in science teaching.
- The history of science may be a conducting axis to establish parallels and differences with today's accepted scientific models and theories and may help in guiding students towards conceptual change.

- Tools like the techniques of cooperative learning and the incorporation of computer and other electronic media have become an everyday necessity in the classroom; therefore, science teaching must count on them in every school. But their use should be bound to the achievement of conceptual change by students.
- Teachers must be aware of the conception of science held in textbooks and select the ones that agree with the nowadays conception to succeed in making the future citizens able to assume a critical position towards the results of scientific research.

**References**

Banerjee A. C., (1991). Misconceptions of students and teachers in chemical equilibrium. *International Journal of Science Education*, 13(4), 487-494.

Bardanca, M., Nieto, M., Rodríguez, M. C. (1993). Evolución de los conceptos ácido-base a lo largo de la enseñanza media. *Enseñanza de las ciencias,* 11(2), 125-129.

Barker, V. (2000). Beyond appearances: students' misconceptions about basic chemical ideas. *A report prepared for the Royal Society of Chemistry.* 42-45.

Bell, R. P. (1969). Acids and Bases, their quantitative behaviour. Methuen & Co. Ltd. and Science Paperbaks, London, Great Britain.

Bodner, G. M. (1992). Why changing the curriculum may not be enough. *Journal of Chemical Education*, 69(3), 186-190.

Borsese, A. (2000). Comunicación, lenguaje y enseñanza. *Educación Química,* 11(2), 220-227.

Caamaño R. A. (2001). La enseñanza de la química en el inicio del nuevo siglo: una perspectiva desde España. *Educación Química*, 12 (1), 7-17.

Camacho M., Good R., (1989). Problem solving and chemical equilibrium: successful versus unsuccessful performance. *Journal of Research in Sciente Teaching*, 26(3), 251-272.

Carretero, M. (1993). Constructivismo y Educación. Ed. Edelvives. España.

Carretero, M. (1996). Construir y Enseñar: Las ciencias experimentales. Aique Grupo Editor, España.

Cros, D. & Maurin, M. (1986). Conceptions of first-year university students of the constituents of matter and the notions of acids and bases. *European Journal of Science Education* 8 (3), 305-313.

Cros, D., Chastrette, M., Fayol, M. (1988). Conceptions of second-year university students of some fundamental notions in chemistry. *International Journal of Science Education,* 10, 331-336.

De Manuel, T., Jiménez, M., & Salinas, F. (2000). Las concepciones sobre ácidos y bases de los opositores al cuerpo de profesores de secundaria. *Alambique: Didáctica de las ciencias experimentales*, 24, 66-67.

Díaz, B. F. & Hernández, R. G. (1998). Estrategias docentes para un aprendizaje significativo, McGraw Hill, México.

Felder, R. M. (1996). Active-inductive-cooperative learning: an instructional model for chemistry?. *Journal of Chemical Education,* 73(9), 832-836.

Gabel, D. (2000). Theory-based teaching strategies for conceptual understanding of chemistry. *Educación Química,* 11(2), 236-243.

Gabel, D. (1999). Improving teaching and learning through chemistry education research: a look to the future. *Journal of Chemical Education*, 76(4), 548-554.

García-Leija, P. (2001). Los conceptos ácido-base e ideas previas relacionadas. Tesis de Licenciatura, Facultad de Química, Universidad Nacional autónoma de México (UNAM). México.

Garnett P. J., Garnett P. J. & Hackling M. W., (1995). Students' alternative conceptions in chemistry: a review of research and implications for teaching and learning. *Studies in Science Education*, 25, 69-95.

Gil Pérez, D. (1993). Contribución de la historia y de la filosofía de las ciencias al desarrollo de un modelo de enseñanza-aprendizaje como investigación. *Enseñanza de las ciencias*, 11(2), 197-212.

Griffiths, A. K. (1994). A critical analysis and synthesis of research on students' chemistry misconceptions. In: Schmidt, H. J., Problem solving and misconceptions in Chemistry and Physics. ICASE, Dortmund,

Hand, B. M. (1989). Student understandings of acids bases: A two year study. *Research in Science Education*, 19, 133-144.

Hawkes, S. (1992). Arrhenius confuses students. *Journal of Chemical Education*, 69(7), 542-543.

Herron, D. & Nurrenbern, S. (1999). Improving Chemistry learning. *Journal of Chemical Education*, 76(10), 1354-1361.

Hesse, J.J., & Anderson, C. W. (1992). Students' conceptions of chemical change. *Journal of Research in Science Teaching*, 29(3), 277-299.

Hodson, D. (1996). Practical work in school science: exploring some directions for change. *International Journal of Science Education*, 18(7), 755-760.

Huann-shyang Lin (1998). The effectiveness of teaching Chemistry through the history of science. *Journal of Chemical Education*, 75(10), 1326-1330.

Jensen, W. B. (1980). The Lewis Acid-Base Concepts. John Wiley & Sons, Inc. A Wiley-Interscience Publication, USA.

Jensen, W. B. (1998). Logic, history and the Chemistry textbook: I. Does Chemistry have a logical structure? *Journal of Chemical Education*, 75(6), 679-687.

Jensen, W. B. (1998). Logic, history and the Chemistry textbook: II. Can we unmuddle the Chemistry textbook? *Journal of Chemical Education*, 75(7), 817-828.

Jensen, W. B. (1998). Logic, history and the Chemistry textbook: III. One chemical revolution or three? *Journal of Chemical Education*, 75(8), 961-969.

Nakhleh M. B. & Krajcik J. S. (1993). A protocol analysis of the influence of technology on student's actions, verbal commentary, and thought processes during the performance of acid-base tritations. *Journal of Research in Science Teaching*, 30(9), 1149-1168.

Nakhleh, M. B. & Krajcik, J. S. (1994). Influence of levels of information as presented by different technologies on students' understanding of acid, base, and pH concepts. *Journal of Research in Science Teaching*, 31(10), 1077-1096.

Osborne, R. & Freyberg, P. (1995). El aprendizaje de las ciencias: implicaciones de las "ideas previas" de los alumnos. Ed. NARCEA, Madrid.

Paixao, M. F. & Cachapuz, A. (2000). Mass conservation in chemical reactions: the development of an innovative teaching strategy based on the history and philosophy of science. *Chemistry Education: Research and Practice in Europe*, 1(2), 201-215.

Pozo, J. I. & Gómez Crespo, M. A. (1998). Aprender y enseñar ciencia. Ediciones Morata S. L., Madrid.

Pozo, J. I., Gómez Crespo, M. A., Limón, M. & Sanz Serrano, A. (1991). Procesos cognitivos en la comprensión de la ciencia: las ideas de los adolescentes sobre la química. C.I.D.E. Madrid.

Rayner-Canham, G. (2000). Química Inorgánica Descriptiva. Pearson Educación, 2ª edición, México.

Rayner-Canham, G. (1994). Concepts of acids and bases. *Journal of College Science Teaching*, 23(4), 246-247.

Ross B. & Munby H. (1991). Concept mapping and misconceptions: a study of high-school students' understandings of acids and bases. *International Journal of Science Education*, 13(1), 11-23.

Schmidt, H. J. (1991). A label as a hidden persuader: chemists' neutralization concept. *International Journal of Science Education*, 13(4), 459-471.

Shiland, T. W. (1999). Constructivism: the implications for laboratory work. *Journal of Chemical Education*, 76(1), 107-108.

Sisovoc, D. & Bojovic, S. (2000). Approaching the concepts of acids and bases by cooperative learning. *Chemistry Education: Research and Practice in Europe*, 1(2), 263-275.

Toplis, R. (1998). Ideas about acids and alkalis. *School Science Review*, 80 (291), 67-70.

Treagust, D., Duit, R., & Nieswandt, M. (2000). Sources of students' difficulties in learning Chemistry. *Educación Química*, 11(2), 228-235.

Web site: http://ideasprevias.cinstrum.unam.mx:2048

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# 101 EVENT CENTERED LEARNING FACING INTERDISCIPLINARY PROBLEMS

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**Abstract**

The Science, Technology and Society (STS) perspective is based on the proposition that science teaching should not only prepare for the understanding of natural phenomena, but also consider the relations among science, technology and society. This thesis, situated as an intervention in the shool environment, presents a study which aim was to analise the didatic possibilities of the Event Centred Learning (ECL) approach for introducing STS in secondary school teaching. In order to turn possible the analysis, we considered issues like how to reach teachers, pupils and schools; about the making of teaching materials and about how to approach interdisciplinary questions and their implementation in the school environnement. From those starting considerations it was possible to evaluate the ECL approach as related to the following aspects: issues of transversability and interdisciplinarity; its role in teacher and students development; as a teaching strategy; the objectives of Scientific and Technical Literacy. The Goiania radioactive accident was choosen as the event for the elaboration of a teaching module that was introduced in two classes of the 8th grade (age about 15) of fundamental school. The dimension of the Goiania accident makes it possible the discussion of various aspects linked to economics, health, environment, social and personal risk. On the other end, the understanding of scientific and technological questions is also involved. The event also turns it possible to create an adequate climate for working the scientific dimension and its connections with the social and technological ones. The production of the teaching materials according to the demands of the STS perspective was supported by concepts derived from the Didactics of Science. For inserting the approach in schools, we defined procedures tuned to the features of ECL and the school subjects, which jointly were involved in the implementation of the module (teachers of Geography, Portuguese and Science). Two schools were involved during eight weeks, using an average of three weekly lessons. The main results to be stressed are that the approach made it possible to treat the various dimensions of our object of study, and to consider different interdisciplinary levels (curricular, pedagogical, and didactic), and that the interventions were meaningful experiences for teachers, pupils and for the schools. The study also led to outlook a strategy, which may be named "innovation by infiltration" that could be more effective than radical curricular changes.

## Introduction

The Science, Technology and Society perspective (STS) is based on the assumption that science teaching, besides providing knowledge for one to understand natural phenomena, must also consider the relationships established between Science, Technology and Society. This report presents a research which can be defined as an intervention in the school environment and whose main objective was to analyse the didactic possibilities of the Event Learning Centred Approach (ELC) in an attempt to introduce STS in elementary school (7th and 8th grade). In order to accomplish this analysis, we have developed reflections and considerations on how to reach teachers, students and schools, how to elaborate relevant didactic materials and how to address interdisciplinary issues and its implementation in the school environment.

The starting point of the investigation was the building of a teaching module called "The Goiânia radioactive accident", which was experimentally applied to two 8th grade groups (30 students between 13 and 15 years of age each). One of them was part of the public school system; the other one pertained to a private school.

The activities involving students lasted for five weeks during 1998 (private school) and 1999 (public school). Throughout this period, the module was carried out by handling six classes every week, comprising the following subjects: Science, Geography and Portuguese. This means that, for each of the subjects involved, just about half of the classes were dedicated to the module.

The centralising event chosen was the Goiânia radioactive accident. The option for a theme that is related to nuclear technology was due to its distinct emotional appeal and to the opportunity to approach a large range of aspects, like the ones related to social responsibility, public health, personal and social risk, along with the scientific and technological issues usually addressed.

Students activities were preceded by meetings with the teachers who would take part in the research (six meetings, ninety minutes long) in order to present to them the STS perspective and the ECL approach, the didactic materials designed to develop the subject and, first of all, to discuss the role and the tasks concerning each one of the teachers, as a way of encouraging interdisciplinary work.

During the first meetings, the tension was concentrated in two points: the command of the subject and the transposition of concepts from the context of the accident to the specific context of each educational subject. This interchange must be very careful not to betray neither the facts and concepts nor the intentions of the educational subjects. To overcome this barrier, special meetings were set as a way of ensuring that concepts would be understood and that guiding lines would be settled which would allow all of us to handle many of the different contexts suggested by the theme itself. This creative process resulted in the fact that we (teachers and researcher altogether) were able to face the fierce battle of constructing real interdisciplinarity.

The event centred learning approach introduced the Goiânia accident in a comprehensive way, that is to say, studying the Goiânia accident meant investigating different attributes of radiation and its effects, including social and technological aspects. In this sense, integrated work meant restoring the totality of the event and outlining the interactions and interrelations between different aspects detected in the event. This approach demanded interaction between school subjects and generated substantial changes in educational dynamics. Therefore, the problem-situation was not prescribed exclusively to study or to investigate nuclear radiation and the manufacture of the equipment implied in the accident or still the social facts involved (the social implications given by the discard and opening of an equipment carrying radioactive material): addressing this particular event imported in considering the different dimensions it would suggest.

From the point of view of the natural sciences, the approach should encompass the study of the radiation phenomenon, its interaction with matter, its biological effects (that means the conceptual fields of Physics, Chemistry and Biology) and the concepts of irradiation and contamination inside this context (a nuclear accident). Throughout this process, facts that are important for the scientific knowledge development dynamics (contingency of theories, conflicting opinions and explanations given by scientists) were mentioned and reflected upon. In summoning their own understanding, students were able to recognise the possibility of different ways of solving a given problem.

Regarding technology, the approach has emphasised its role in knowledge development and application to satisfy social demands and therefore it has provided the means for the students to understand the stress that technological progress impose upon society's life and rhythm.

From the point of view of social life, the approach opened debates that rendered clear their influence as citizens and made them think about issues deeply rooted in common life, for instance ethical and environmental questions posed by scientific and technological development.

The continuous growth of understanding about the many dimensions that this subject matter has brought to the teaching-learning situation forced us to confront different levels of educational interdisciplinarity, as mentioned by Lenoir (1998). The first one — curricular interdisciplinarity — made its appearance while we were choosing the subjects that, by using the same topic and didactic material, would comprise the core group capable of meeting the needs established by the approach itself, that is to say, easing the students understanding of the mutual dependence between Science, Technology and Society.

Based on the approach requirements, the conceptual parameters involved and the curriculum set for each school subject, we decided the work could be shared among the teachers in charge of Science, Geography and

Portuguese. The Science teacher could manage to work out the interdependence and convergence of displaced concepts — scientific notions dislocated from scientific subjects (Physics, Chemistry and Biology) while the Geography teacher could address technological, social and environmental issues. On the other hand, such displacements redefine the subject matter and, in order to consider it, we must readapt the language in use. Accordingly, we decided to include the Portuguese teacher, who would be able to work out this aspect while helping and supervising the students in writing.

The challenge of the second level of educational interdisciplinarity — didactic interdisciplinarity — started when we had to establish how to highlight and consider all the different sides of the issue. We decided to elaborate a teaching module based on two texts: *The Goiânia Accident* and *Nuclear Radiation*. In the first one, the accident and its consequences are described in detail and, in order to stress the social, political and environmental sides of the matter, the document was enriched with statements from people directly involved (physicians, technicians and physicists). Even though this document was mainly informative, we tried to maintain some conceptual treatment of the issue, which should keep its manifold quality.

Regarding the weaving of the second text, which had a conceptual nature, we faced greater adversities, related essentially to the decision about what course the text should follow, what atomic model it should use and how it should organise its levels of enunciation. A plunge into the concepts of Science Didactics supplied us with the elements needed to face de difficulties inherent to the transposition process — from a formalised wisdom (wise wisdom) to an educational wisdom or knowledge. As an example, the assessment of the empirical command of the subject leaded to the mapping of the level of conceptual representation the students were capable of, in relation to the phenomenon under scrutiny; this diagnostic provided the means for defining the itinerary, the models and the conceptual structure of the text and, at the same time, emphasised the social function of knowledge and presented a conception about how it is created.

The challenge of the third level of educational interdisciplinarity — pedagogical interdisciplinarity — started when we had to plan the intervention, i.e. when we needed to have recourse to the idea of integration. This measure takes us to several questions about subject and object of investigation, as for instance: why — and what — should we integrate? Who does it? How can we promote the integration process developed by the subject?

To answer these questions, we must confront the interdisciplinary context.

The very fact of choosing ECL as a way of orchestrating scientific, technological and social traits of knowledge is illustrative of answers we found for at least two of the questions posed above: what should we integrate, and why. The interrogation "who integrates?" may be considered from two points of view. The first one arose during the task of articulating the proposal with the programs for each school subject. Here, the teachers were the authors of the integration. The second one came into sight when it was time to synthesise knowledge, and then the students were responsible for the process.

The first stage of the project consisted in a negotiation between researchers and teachers, for the course of action was partially determined by the approach and, starting from these pre-defined guidelines, the teachers should articulate the themes and arguments presented by the module with the program established for each school subject. The main points agreed upon were:

- Students would be held responsible for the integration of knowledge;
- Due to the student's responsibility towards their own learning process, the context would demand an inversion of roles. The development of the concepts would be, from now on, a task for the students, while the teacher would assume the role of a mediator responsible for organising and keeping up the transit between students and knowledge;
- Students should do teamwork.

To corroborate the definitions above and to offer support so the teachers could face their tasks, the first step taken was to present and discuss the conception and the main attributes of both the STS perspective and the ECL approach. We stated that, from our point of view, suggesting didactic activities that would create areas of dialogue and exchange among students and situations that would encourage knowledge reorganisation, i.e. that would demand an effort towards a synthesis of the discussions in order to structure one's thoughts, was a feasible path leading to the goals we had set.

In both interventions, the teachers responsible for the Geography classes were the ones who had more satisfactory performances. They were able to harmonise the context of the event with the context of the school subject, suggested diversified activities to promote the discussion about social and technological context, emphasising the uses of radiation. The Portuguese teachers did not suggest different activities, but they were diligent in organising the process and structuring the readings. We had problems with Science teachers in both interventions.

We could at first suppose that these teachers were in a better situation in relation to the others, because many of the concepts used to understand and explain the event had already been submitted to the process of didactic transposition (which resulted in the document *Nuclear Radiation*) and were part of the school curriculum, in its Science field. Nevertheless, even after the discussions, they were not ready to face the challenge of interdisciplinary work. Through the analysis of the debates and interviews, we can indicate some of the main obstacles.

The first barrier consists in the feeling of being evaluated, regarding the specialised knowledge, by a researcher in his/her field of activity. This is an element that generates strong resistance. A second ingredient may be found in the educational process each of the professionals has gone through. The course followed by Geography teachers creates, due to the very nature of its aims, many possibilities for interdisciplinary work. This is true also for the course followed by Portuguese teachers, because the language can dwell in varied contexts. As for the educational process of the Science teacher, it is very strict regarding formalism and it hardly consents in discussions that could give way to major changes in the object of study.

Using concepts formulated by Bernstein (1971), we may suppose that an education in a scientific field tends to produce teachers inclined to "classification" and to "categorising", where the first term refers to the "strength" of the frontiers between school subjects and the second one to the level of control over the selection and organisation of the knowledge in the pedagogical relationship. In this case, teachers of Science (a subject that is traditionally considered very specific and sometimes troublesome) would find it more difficult to interact with teachers from other knowledge fields.

In general, we can say that, in their writings and other manifestations, the students made a point of stressing all the three aspects (scientific, technological and social). Concerning the scientific context, we clearly note there was the intention of selecting and working with concepts that are important for the comprehension of the phenomenon; they have highlighted also the different contexts where radiation occurs. In five of the works created by them at the end of the program, the students were willing to accentuate the need to look for information before taking any decisions about something unknown. Other projects discussed the effects and symptoms that can be ascribed to being exposed to radiation, suggesting that people should consult a physician as soon as possible, delivering a complete report about what had happened and always mentioning any contact with unknown substances or chemicals.

Another point that deserves prominence is the fact that the students did not make use of a current practice when it comes to school papers and essays: the plain copy from books or other sources, even when defining concepts. The students were always looking for their own formulations, even when at first they could not find it. The teachers evaluated the writings and other kinds of work were above average, if weighted against other works made by the same students.

*"Working with STS inside the school was a good experience, for the students well as for the teachers. With this project, we were able to notice the potential we have to develop this kind of activity and also to recognise what are our deficits, not only in adapting scientific texts to a language that is more adequate to the age group of our students".*

*"The record shows all the different stages of the work developed in the classroom. Besides the interest of the case itself, it was interesting to observe, in the reports about the meetings with the researcher, how the particularities of each teacher and subject produced questions for all fields of knowledge, following the 'point of view' of each subject..."(Carmem Cecília Pereira, Portuguese teacher).*

The examination of the data collected in this research, allow us to stress some very important aspects established by the ECL approach. First of all, we will consider the various situations that authorised teachers, students and researcher to get involved with interdisciplinary issues.

The students started to get involved with interdisciplinary questions right at the first discussions intended to outline the main activity. The most important consequence of this commitment was the request, expressed by the majority of the students groups, to modify the original activity. The analysis of the final production also shows that the close attention dedicated to the articulations between the three components (Science, Technology and Society) could be felt in all of the works. They selected and elaborated concepts that are very important for the understanding of the phenomenon, presented different sides of it and indicated other equipment where the phenomenon would occur, discussed effects, symptoms and applications that can be ascribed to radiation.

The teachers had to face interdisciplinary issues in several moments. During the initial organisation, which was designed to offer them support to deal with the changes imposed by the new approach, they had to face situations that involved negotiating and articulating of information and knowledge from other fields, as well as the transposition of questions and issues to different contexts. They also had to confront interdisciplinarity in the classroom, when answering all the questions posed by the students.

Finally, another significant element was the engagement of the researcher who, besides participating in all steps and situations mentioned above, also concentrated the attention on interdisciplinary problems while defining, articulating and developing the didactic material that was designed to prompt discussions about social, scientific and technological aspects.

The way we see it, the pro-active engagement shown by Portuguese and Geography teachers, their discussions, their suggestions of activities, their commitment with the students and the quality of their production, are elements that authenticate the positive evaluation of the effectiveness of such interdisciplinary confrontations.

Another element that can be seen as a positive appraisal of the approach is the definition of a space for discussion, which made possible the constitution of relationships between systematised knowledge and real life issues. Discussions about topics like responsibility, lack of information, lack of training (noted in specialists, technicians, medical class and population in general) have been stated and discussed.

We can conclude, from the reflections and examinations made in the course of this research work, that de STS perspective assumes an interdisciplinar viewpoint and requires a series of complementary actions, including initial and continuing education for the teacher, elaboration of didactic and paradidactic materials and, most of all, the end of the curricular reforms or orientations done without the human resources training necessary for effective fulfilment of the changes.

In this sense, we agree with Fourez (1994) when he states that to create an interdisciplinar model, there must be a definite formation for teachers and for students. When it comes to social, technical or political decisions, hurried actions may be dangerous. Advancement must come step by step. This is necessary because in an interdisciplinary work there are no definitive rules to determine which point of view we should prefer. Decisions like this must be submitted to negotiation during the project application. According to Fourez, interdisciplinary work is similar to a political trajectory: none of the sides involved has the right to impose rules.

We believe that the we are allowed, by the experience described, to foresee a strategy, that we could call *innovation by infiltration* and that is more effective for the introduction of radical changes (medium and long range) than other procedures which intend to impose major and immediate changes to the curricular structure.

Through that strategy, teachers, technical team members and managers would acquire new practices and concepts, founding a new modality of continuing education aiming at a preparation for interdisciplinary practice.

With the appropriate adaptations, the observations above can also indicate alternatives for teacher education, mainly in the scientific areas, where highly specialised fields and professionals seem to contribute to the drawing of clearly marked frontiers. Ideally, this would be done through the institution of guided probation inside schools where projects like the one described in the case studies would be applied in a day-to-day basis. If this were not possible, the reading and examination of case studies, properly edited and published, would constitute a first approximation towards the practice we support. Another good strategy would be — why not? — the collective engagement of Teaching Methodology and Practice students, from different fields of knowledge, in preparing new activities using the ECL approach.

### References

ASTOLFI, J. P. & DEVELAY, M. **A Didática das Ciências.** Campinas,SP : Papirus, 1990.

BERNSTEIN, B. "On the classification and framing of education knowledge". In: YOUNG, M. F. D. (org.) Knowledgeand Control. Collier – Macmillan, London, 1971.

FOUREZ, G.; LECOMPTE, V. E.; GROOTAERS, D.; MAATHY, P. & TILMAN, F. **Alfabetización Científica y Tecnológica**. Buenos Aires, Argentina: Ediciones Colihue, 1994.

JANTSCH, A. P. & BIANCHETTI, L. "Imanência, História e Interdisciplinaridade". In: JANTSCH, A. P. & BIANCHETTI, L. (orgs.). **Interdisciplinaridade : para além da filosofia do sujeito**. Petrópolis,RJ: Vozes, 1995.

LENOIR, Y. "Didática e Interdisciplinaridade: Uma Complementaridade Necessária e Incontornável". In: FAZENDA (org.). **Didática e Interdisciplinaridade**. Campinas, SP: Papirus, 1998.

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# INTRODUCTORY TEACHING TOOLS FOR THE STUDENTS OF NON-CHEMISTRY MAJOR COURSES: MYSTERIES, SCIENCE-FICTIONS AND CHINESE CLASSIC LITERATURE – FORENSIC DETECTION OF AN ARSENIC MURDER IN THE 12TH CENTURY —

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**Abstract**

We have tried to use several famous mysteries, science fiction books and various classic literatures as introductory tools in the sequential lectures for freshmen or sophomores of these courses in several universities. In these decades, in several universities or colleges in Japan, a strong chemophobia exists among the students of non-chemistry major courses which is a significant barrier to carrying out the general chemistry lecture. The students have frequently shown morbid fear against chemical symbols, structural formulas like the benzene ring, and so on. These trends appear not only in law, economics and pedagogy students, but also, surprisingly, in students of computer science or nursing courses. Perhaps it may be the result of physics chauvinism and/or the inaccurate articles and propaganda of mass-communication media. To overcome these difficulties, we have selected various literary works from ancient works to recent works including mystery and science fiction novels. During the selection, we have found the interesting example of the forensic arsenic detection prior to James Marsh (five to seven centuries ago). In one of the Chinese Four Great Curious Books, "Shui-Ho-Chuan" (English title: "All Men are Brothers" translated by Mme Pearl Buck), which was written by Lo Kwan-Chung in the beginning of Ming-dynasty (around 1350), it was described that the black arsenic deposits (arsenic mirrors) can be observed on the skeleton after the cremation of arsenic-poisoned victims. Such examples of new approaches have been able to induce somewhat positive responses and to remove apparent shields of students' chemophobia at least partially.

In these decades, we have recognized the strong chemophobia that is widely spread among many students of non-chemistry major courses. They have frequently shown morbid fear against chemical symbols, structural formulas like the benzene ring, and so on. These trends appear not only in law, economics or pedagogy students, but also, surprisingly, in the students of computer science, electronics and nursing courses. Perhaps it may be the result of physics chauvinism and/or the inaccurate articles and propaganda of mass-communication media.

Most of these students are thinking that knowledge of chemistry is thoroughly useless and only valid for "mad scientists" like Dr. Viktor Frankenstein. These prejudices against chemistry seem to be derived at least partly from the teachings and modern textbooks that are used in secondary schools, which are rich in physico-chemical and mathematical topics and exercises. (We have once found the following startling expression in an introductory science book: "Chemistry is rather a newer science than physics, geology, biology and medicine. Therefore the coverage is much narrower than those sciences of long and glorious history.")

Some of our colleagues are eager to introduce various teaching aids such as audio-visual tools and self-teaching computer software, to overcome these difficulties. However, it seems these aids only have slight effects on students because of the student's groundless prejudice against material science and chemistry. It is also interesting and effective to introduce the laboratory practice concerning Crime Lab Experiments [Barber: 1991] to science teaching, but our facilities are rather poor to cover the recent developments of forensic science.

Therefore, we have tried to use several famous mysteries, science fiction works and other literary works as introductory tools in the sequential lectures for the freshmen or sophomores in these courses in several universities. These new approaches have been able to induce somewhat positive responses and to remove apparent shields of student's chemophobia at least partially.

On the selection of texts, there are some books about forensic science, which were produced by A. C. S. (Gerber: 1983, Gerber and Saferstein: 1997, Stocker: 1997). All of them contain chapters concerning fictitious topics such as Sherlock Holmes mysteries, or Dorothy Sayers, Umberto Eco, and Patricia Cornwell books. We have found much interesting chemical descriptions in these, and other literary works and historical readings, which have been overlooked for a long time. These topics are seemingly impressive to students because they are contrary to their customary expectation. Several examples will be shown in the following.

### Forensic detection of arsenic murder

Lo Kwan-Chung's "Shui-Ho-Chen" (English Translation was carried out by Mme. Pearl Buck, "All Men are Brothers") is one of the "Chinese Four Great Curious Books." This long novel has many chapters, and several parts were compiled into the famous pornographic novel "Chin-Ping-Mei."

Wu Ta-Lang, the elder brother of the brave hero Wu Sung, was poisoned by his beautiful wife Pan Chin-Lieng (Gold Lotus). She obtained white arsenic from Hshi-Men Ching, her rich lover and usurer. After Wu Ta-Lang's death, she sent her husband's corpse to the crematorium, and immediately married Hshi-Men. Wu-Sung was already imprisoned by a false charge.

Several years later, Wu Sung returned to his home by imperial amnesty. His brother's ghost appeared in the night and told him that his wife and Hshi-Men poisoned him to death. Wu Sung soon visited the coroner.. Coroner Ho Chu told him "We have found black spots on your brother's burnt skeleton after cremation. This spot proves that he was poisoned by white arsenic, but it was strictly hidden to avoid the accusation of Hshi-Men."

The "black spots on the burnt skeleton" seem to correspond to the "arsenic mirror" which was found to prove the existence of arsenic in the victim's organs, which was introduced by English chemist R. Marsh in 1828. The date that this long novel was written is estimated to be 1350, at the end of Yuan dynasty or the beginning of Ming dynasty. Therefore, such arsenic detection has a long history in China prior to the modern forensic chemistry discovery.

### Platinum chemistry description in Casanova's "Memoire"

Marchionesse d'Urfe was one of the eager alchemists in Paris. Casanova visited her laboratory and was shown many products made by her. Among them, beautiful silver trees (l'arbore de Diane) and automatically coal-feed atanor are her boasting products.

She showed Casanova a small pot filled with platinum metal, which was given to her by the English alchemist R. Wood, and said that "This metal cannot be dissolved in nitric or hydrochloric acid, but the mixture (*aqua regia*) dissolves it easily. The addition of salmiak (ammonium chloride) to this *aqua regia* solution produces insoluble white precipitate (namely ammonium hexachloroplatinate)."

This description is dated at around 1757. It is probably one of the earliest platinum chemistry texts in the world with the exception of ordinary textbooks.

Such descriptions were written by non-chemists (or at least non-professionals) but the content seems to be very accurate and interesting, which seems to be important from our viewpoints.

Although most of the students have read only the translation of the greatly abridged (juvenile) version of these classics, it seems to be very effective for them to read again the perfectly translated ones which can be purchased today in pocket-book size.

Such approaches are effective in removing (or at least curtailing) the barrier that students have towards the natural science lectures (including chemistry) that results from a prejudice of undetermined origin.

**Results and Discussion:**

It is very difficult to evaluate clearly the consequences that our lectures have on the freshmen or sophomores over a short period, because the expected positive effects will appear rather slowly after the lectures. The students' responses in the reports or the answers in the terminal examinations are not likely to be very indicative in most cases. Perhaps it may be due to their inexperience with these topics, which were selected by us from very different perspectives and which were contrary to their expectations. Therefore, only qualitative evaluations are possible at this stage. However, a large number of these students (ca. 90%) have shown astonishment at the unexpected discovery of the universality (or ubiquity) of chemistry (or material science) in literature or historical descriptions. They had been under the impression that the natural sciences (including chemistry) are strictly self-conclusive and that there appearance in other areas would therefore be extremely rare, or negligibly small.

It seems also remarkable that the student's questions related to chemistry or natural science became much more clear and precise than they were before the serial lectures by us. At the beginning of each semester, many of them would make somewhat absurd or incoherent questions concerning material science, perhaps because of their very narrow perspectives or their misconceptions. These may be due to the influence of mass media's inappropriate and exaggerated reports. The frequency of these rather primitive questions decreased gradually but remarkably.

It is also important for many students to be aware that the natural science itself has a long history apart from many philosophical (or metaphysical) areas. Most of them believe that today's science has been developed in recent years (for instance, in only one-decade) like many technological or engineering products. After becoming aware of the long history of science, most of them are seemingly capable of having a much broader and flexible understanding of various phenomena. After taking our lectures for about a half semester, several students were able to point out the serious errors in newspapers and TV news reports.

Using these non-ordinary literary introductory tools, which were assumed to be non-chemistry (or non-scientific) topics by most students, seems to be a rather effective way at removing some parts of the student's chemophobia shields. This will hopefully improve their scientific knowledge in their future lives.

Our trials at using literature or historical works as teaching aids are still continuing. Our continued research will elucidate more effective examples and better tools for use in introductory courses. Along with several colleagues, we are now making selected collections of these teaching tools, and parts of our lecture notes have been published in small books [Imamura and Yamasaki, 1987, Yamasaki, 1989]. Other general references and lists of mysteries and science fiction books are shown below.

## References

### Recommended general references.

J. Barber, "Teaching Science through Crime Lab Investigations", *International Newsletter on Chemical Education,* No.35, 6-9(1991).

Samuel Gerber : "Chemistry and Crimes"(A.C.S. ) (1983)

Samuel Gerber and Richard Saferstein : "More Chemistry and Crimes, from Marsh Test to DNA Profile"(A.C.S.) (1997)

T. Imamura and A. Yamasaki, "Mystery and Chemistry (in Japanese)" (Shokabo) 1987

W. B. Jensen, "Captain Nemo's Battery: Chemistry and Science Fiction of Jules Verne", *Chemical Intelligencer,* 3(2), 23-32(1997).

Peter Nicholls : "The Science in Science Fiction" (A.A.Knopf) (1983)

J. H. Stocker: "Chemistry and Science Fiction"(A.C.S.) (1997).

A.Yamasaki, "Chemistry and Science Fiction (in Japanese) " (Shokabo) 1989.

A.Yamasaki and A. Furuhashi, "SF and Mysteries as the Teaching Tool for the Students of Non-Chemistry Major Courses", Abstracts of the 16th ICCE (Budapest, 2000)

SF Bibliographic Collection (Five volumes. Compiled by Fujio Ishihara, Professor Emeritus, Tamagawa University) and its database Version.

### Selected Topics and Corresponding Examples (only partial) used in our Lectures in these years:

*Nuclides, Isotopes, Radioactive Decay*
Isaac Asimov: "Pate de Foix Gras", "The God Themselves".
Robert Heinlein: "The Door into the Summer"

*Gaseous law*
Jules Verne: "Cinq semaines en ballon, voyage de couvertes(Five Weeks upon Balloon)".
thermal expansion of gases

*Allotropy, Polymorphism*
Jules Verne: "Etoile les sud(South Star)". artificial diamond
Michael Crichton: "Congo" semiconductor diamond
Arthur C. Clarke: "The Fountains of Paradise"

*unimolecular carbon fiber*
(fullerenes or nanotubes)
Kurt Vonnegut, Jr.: "Cat's Cradle" Ice 9 (fictitious)

*Electrochemistry*
Jules Verne: "Vingt mille lieue sous les mers" (20000 miles under the sea)",
Bunsen electric battery
Dorothy Sayers: "Abominable History of a Man of Copper-Fingers"
Sheffield plating, cyanide bath

*Analytical Chemistry, Forensic Chemistry*
Lo Kwan Chung: "Shui-Ho-Chen(All men are brothers)

*historical description of arsenic murder detection*
Sir Arthur Conan Doyle: "The Study in Scarlet"

*blood stain identification*
Dorothy Sayers: "Strong Poison" Marsh test
Ed McBain: "Poison" nicotine color reaction
Patricia Cornwell: "Post Mortem" laser fluorescence

*Inorganic Toxic Substances*
Barbara Pole: "Primadonna at Large" conc. ammonia solution
Alisa Craig (Charlotte McLeod): "The Terrible Tide"

*ammonia and bleach*
F. W. Crofts: "The Death of Andrew Harrison (Death in Cygnette)"
carbon dioxide (actually, carbon monoxide)
Agatha Christie: "The Pale Horse" thallium compounds

*Natural Organic Chemistry, Alkaloids*
Alexandre Dumas: "Les Comte Monte Cristo" brucine, hashish
Agatha Christie: "The Thumb Mark of St. Peter" pilocarpine
"The Mysterious Affair at Styles" strychnine
"Curtain" physostigmine, eserine, datura alkaloids
Charlotte McLeod: "Rest in Merry" taxine
"The Convivial Codfish" colchicine
Ellis Peters: "Monk's Hood" aconitine
Dorothy Sayers: "Documents in the Case" muscarine

*Clinical Chemistry and Metabolic Disorder*
Daniel Keyes: "Flowers for Algernon" Phenylketonuria
Patricia Cornwell: "Post Mortem" Maple Syrup Uremia
Agatha Christie: "The Mirror Cracked Side by Side"
rubella (German measles)

Several literary work of Japanese mystery and science fiction writers including Saburo Kohga[1], Shin-ichi Hoshi[2], and Hideaki Sena[3], were also utilized as examples of many chemical topics.

**Keywords:** introductory chemistry teaching tools, science fiction and mystery, Chinese classic literature, ancient forensic arsenic detection

1 (1893-1945) Industrial chemist (real name: Yoshitame Haruta). Studied ammonia synthesis under Prof. Fritz Haber.
2 (1925-1997) Biochemist and ex-President of Hoshi Pharmaceuticals Co. Author of about one thousand "short-short" stories and many juvenile SF. Many of them have been translated into foreign languages (English, Russian, Chinese, Spanish and others).
3 (1968- ) Pharmacochemist (now in Tohoku University). Author of best-seller horror-SF novel "Parasite Eve".

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# THE TESTING OF SKILLS IN DUTCH CENTRAL EXAMINATIONS

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**Abstract**

Physics education in the Netherlands has gone through a number of reforms over the past two decades. At an early stage a shift was made from subject-oriented education towards real-life-oriented education. An argument in favour of this was that the learning process benefits when students see the natural relationship between physics and reality, and learn to apply physics in various real-life situations. The central physics examinations have reflected and accelerated this practice. All exercises and questions in the exam papers have been grouped as to the real-life setting in which they function. There is, for example, an article about fall-out caused by nuclear experiments, about the transmission of forces in riding a bicycle, an investigation of why diving glasses make things visible under water, for what purposes lasers are used in hospitals, etc. To make these settings sufficiently accessible to the candidates, they have to meet a number of criteria. Centrally administered exams in the Netherlands are marked by the student's own teacher and counterchecked by a centrally appointed examiner. Consequently the marking schemes have to answer strict criteria in order to guarantee a sufficiently high correspondence between marker results. To achieve this important aim a simple and straightforward model has always been applied. In recent years, however, the Dutch educational system has been fundamentally overhauled. To meet the rapidly changing demands of society, curricula of all school subjects have been revised. The emphasis has shifted from knowledge-based education to skills-based education. One of the aims was to achieve greater coherence between the various science subjects, specifically with respect to some general skills the students must develop. Nine types of skill-oriented questions have been developed. In the physics examinations they are used to test not only the candidates' competence in physics, but also their more general skills.

Recently, experiments explore the possibilities of the computer in the field of skills testing. We are in charge of the construction, development and analyses of the central physics examinations for secondary- and pre-university education. We would like to present and discuss the specific characteristics of these exams, drawing particular attention to the use of real-life settings, the assessment of skills and the marking schemes. To get an impression, two exercises with marking schemes are included in the appendix.

## 1. Introduction

In the 1980's, the introduction of real-life settings in physics and science education generally became more and more relevant. This was closely linked to the growing integration of science into society as a whole: science had to be made accessible to a broad public and it had to generate immediate profits. As a consequence the emphasis in science education shifted from subject-oriented towards real-life-oriented. Another reason for this shift was the didactical benefit it was supposed to have. Gagné (1985) stated that learning is more effective when the learner knows what the goal of a learning activity is. Real-life settings provide such a goal. Apart from the fact that they force the pupil to use and to apply his knowledge in a variety of circumstances. In this respect flexibility and transfer of knowledge are key-issues. Eijkelhof et. al. (1989) refer to 'real-life oriented' education: the organising principle for instruction is not the structure of the science-subject, but a set of deliberately chosen real-life settings are the starting point for teaching and learning. An extra reason for using real life situations in science education was to motivate pupils, girls in particular.

In the Netherlands these arguments were fully acknowledged at an early stage. Real-life settings played an important part in the daily practice of instruction - Goodlad et. al. (1979) refer to this as the "operational curriculum" – and so they did in the central physics exams which are supposed to reflect this daily practice. It is very likely that the wide introduction of real-life settings in the central examinations has accelerated the shift towards real-life-oriented education in physics. In 1989, the changes in the operational curriculum were followed by a reform of the formal curriculum: real-life settings were now prescribed explicitly. From then on *all* tasks in the central physics exams were based on real-life situations. Towards the end of the nineties there was another reform of the Dutch educational system. Unlike earlier reforms this time not only the operational curricula were addressed but the educational system as a whole. The main goal was to meet the rapidly changing demands of society. A new type of employee is needed to meet these demands. The skill to retrieve accurate information often becomes more important than the actual possession of knowledge. A secondary goal was to achieve better co-ordination between higher vocational and university education.

Some of the key elements of the new system are:

- Greater emphasis on general skills, formulated coherently *for all subjects*;
- Greater emphasis on the personal responsibility of students for their own progress;
- School-based portfolio assessment during the last two or three years of the course.

At the end of the course there are still the compulsory, centrally organised examinations. The fail/pass decision is based on the mean value of the marks for school-based assessment and those for the central exams. Like it always has been, the student's own teacher marks the central exams, counterchecked by a centrally appointed examiner.

## 2. Real-life settings

As said earlier, the central physics exams in the Netherlands have always been strongly based on real-life settings. Although the real-life settings are prescribed in the curriculum, the exam writers feel free to use settings unknown to the candidates. In order to be sufficiently accessible for the candidates, the real-life settings have to meet strict criteria.

The setting must be:

a. realistic (although a well-considered simplification of reality is often necessary);
b. functional (the questions should fit the setting or be provoked by it; if the questions can be answered without referring to it, the setting is not functional);
c. efficient (the quantity of text, graphs and/or illustrations needed to explain the setting must bear a reasonable relationship to the number of questions);
d. recognisable (especially the physics should be relevant to the candidates or made to be so in a few words);
e. equal for all (the setting should not benefit specific groups or individuals);
f. acceptable (in terms of moral and ethical values; the settings should not cause deep emotions or be controversial).

This list can be completed by properties that may not be necessary from an assessment point of view, but are definitely desirable. It is of course an advantage if the settings are interesting, challenging, relevant, educational, because the exam questions will sooner or later find their way into the classroom and become part of the operational curriculum.

The list of examples of suitable real-life settings is varied and as good as infinite. It may be an article about fall-out caused by nuclear experiments, the transmission of forces in the riding of a bicycle, the properties of diving glasses that make things visible under water, the x-ray apparatus of a dentist, the propulsion mechanism of a magnetic train, the use of lasers in a hospital, etc. We would like to devote a workshop to the presentation and discussion of some real-life settings in recent exam papers and of the corresponding questions and marking schemes.

A recent development in our examinations is the use of computers. After an initial experiment in 2001, new experiments on a larger scale have been planned for the coming years. As for now, the purpose is not just to replace pen-and-paper, but also to test certain skills that cannot be addressed without a computer at hand. One of the tasks in the first computer aided exam contained a video in which candidates had to make measurements in answer to questions about the motion of a tennis ball, the average forces during hitting, etc. In another one they had to run a computer-model in order to improve the model that was presented (Boeijen e. a., 2001).

## 3. Assessment of skills

In the new curricula much attention is paid to the formulation of general skills, common to all subjects, such as: linguistic and arithmetic competence, information handling, communication, technical design, research methods and the use of computers. It goes without saying that the acquisition of most of these skills is best tested in a school-based portfolio assessment. However, some of these skills are also tested in our central (written) exams. This is one of the issues we want to focus on in this paper.

## 4. Types of skill-questions

In order to prepare teachers and pupils for the new science examinations, syllabi have been published in which differences and correspondences with the traditional exams are explained. Apart from that various types of skill-questions have been developed and introduced, each question-type illustrated with examples.

The following nine types of general skill-questions have been classified, subdivided into three categories (Hendricx e. a., 1998):

*Information processing skills*

a 'Interpretation of information' question.
The candidate has to use his knowledge of physics to make sense of the information provided.

b 'Selection of information' question.
The candidate has to select the required information from the bulk of information provided.

c 'Restructuring of information' question.
The candidate has to transform information provided into a differently structured format (summary, scheme, table or graph, etc.).

d 'Plausibility of information' question.
The candidate has to judge the plausibility of information provided.

*Linguistic skills*

e 'Identification of arguments' question.
The candidate has to mention or recognise arguments that support a given point-of-view.

f 'Point of view' question.
The candidate has to take a point of view by presenting and weighing arguments pro and con.

*Experimental skills*

g 'Hypothesis' question.
The candidate has to formulate (or recognise) a hypothesis in a given experimental setting.

h 'Plan of action' question.
The candidate has to formulate a plan of action or improve or comment on a given one.

i 'Drawing of conclusions' question.
The candidate has to draw conclusions from given experimental data, or decide whether or not given conclusions are reasonable.

Questions in a central, written examination have to meet strict criteria. One of those criteria is that a question has to be objective: an answer given by a candidate should receive the same mark from different markers. Not all question types, as defined above, meet this requirement in the same way. Naturally, the 'Plausibility of information' question and the 'Point of view question' are more suitable in an oral examination setting. The 'Hypothesis' question, however, is less suitable in written exams.

A second criterion, of great importance, is that questions are mutually independent. It is clear that such independence is hard to achieve when in an experimental setting where the candidate starts off from the wrong hypothesis.

The remaining six types of skills-questions have been introduced in the central examinations in the course of three years following the educational reform. Unlike the 'information processing skills' questions - quite common in exams before the reform - the linguistic and experimental skills questions were new for both candidates and teachers. All the same, the acceptance of these questions has been most satisfactory. We would like to present and discuss some of these questions and accompanying marking schemes in a workshop.

## 5. Marking schemes

As we have pointed out, questions in a written, central examination must be objective. In the Dutch situation, this requirement is of vital importance, given the fact that the candidate's own teacher marks his answers, counterchecked by a centrally appointed second marker. (This is in contrast with the situation in the United Kingdom, where marking experts do the marking centrally.)

It is for this reason that marking schemes have to be designed in such a way that every possible error a candidate may make is taken into account. An important means to achieve this end is to try out the tasks involved. A statistical analysis of the try-outs enables us to maintain a defined standard of difficulty of the exams (within certain limits). Another requirement that our marking schemes have to meet is that they are as simple and clear as possible. The system practised over the years is quite straightforward: the necessary steps towards the right answer are made explicit and each correct step is awarded one point. This practice is generally accepted and the correspondence between markers' results is high. Whenever the candidate has to calculate a certain value the system is simple indeed. It is clear that designing a marking scheme for skill-oriented questions is far from easy; it is indeed quite a challenge! It is not just the marking scheme, but first of all the formulation of the question itself that matters. We will present and discuss a number of marking schemes in our workshop.

## 6. Conclusions and recommendations

The central, written physics examinations for A-levels in the Netherlands and the corresponding marking schemes have to meet very strict requirements. All tasks and questions are grouped according to real-life settings. To make these settings sufficiently relevant and accessible to the students, they have to meet certain criteria.

Apart from testing the candidates' competence in physics and corresponding skills, the exams also test more general skills, like information processing, linguistic and experimental skills. Experiments exploring the possibilities of the computer in skills testing are in progress. The authors would like to present and discuss the specific characteristics of these exams.

## 7. References

BOEIJEN, G. and POST, H. (2000). Computers and Exams. (Dutch title: Computers en Examens.) Arnhem, The Netherlands: Cito.

EIJKELHOF, H.M.C., VAN DER VEEN, K (1989). Working with real-life settings. (Dutch title: Werken met real-life settingen.) Zeist, The Netherlands: NIB.

GAGNÉ, R.M., (1977). The conditions of learning (3rd ed.). New York: Holt, Rinehart and Winston.

GOODLAD, J.J., KLEIN, M.F. and TYE, K.A. (1979). The domains of curriculum and their study. In J.L. Goodlad e. a., Curriculum inquiry: the study of curriculum practice. New York: McGraw-Hill.

HENDRICX, J. and KNEEPKENS, B. (1998). Syllabus for physics, with examples of exams. (Dutch title: Syllabus Natuurkunde, met voorbeeldexamens.) Arnhem, The Netherlands: Cevo and Cito.

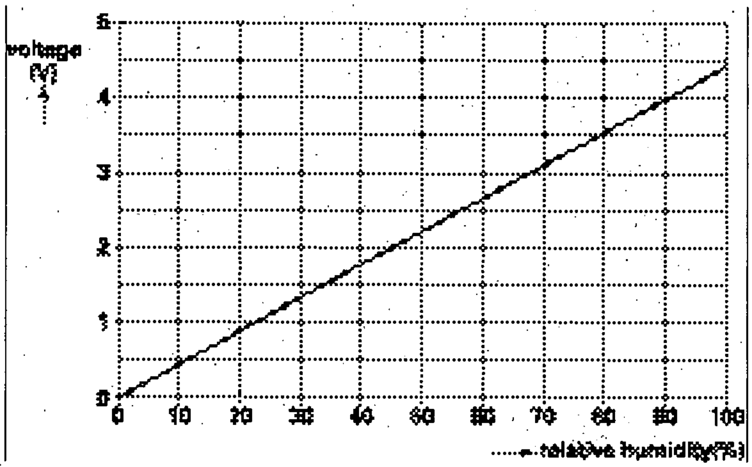
## APPENDIX

**Assignment 2 Bathroom fan**

A bathroom has been equipped with a fan. When somebody takes a shower, damp air is carried off and when the toilet is used unpleasant smells are dealt with.

A humidity sensor measures the humidity of the air. Figure 2 represents the output voltage of this sensor as a function of relative humidity.

*3p 5 Establish the sensitivity of the sensor.*




An automatic system is designed, operated not only by the humidity sensor, but also by a pressure switch under the toilet seat. Only when the seat is used the switch is on and communicates a high signal. The aim of the system is to switch on the fan as soon as the relative humidity in the bathroom exceeds 70% or the toilet seat is used. Figure 3 gives an incomplete representation of the system's circuit.

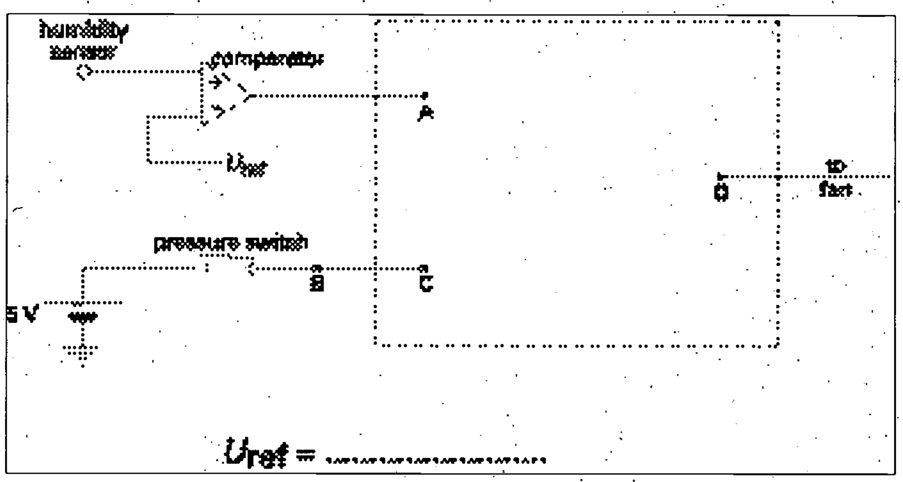



Figure 3.

The fan is switched on when the signal at D is high.

Figure 3 also appears in the appendix. Use this version for the next assignment:

*3p. 6. Draw the necessary operators with the appropriate connections within the rectangle represented by the dotted lines. Next indicate the value at which the reference voltage of the comparator should be set.*

We want the fan to continue running for a while after the toilet has been used. Therefore, the circuit in figure 3 has been extended between B and C. The extension is represented in figure 4.

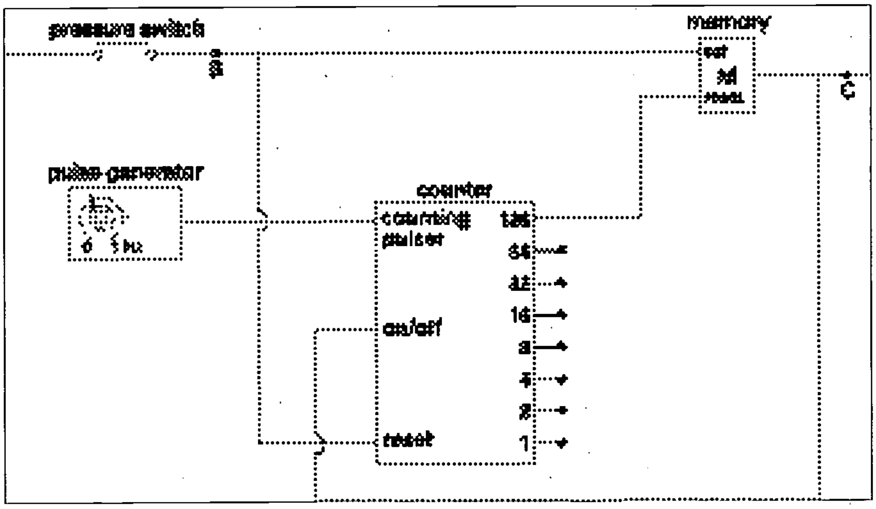


Figure 4

As long as the toilet is used the counter does not run.

*3p. 7. Explain by means of figure 4 why the counter starts to run when pressure is lifted from the toilet seat.*

The pulse generator connected to 'counting pulses' is set at 0.40 Hz.

Relative humidity is below 70%.

*4p. 8. Determine how long the fan continues to run after somebody has got off the seat.*

The fan has a power of 45 watt and is switched on for an average of 12 hours a week.

The price of 1 kWh is 0.16 euro.

*3p. 9. Calculate the energy costs for a period of one year due to use of the fan.*

**Marking scheme of:**
**Assignment 2 Bathroom fan.**

**Maximum score 3**

*5. result: The sensitivity of the sensor equals 0.044 V per % (relative humidity).*

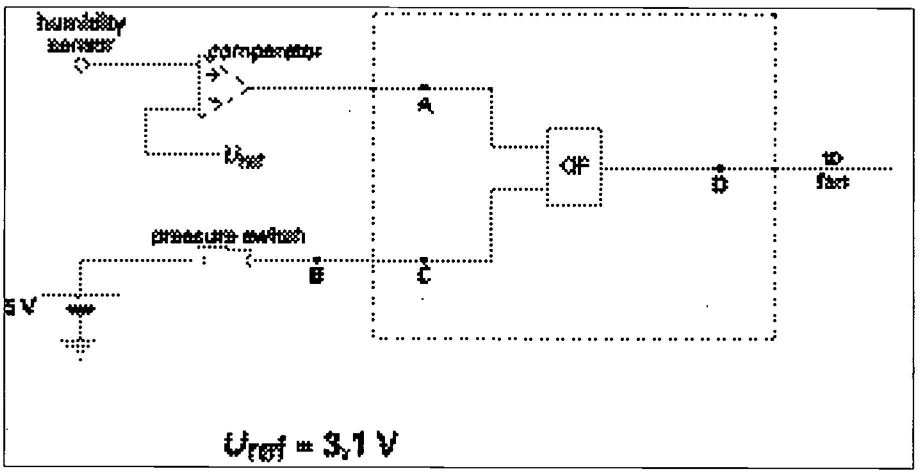
example of an answer:
The sensitivity of the sensor equals the slope of the graph.
This slope is $\frac{4.4}{100} = 0.044$ V per % (relative humidity), a difference of 0.001 V/% is acceptable).

- statement that the sensitivity of the sensor equals the slope of the graph 1
- determination of the slope of the graph 1
- completion of the establishment 1

*Remark*
*The inverse value is given as a result: maximum 2 p.*

Maximum score 3

*6. example of an answer:*




- OR-gate with connections 2
- establishing $U_{ref}$ (a difference of 0,1 V is acceptable) 1

**Maximum score 3**

*7. example of an answer:*

The counter counts when the on/of switch is high and the reset is low at the same time. At the moment the person rises from the toilet seat, the reset alters to low.

The Memory output (that was high) stays high, so the same goes for the on/of switch of the counter. (The counter starts counting).

- statement that the counter counts when the on/of is high and the reset is low at the same time 1
- statement that the reset alters to low 1
- statement that the on/of switch of the counter stays high (and the counter starts counting) 1

**Maximum score 4**

*8. result:* $t = 3.2 \cdot 10^2$ *s*

example of an answer:
The fan is switched off as soon as the Memory is reset.
This happens after 128 pulses.
One pulse lasts $\frac{1}{40} = 2.50$ s.
So the fan is switched off after $128 \cdot 2.50 = 3.2 \cdot 10^2$ s.

- statement that the fan is switched off as soon as the Memory is reset 1
- statement that this happens after 128 pulses 1
- use of $T = \frac{1}{f}$ or $f = \frac{1}{T}$ 1
- completion of the calculation 1

**Maximum score 3**

*9. result: The energy costs in a year are • 4.5.*

example of an answer:

For the energy the fan needs, goes: $E = Pt$.

The fan uses in one year $0.045 \cdot 12 \cdot 52 = 28.1$ kWh

So the energy costs in a year are $28.1 \cdot 0.16 =$ € 4.5

- use of $E = Pt$ 1
- calculation of number of kWh that are used in one year (or week, or day) 1
- completion of the calculation 1

**Assignment 5**
**Tritium in a light emitting plastic watch.**

Read the article below.

> ROTTERDAM, 24 SEPT. According to the Austrian Ministry of Health a plastic watch with a light emitting face can lead to an increased concentration of the radioactive element tritium in the blood and urine of the wearer. Tritium is a weak beta radiator introduced years ago as a replacement of dangerous radium in light emitting watch faces. According to the Ministry it is a proven fact that tritium penetrates both the plastic watch casing and the skin of the wearer. Metal casings are impenetrable for tritium. Some wearers had a concentration of tritium in their urine corresponding to 800 becquerel per litre. This results in an extra radiation load of 0.02 millisievert a year. Tritium can therefore not be considered to be a health risk.
>
> *NRC Handelsblad, 24 september 1993*

Health risks caused by radioactive elements can occur in the form of radiation and contamination.

*3p.19. What is the characteristic difference between radiation and contamination and which of the two occurs in the case of tritium?*

Tritium is a hydrogen isotope. The nucleus consists of 1 proton and 2 neutrons.

*3p. 20. Give the decline reaction of tritium.*

*3p. 21. Calculate how long it takes until the tritium activity has declined to 12.5% of its initial value.*

If a person's urine has an activity of 800 Bq per litre, the activity in the body as a whole is much higher.

A person's body with a body mass of 70 kg is exposed for one year to tritium radiation with an average activity of 16 kBq.

The dosis equivalent $H$ answers to:

$$H = Q\frac{E}{m}$$

in which:

- $H$ is the dosis equivalent (in Sv),
- $Q$ is the so called weighing factor (quality factor); $Q = 1$ for ß-radiation,
- $E$ is energy (in J),
- $m$ is mass (in kg).

The ß-particle has an energy of $2.9 \cdot 10^{-15}$ J

*3p. 22. Demonstrate by means of a calculation that the estimate in the article of the extra radiation load caused by tritium exposure is correct.*

*3p. 23. Do you agree with the conclusion of the article? Explain your point of view. In doing so give a relevant value from table 99E in the BINAS information book.*

**Marking scheme of:**
**Assignment 5 Tritium in a light emitting plastic watch.**

**Maximum score 3**

*19. example of an answer:*

In the case of radiation: The source is outside the body.
In the case of contamination: The source is inside (or: on) the body.
In the case of tritium we therefore are dealing with contamination.

- statement that in case of radiation the source is outside the body 1
- statement that in case of contamination the source is inside (or: on) the body 1
- conclusion that in the case of tritium we are dealing with contamination 1

**Maximum score 3**

*20. answer:*

$^{3}_{1}H \rightarrow ^{3}_{2}He + ^{0}_{-1}e$ or $^{3}H \rightarrow ^{3}He + ^{0}_{-1}e$

- electron on the right side of the arrow 1
- He as a product of the reaction 1
- number of nucleons equal on both sides 1

*Remark*
*Use of a particle different from an electron: maximum 1 pnt.*

**Maximum score 3**

*21. result: It takes 36.9 years.*

example of a calculation:
It takes three half life times until the tritium activity has declined to 12.5% of its initial value. Half life time of tritium is 12.3 years.
So it takes 3·12.3 = 36.9 years.

- looking up half life time 1
- understanding that it takes three half life times until the tritium activity has declined to 12.5% of its initial value 1
- completion of the calculation 1

**Maximum score 3**

*22. example of an answer:*

Due to tritium there are 16·103 decline reactions per second.

So the energy in one year is $365{\cdot}24{\cdot}60{\cdot}60{\cdot}16{\cdot}103{\cdot}2.9{\cdot}10^{-15} = 1{,}46{\cdot}10^{-3}$ J.

The dosis equivalent $H$ is:

$$H = 1 \cdot \frac{1.46 \cdot 10^{-3}}{70} = 2.1 \cdot 10^{-5} \text{ Sv.}$$

The extra radiation load as estimated in the article is correct.

- understanding that $16{\cdot}10^3$ decline reactions per second take place 1
- calculation of the energy in one year (in J) 1
- completion of the calculation (and conclusion) 1

**Maximum score 3**

*23. examples of an answer:*

method 1

The maximum dose is 1 mSv per year (see table 99E of Binas).

The extra radiation load caused by tritium exposure is small compared with this maximum.

So I agree with the conclusion of the article.

- looking up the maximum dosis in table 99E 1
- statement that the extra radiation load caused by tritium exposure is small compared with this maximum 1
- conclusion 1

method 2

The maximum dose is 1 mSv per year (see table 99E of Binas).

The extra radiation load caused by tritium exposure is small compared with this maximum, but is added to all kinds of radiation a person can be exposed to.

So I do not agree with the conclusion of the article.

- looking up the maximum dosis in table 99E 1
- statement that the extra radiation load caused by tritium exposure is small compared with this maximum, but is added to all kinds of radiation a person can be exposed to 1
- conclusion 1

*Remark*
*If table 99E is not used for the conclusion: maximum 1 p.*

**Keywords:** central exams, real-life settings, assessment of skills, marking schemes, the use of the computer in exams

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# THE SCIENCE EDUCATION ENTERPRIZE IN DEVELOPING COUNTRIES AS A BATTLEFIELD OF DIFFERENT DREAMERS: HOW TO OVERCOME GROUPTHINK SYMPTOMS?

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**Abstract**

When discussing science education projects in developing countries, we have rarely taken notice of stakeholders' 'political' stances toward science education. In most cases, few of the stakeholders committed to science education activities in developing countries are aware whether or not they really share the same ideas on the goal, aims, and ideal of science education enterprise. This may be a problem. For these past several decades, science educators have achieved much progress in their understanding of the nature of science, the nature of school science, and the relationship between science education and development, especially from the viewpoints of post-modern theories. Through the progress, there have appeared several critical views on science education among science educators. Though critical views on science education are still not prevailing in science education practices in developed as well as developing countries, such views cannot be ignored when considering the science education enterprise. Thus, in certain specific situations of science education activity, we should be much more aware that each of the stakeholders can take different stances toward science education from one another. However, in reality, stakeholders in a specific science education project, do not seem to discuss this difference. Why? This paper presents a possible reason based on research on decision-making and argues for helping prospective indigenous stakeholders challenge the decision making processes of present science education projects in order to make their own dreams come true.

## Introduction

Science education is a total body of activities which many stakeholders are involved in and committed to. Among such activities are science education policy development, science curriculum development, science textbook development, science teacher education, and science teaching in classrooms. When discussing issues in science education in general and in specific activities in certain specific contexts in particular, science educators are usually unaware of significance of 'educo-politics' (Fensham, 2002). In fact, recent progress in science education research reveals that within the science education community there are various types of political stances toward several aspects of science education. For example, some science educators believe science to be 'the only one legitimate' way of knowing reality, but others believe science to be 'a' way of knowing reality. Also, while some science educators want to adapt school science contents from classical science disciplines (physics, chemistry, biology and earth sciences), others allow components from traditional ecological knowledge or STS issues to be involved in school science contents.

One interesting thing is that while most of them realize the existence of such differences among science educators' political stances toward science or science education, there appears to be few formal discussions on the issue when they are actually involved as stakeholders in certain science education projects especially in developing countries. The situation is as if they had never imagined that there could be different stances or views to 'What science education is?' among the stakeholders concerned. They seem simply to presuppose there is a consensus on 'what science education is?'among the stakeholders.

However, this may be a serious pitfall. Imagine, for example, that you are involved in science curriculum development in a certain developing country or in a certain native people's community. There are stakeholders with different webs of meanings, with different knowledge bases, with different interests, with different political stances toward science and science education and with different value systems in the project team with you. You must sometimes get into a situation where you must argue for your own political stances toward science education, and want to come to realize your ideal. But, such a situation rarely happens within the specific project team. Why does such serious discussion rarely happen? What are the barriers to prevent such discussion?

If science educators want to realize their own dreams, what they should do first is to examine these questions much more seriously. Such trial will uncover the view that the science education enterprise is a battlefield of different dreamers. Thus, science educators, especially those working in developing countries or in settings of marginalized groups, should be much more careful to the political processes or political discussion which should happen in every science education activity, and they should be much more prepared for a well-trained 'negotiator' or 'politician,' who can make their 'own' dreams come true.

The present paper, first, describes possible 'stakeholders' in the science education enterprise, then, discusses various factors producing differentiated political stances among stakeholders, and presents a view concerning why such serious discussion on stakeholders' different political stances rarely happens in science education projects. And finally, the paper argues to help prospective indigenous stakeholders challenge the present situation of science education projects in order to realize their dreams.

### Various Stakeholders Are Involved

There are different types of individuals who are committed to each activity of the enterprise of science education (Fig. 1). For example, in the development of national curriculum standards or courses of study in science, people from the Ministry of Education, academic scientists, professional science educators, and practicing science teachers are involved. Especially in a developing country, there are science education advisers from developed countries and/or international organizations which are also sometimes involved and which support the project financially. In most of the cases such groups of stakeholders seem to have more power over other indigenous stakeholders.

While Fig.1 shows an overall perspective of possible stakeholders as a whole, it is more important is to find out about not only the 'explicit' stakeholders but also the 'implicit' or 'hidden' stakeholders in the activity concerned. Caution must be taken not to miss the 'invisible' stakeholder who is hiding behind a 'visible' stakeholder. For example, in the science textbook development activity, a certain science adviser who is from a certain international organization will introduce a set of science textbooks from a certain country. In this case, we should try to see the 'international organization' and 'the editors of the textbooks' as 'invisible' stakeholders. The adviser never brings the set of textbooks on a random basis. There is a specific intention and interest. The decision may reflect the idea of the international organization. Or if not, at least, this selection reflects the editors' interests and messages into the science textbook development activity. Thus, the 'international organization' or 'editors of the textbooks' can be regarded as 'hidden' or 'invisible' stakeholders.

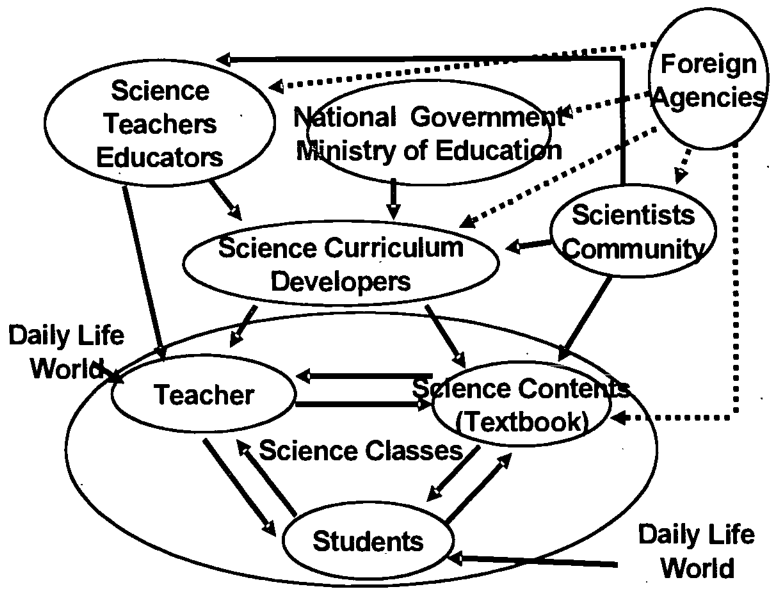


**Fig. 1:** Typical Example of Stakeholders in Science Education Activities

### Factors Leading Stakeholders to Different Stances toward Science Education Enterprise

When we discuss science education projects in developing countries, there have been few cases where stakeholders' stances towards the project concerned, in particular, as well as science education activity, in general, are at issue. One of the possible reasons is that in most cases a certain consensus among the stakeholders has been presupposed without any deeper consideration. Science educators involved are believed to have a shared idea on the science education project. But this may not be the case. Science educators can have different stances toward the science education enterprise, because there are several factors relevant to science education, which lead science educators to different stances. Among the most important are, views on science, on school science, on the relationships between science and technology, on the relationships between science education and development, on teaching and learning in science, on interests in science education etc. Here some of them are discussed briefly.

**1) Different Views of Science**

As is well known, there are different views of science even among the research in science studies. At least, we can identify two major views of science: the universalist perspective and the multiple perspectives (for example, see Stanley and Brickhouse, 1994). From the viewpoint of the universalist perspective, science is the only way of knowing reality. On the other hand, from the multiple perspectives, science is regarded as "a" way of knowing reality, and other ways of knowing reality are possible. While the contrast of these two views is beyond the scope of this paper, it is quite crucial for stakeholders to realize whether or not there is consensus among them in their views of science. In most of the science education projects in developing countries, stakeholders are supposed to be coming from different backgrounds: there are scientists and administrators who are unfamiliar with recent progress in science education research or that of science studies, there are also leading science educators trained in western graduate programs for more than 20 years, and younger science educators who have knowledge of the issues on the nature of science. The former group is unconsciously or consciously standing upon the 'universalist perspective,' while some of the latter are insisting upon the multiple perspective. Thus, in the discussion among stakeholders in a specific science education project, there should be a big battle, but in fact, there are few cases of such battles. They take the issue of the difference in views of science into consideration much more seriously.

**2) Different Views on the Aims of Schooling**

What is schooling for? This is also an important question for which different types of view are possible. One of the drastic contrasts is 'schooling for personal development' vs. 'schooling for national development.' Of course, schooling has always these two facets, but what I would like to focus on here is which of those aspects is more emphasized than the other. Some stakeholders, mostly practicing science teachers, are apt to put emphasis on the pupils' personal development in knowledge, skills, and attitudes, which can make them live better lives in their daily lives. On the other hand, stakeholders from governmental agencies have a stronger interest that pupils serve as skilled 'manpower'. While some parts of the aims have common facets, these two fundamental stances toward schooling are quite different. In the sentences of rationales or goals of a certain project, we can readily find both aims in parallel. It is an ideal, but it is hard to achieve both at the same time in a specific project

**3) Different Views on School Science**

The aim of school science can be seen differently among stakeholders. While some science educators believe that school science should primarily serve to help pupils to make a good living in their own settings, others, for example parents, want their kids to be ready for climbing up the 'ladder' for prospective success in their society. That is, they want them to learn 'academic science knowledge' needed for entering into the next stage of schooling, even if the contents are quite irrelevant in their daily lives. Another viewpoint may be possible. Within the school science context, some believe that contents from western science (scientists' science) should alone be treated, but others may allow the option for contents from indigenous science(s) (Ogawa 1995) relevant to that region. These two types of content constitution reflect different views of school science.

**4) Different Views on the Relationship between Science and Technology**

On the one hand, if stakeholders regard technology as a 'technology driven by science' or 'technology as application of science,' they miss the viewpoint of 'alternative technology' or 'appropriate technology' in a certain rural community. They presuppose a linear and direct relationship between science and technology, and they want to teach science 'for' technology. On the other hand, stakeholders with the latter viewpoint can have a dual stance toward science and technology. They can teach science and technology separately. Such differences can cause a different type of involvement of technology in the science education enterprise.

**5) Different Views on the Relationship between Science Education and Development**
Science education and development is one of the major controversies in developing countries. If development means 'economic development' or 'human resource development' alone, science education seems to be regarded as a 'tool' for economic development. Science education projects in developing countries sometimes have this kind of flavor. However, 'development' has different aspects to its meaning. For example, there may be 'personal development in human nature', 'personal development in daily life', and 'community development in their rural circumstances', etc. Each aspect of development needs a different type of science education. Which aspects of development do stakeholders put special emphasis on? This question may cause some debate.

## Why Only Rarely Is There A Battle of Political Stances Among Stakeholders ?

While there are various possible stances toward the science education enterprise, as discussed above, usually most of the stakeholders are unaware about whether or not they sit at the table of discussion with the 'same dream'. Out of scope is whether or not all of them share the same image of the science education activity concerned. Why? As shown earlier, since there are different political stances among stakeholders, they should be much more careful about that. Rather, it may be regarded as a battlefield of different dreams. There should be various kinds of politics, negotiation, conflicts, struggle, and trade-off among relevant stakeholders' beliefs, interests, and values in every science education activity. The more stakeholders are from different socio-cultural backgrounds, the more severe are the conflicts that are expected to occur. However, reality may be different. Conflicts rarely occur among stakeholders. One reason may be that there is a kind of power relation among the stakeholders. The view of science education held by a certain stakeholder, who has the strongest power (for example, having financial background), will likely be the one reflected at the end product of the process. But are there any reasons? One possible explanation is given from a famous decision-making research model.

**1) Groupthink Model**
Janis (1972, p.9) defines 'groupthink' as 'a mode of thinking that people engage in when they are deeply involved in a cohesive in-group, when the members' strivings for unanimity override their motivation to realistically appraise alternative courses of action.' Among highly cohesive groups, there sometimes is a concurrence-seeking tendency. When this tendency is dominant, the members use their collective cognitive resources to develop rationalizations supporting shared illusions about the invulnerability of their organization. They also display other symptoms of 'groupthink.' (Janis and Mann, 1977, p.129) And, they argued that 'groupthink-dominated groups were characterized by strong pressures toward uniformity, which inclined their members to avoid raising controversial issues, questioning weak arguments, or calling a halt to soft-headed thinking' (p.130).

Janis and Mann (1977) point out five antecedent conditions for 'groupthink'. These are: 1) a high cohesiveness among the members, 2) insulation of the group from others, 3) lack of methodological procedures for search and appraisal, 4) directive leadership, and 5) high stress with a low degree of hope for finding a better solution than the one favored by the leader or other influential persons (p.132). There are possible pressures to the 'groupthink' situation. And once the 'groupthink' situation happens, the symptoms below will appears: 1) an illusion of invulnerability, 2) collective efforts to rationalize, 3) an unquestioned belief in the group's inherent morality, 4) stereotyped views of rivals and enemies, 5) direct pressure on any member who expresses strong arguments against any of the group's stereotypes, illusions, or commitments, 6) self-censorship of deviations from the apparent group consensus, 7) a shared illusion of unanimity, and 8) the emergence of self-appointed "mindguards." (pp.130-31)

They argue that the symptoms that result include 1) incomplete survey of alternatives, objectives, and risks of preferred choice, 2) poor information search, 3) selective bias in processing information at hand, 4) failure to re-appraise alternatives, and 5) failure to work out contingency plans. (p.132)

**2) Implication of the Groupthink Model**
What the model implies is that the decision making process made by a group of stakeholders involved in science education projects (especially those in developing countries) can be explained by the model. In many aspects in science education, stakeholders can have a chance to take different stances theoretically, but in fact, minor opinions or stances are rarely expressed in the discussions among stakeholders, because major opinions held by most of the stakeholders are apparent and minor stakeholders have escaped from expressing their respective stances or opinions. The science education community as a whole, should start to tackle, from the viewpoint of the groupthink model, the decision making processes.

**3) How to Overcome the Pitfall of Groupthink?**
Some prescriptions are proposed by Janis (1972, pp.209-219). They are:

a) The leader of a group should assign the role of critical evaluator to each member, encouraging the group to give high priority to airing objections and doubts.
b) When assigning a mission to a group, the leaders should be impartial instead of stating preferences and expectations at the outset.
c) The organization should routinely follow the administrative practice of setting up several independent groups to work on the same policy question, each carrying out its deliberations under a different leader.
d) Throughout the period when the feasibility and effectiveness of policy alternatives are being surveyed, the policy-making group should from time to time, divide into two or more subgroups to meet separately, under different chairmen, and then come together to hammer out their differences.
e) Each member of the group should discuss periodically the group's deliberations with trusted associates in his own unit of the organization and report back their reactions.
f) One or more outside experts or qualified colleagues within the organization who are not core members of the group should be invited to each meeting on a staggered basis and should be encouraged to challenge the views of the core members.
g) At every meeting devoted to evaluating policy alternatives, at least one member should be assigned the role of devil's advocate.
h) Whenever the policy issue concerned relationships with a rival nation or organization, a sizable bloc of time (perhaps an entire session) should be spent surveying all warming signals from the rivals and constructing alternative scenarios of the rivals' intentions.

These are still general examples to overcome the problems of groupthink. Science educators should, of course, find their own specific solutions to prevent groupthink using their own ideas on the decision-making processes.

## The Way Forward

Recently, science education development in developing countries has gradually been taken contol of by science educators in respective countries. However, since most such indigenous science educators (generally education leaders in their countries) have been well-trained in western developed countries, they sometimes act as 'western science educators.' This does not seem to be good for developing appropriate science education programs for the people. They should have plural eyes that focus on both education in general and on science education in particular. They should be a 'four-eyed fish' in the river (Ogawa, 1996). If indigenous science educators want to take a real initiative to establish their own science education, they must be prepared not only to obtain knowledge of the new findings of science education research at much a greater degree than that of foreign stakeholders, but also for the political strategies and skills for negotiation, consensus making, compromise making, and especially for the wisdom to overcoming the pitfall of groupthink. They must express their own voices in the discussions of the project. How can they be free from the problem of groupthink? Who and how can take an initiative? Now is the start of a long journey to discover solutions.

## References

FENSHAM, P., (2002). Time to Change Drivers for Science Literacy. Canadian Journal of Science, Mathematics and Technology Education, in press.

JANIS, I., (1972). Victims of Groupthink, Boston: Houghton Mifflin.

JANIS, L., (1982). Groupthink: Psychological Studies of Policy Decisions and Fiascoes, Boston: Houghton Mifflin.

JANIS, I. and MANN, L., (1977). Decision Making, New York, Free Press.

OGAWA, M., (1995). Science in a Multiscience Perspective. Science Education, 79(5): 583-593.

OGAWA, M., (1996). Four-eyed fish: The ideal for non-western graduates of western science education graduate programs. Science Education, 80(1): 107-110.

STANLEY, W.B. and BRICKHOUSE, N.W. (1994). Multiculturalism, Universalism, and Science Education, Science Education, 78(4): 387-398.

**Keywords:** stakeholders, views on science education, developing countries, groupthink

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# ESSENTIALS OF MATHEMATICS IN TEACHING CHEMISTRY

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**Abstract**

In this paper, mathematical skills necessary for understanding the subject of chemistry are described, which are believed to enhance the pedagogy of chemistry course and build confidence of students in the justifications of the subject matter. The features of some frequently used mathematical applications in chemistry, addressed in this article are: (i) Numbers and Dimensions; the different classes of numbers and relations between physical quantities based on dimensional analysis are described (ii) Variables, Functions and their applications in chemistry are discussed (iii) Differential Calculus and Ordinary Differential Equations and Partial differentiation and their applications in chemistry are described. (iv) The application of integration in chemistry is discussed. (v) Series Expansions of Functions and its applications for the solutions of integrals and linear differential equations are described. (vi) The method of Determinants and Matrices and their utility in chemical applications are illustrated. The choice of material presented in this article has been evolved from teaching a course "Mathematics for chemists" for the last fifteen years to the M.Sc. chemistry students in the University of Peshawar, Pakistan. The emphasis in the paper is on the application of mathematical skills rather than on the proving of theorems. Mathematical techniques are illustrated with chemical examples taken from the referred texts. It has been our experience that the knowledge of mathematical skills in chemistry greatly enhances the student's learning and understanding of the material in the texts and also increases their research capability i.e. in the analysis and presentation of their experimental data.

## Introduction

With the advancement of science and technology, focus of chemical research has changed thereby affecting the topics covered in a modern chemistry course. The interaction between different science subjects has been increased. The need of knowing related subjects has enhanced due to the many fold applications of chemistry. Chemistry is sister to all the subjects of natural science and is also an important subject in medical and in engineering sciences. Due to its widespread applications and complexity of the problems, it has involved mathematics as main partner in achieving its goals. Taking the mathematics as a tool many complicated problems are solved and the results are obtained in a simple but logical way which otherwise would have been very difficult[10]. A report in *Science*[1] concerning a novel use of macromolecules, suggests that we may soon be experiencing a dramatic reversal in the traditional role played by chemistry and mathematics. It further speculates that where as in the past chemists with intractable numerical problems have usually had to defer to those with superior mathematical skills, in the future it seems that just the opposite may be occurring. Mathematicians could be looking to chemists to solve a whole range of problems that even mathematicians themselves admit are exceedingly difficult to solve.

Although chemistry is difficult with mathematics but it is impossible without it. Let us admit that mathematics has seldom been popular among chemists in general. The physical chemistry in particular, that provides theoretical basis for the chemical reactions to occur use mathematics as a tool for description. In my years of teaching chemistry, I have found it helpful to review mathematical topics before using them to explain chemical concepts to students. The students face problems in learning chemistry mostly because they in their undergraduate courses opt chemistry as a major without mathematics in combination. As a result the stuff admitted in the postgraduate chemistry department has less that 1% of the students who are acquainted with mathematical skills.

An attempt is made in this article to present some mathematical methods, the need for which arise in teaching chemistry, which enhances the students pedagogy, understanding of the subject and in building confidence. Some of the topics of equal importance like Symmetry and Group theory, Coordinates System, Probability and Statistics, which though are not covered in this article, are also extensively applied in chemistry. I may suggest that a course that cover the topics given in this article and also the few mentioned above may be made essential for all those who chose chemistry as their carrier subject and particularly to those who have not opted for mathematics in their undergraduate studies.

**Need of Mathematics for Teaching Chemistry**

Students of chemistry have, in general, a more limited mathematical background than physics or engineering students. Teaching mathematical applications in chemistry at the graduate/undergraduate level enables the students to comprehend the advanced chemistry courses like those of quantum mechanics, statistical mechanics, mechanics of molecules, thermodynamics, chemical kinetics, chemical equilibrium, surface phenomena, electrochemistry, spectroscopy, polymer chemistry, gases, liquids, solid state chemistry, decay and radiation processes, etc. etc. We admit 120 students in the chemistry department each year in M.Sc. previous class, and equal number in the final M.Sc. final class. Some of these students enroll in the M.Phil/Ph.D program of the department. Both theory and experimental work is extensively involved in chemistry. The theory courses in particular the physical chemistry, analytical chemistry, inorganic chemistry and environmental chemistry use different levels of mathematics for description of the subject matter. The physical chemistry paper in the exam has compulsory questions from applications of mathematical in chemistry.

Experimental work/research, need preparation of standard solutions, solution speciation, instrumentation, data collection, plotting of the data and graphs according to certain equation related to the study. Often slope and intercept are obtained from the linear graph which are then used to calculate other parameters related to the study. For example rate constant of a kinetic reaction obtained from the slope are then used in the Arhenius equation to evaluate the activation energy, the value of which is then used for computing enthalpy, entropy and Gibb's free energy of the reaction. Similarly data of an equilibrium reaction can be manipulated.

Students need to learn mathematics as a tool for the completion of both theoretical mad experimental work. In a situation when less than 1% of the students with mathematics background can learn and understand the subject matter and for the rest it is hard to patch with, the need of teaching mathematics become evident. Some times the students do not have the idea of imaginary numbers, complex numbers or complex conjugates and they are almost ignorant of rules of differentiation and integration. They know that ln x = 2.303 log x, but they do not give satisfactory answer for why multiply with 2.303 for the conversion. Let us consider another simple example of the evaluation of thermal energies of a mole of gas molecules, in order to understand the need of mathematics in teaching chemistry. The derived equation for thermal energy is $E - E_0 = \frac{RT}{q} \times \frac{dq}{dt}$, where $q$ is called partition function which is by definition the summation in the denominator of the Boltzmann distribution equation and is given by $q = \sum_i g_i e^{-(\varepsilon_i - \varepsilon_0)/KT}$. The equations of $q$ and $dq/dt$ for translation, rotation and vibration types of energies are needed to be inserted in the thermal energy expression. Following table shows the expressions and indicates the operations needed to get the result. Differentiation and integration both are used.

**Table-1.** Calculation of thermal energy of gas molecules.

| Energy type | Partition function | Thermal energy |
|---|---|---|
| $e_{trans} = \frac{n^2 h^2}{8ma^2}$ | $q_x = \int_0^\infty e^{-\frac{n_x^2 h^2}{8ma^2 kT}} dn_x = \sqrt{\frac{2pma^2 kT}{h^2}}$ | $(E - E_0)_{trans} = \frac{3}{2} RT$ |
| $e_{rot} = J(J+1)\frac{h^2}{8p^2 I}$ | $q_{rot} = 2\int_0^\infty J e^{\frac{-J^2 h^2}{8p^2 IkT}} dJ = \frac{8p^2 IKT}{h^2}$ | $(E - E_0)_{rot} = RT$ |
| $e_{vib} = \left(v + \frac{1}{2}\right) hn$ | $q_{vib} = \sum_{v=0} e^{-\frac{[(v+\frac{1}{2})hn - \frac{1}{2}hn]}{kT}} = 1 + e^{-\frac{hv}{kT}} + e^{-\frac{2hv}{kT}} + xxx = \frac{1}{1 - e^{-\frac{hv}{kT}}}$ | $(E - E_0)_{vib} = \frac{RT\left(\frac{hv}{kT}\right)}{e^{\left(\frac{hv}{kT}\right)} - 1}$ |

**Numbers and Dimensions**

A young child learns and grasps early the concept of numbers that we call positive integers and zero. In the elementary school he learns addition, subtraction and division of integers. Then he learns fractions like n/m. The collection of all the numbers that can be written as n/m, where n and m are integers (excluding m = 0), is called the **rational number system** since it is based on the ratio of whole numbers. The rationales include both fractions and whole numbers. Later in the student's early teens, **irrational numbers** are learned. These numbers come from two sources: algebraic equations with exponents, for example, the quadratic $x^2 = 2$; and geometry, like the ratio of the circumference to the diameter of a circle, $\pi$. For $x^2 = 2$, the unknown is neither a whole number nor a fraction, but is a decimal expression 1.41421356..up to infinite decimal places[2], the digits do not display a repetitive pattern. The rationales are thus supplemented by Irrational numbers, i.e. the numbers that are represented by infinite non repeating decimals. The totality of these two kinds of numbers is known as the **real number system**. The student faces a new complication when he comes to solution of the equation of the form $x^2 = -2$, or $x^2 = -1$. He knows that no real number times itself will yield a negative real number. To cope with the dilemma, a larger system of numbers the **complex number system** - which has both real and imaginary parts, is usually presented in high school. The solution of the problem that he gets is $x = \sqrt{-2} = 2\sqrt{-1}$, $x = \sqrt{-1}$. The result that obtained is not real number so obviously we call it an **imaginary number.** The number $\sqrt{-1}$ is represented by, i (iota). Now a number $z = a + bi$ has '*a*' and '*b*' which represent real numbers and $i = \sqrt{-1}$ is imaginary. We say that the number 'z' has a real part 'a' and imaginary part 'b'. Note that both the real and imaginary parts of complex number have real numbers. Two complex numbers are said to be equal if, and only if, the real part of one equals the real part of the other and the imaginary part of one equals the imaginary part of the other. That is, if $z = a + ib$, $w = c + id$ and $z = w$ then $a = c$, $b = d$. A pair of complex numbers are said to be conjugate of each other if they have identical real parts and identical imaginary parts except the imaginary part being opposite in sign. Thus if $z = a + ib$ then $z^* = a - ib$. and it is important to note that $zz^* = a^2 + b^2$, which is always a positive number. The quantity $|z| = \sqrt{zz^*}$ is known as absolute value of z, which is always positive and real. In quantum chemistry the probability of finding a particle in an area of space is given by $\psi\psi^*$ where $\psi$ is wave function and $\psi^*$ is its complex conjugate. The $|\psi|$, is both positive and real. The wave function $\psi$ is thus called a "well behaved function" in quantum chemistry. For considering electron motion around nucleus we need polar coordinates. A useful relation called Euler formula provides a link between exponential and trigonometric function; $e^{i\theta} = \cos\theta + i\sin\theta$, which is used in finding probability of electron around nucleus.

Measurement is the essence of science. Without exact quantitative measurements no fact or law can be established in science. Every quantity has a magnitude and a scale or unit of measurement. Since 1960 an international system of units "**SI**" units has been adopted which uses decimals for measuring physical quantities. This is also called **MKS system**, which represents length in meters, mass in kilogram and time in seconds having symbols as 'm', 'kg', and 's' respectively. These fundamental units are used to define the **derived units** in chemistry. As the unit of length is meter (m), so the unit of volume will be $V = m \times m \times m = m^3$ (cubic meters). Density is ρ = mass/volume = kg/$m^3$ = kg. $m^{-3}$, concentration = number of moles/volume = mol/l = mol/$dm^3$ =mol $dm^{-3}$. Dimensional analysis is a method of checking and predicting relations between physical quantities and is based simply on the principle that the dimensions must balance in an equation. Take for example the units of ideal gas constant R, defined by the relation R= PV/nT. If pressure is in atmosphere (atm.), volume in $dm^3$ (or liters) and temperature in Kelvin (K) and n in moles (mol), then R = 0.0825 liter atm $mol^{-1}$ $K^{-1}$. If we need to use SI units instead then we make use of the conversion factors:1atm = 101325 $Nm^{-2}$,1$dm^3$ = $10^{-3}$m , 1J = 1Nm, so R in the derived units will be R = 8.3144 J $mol^{-1}$ $K^{-1}$ which is expressed in the energy units.

Numbers, dimensions and units are needed to every chemistry student for understanding and learning of general chemistry and in the quantitative chemical analysis. The topics of fundamental interest may include, measurement of temperature in different scales, weight, length, area, volume, density, gas laws calculations, molecular weights determination (from: formula, gram molecular weight, lowering of freezing point, elevation of boiling point, osmotic pressure), law of combining weights, determination of atomic weights (from: chemical analysis, equivalent weight), percentage composition, calculation of formula, calculations based on chemical equations, calculations involved in preparation of standard solutions (normality and molarity), law of mass action, ionic product of water, solubility product, specific heat, heat of fusion and vaporization, heat of reaction and Faraday's laws of electrolysis, etc. It is observed that if the concept of students regarding numbers, units of dimensions and the significant figures are clear then they feel confident in learning and understanding the subject matter in the texts and similarly in performing the laboratory work.

**Variables, Functions and their Graphs**

Experiments in chemistry deal with variable parameters. Some fundamental constants[3] involved in calculations are always available in the chemistry texts. When one variable "*x*" changes (independent variable) producing a change in another variable "*y*"(dependent variable) during the experiment then we say that "*y*" is a function of "*x*", represented mathematically as $y = f(x)$. A chemist then looks at the best way to express the relationship between these parameters. He has a choice of several types of different functions both **algebraic** and **transcendental**, for expressing results in the form of an equation. The equation is then plotted on a graph paper to show the trends of variation in the data. The simplest function that gives a linear graph is called **linear function**. From the graph of the linear function, the intercept i.e. the value of *y* when $x = 0$, and the slope of the line is obtained. Slope $= \frac{dy}{dx}$, is equal to tangent of the angle θ between the graph line and the x-axis. Values of slope and intercept are then interpreted to get quantitative predictions about the chemical process. Whenever an agreement between experimental data and theoretical values are tested a straight-line graph is preferred. Many equations, which are not, originally in the form of straight line are manipulated in to straight-line equation before scaling the graph. For instance the Freundlich adsorption isotherm is expressed as: $\frac{x}{m} = kp^{\frac{1}{n}}$, where $\frac{x}{m}$ is the amount of gas adsorbed per unit mass of adsorbent *p* is the equilibrium pressure of the gas and k and n are arbitrary constants. Plot of this equation will not give straight line but the logarithmic form of it i.e, $\log\frac{x}{m} = \log k + \frac{1}{n}\log p$, give a straight line graph, with slope $= \frac{x}{m}$ and intercept = log k. Let us take another example, the kinetic expression for first order reaction is given by $k = \frac{2.303}{t}\log\frac{a}{a-x}$ which is not in the form of straight line and is difficult to plot. It may be rearranged as $\log\frac{a}{a-x} = \frac{kt}{2.303}$ or $\log(a-x) = -\frac{kt}{2.303} + \log a$. The plot of $\log(a-x)$ vs *t* will give a straight line with a slope $= \frac{k}{2.303}$ and intercept = log*a*. Thus we find from the slope the value of rate constant 'k' and from intercept the initial concentration . Besides linear functions other algebraic functions important in chemistry are: (i) *Quadratic function*; equation of the form $y = ax^2 + bx + c$ is called quadratic function. If there are real values of x for which $ax^2 + bx + c = 0$, the curve will intersect the *x* axis at the

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value of x given by the formula $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$. For example the equilibrium constant for the dissociation of a salt is given by the formula $\frac{K}{c} = \frac{\alpha^2}{(1-\alpha)}$. On rearranging it gives $\alpha^2 + \frac{k\alpha}{c} - \frac{k}{c} = 0$, which is in the form of quadratic equation where $a = 1$, $b = \frac{k}{c}$ and $c = \frac{-k}{c}$. So $\alpha = \frac{k}{c} \pm \frac{\sqrt{\frac{k^2}{c^2} + 4\frac{k}{c}}}{2}$. (ii) *Single-valued function*; like wave functions ($\psi$) in quantum mechanics which are *eigen* functions having single values. (iii) *Many-valued function*, like $y = x^2$ , where there are two values of *y*, i.e. $+\sqrt{x}$ and $-\sqrt{x}$ or $\pm\sqrt{x}$ for each value of *x*. (iii) Functions of many variables; a function that depend on more than one variable is said to be of many variables, for example for the Ideal gas $P = \frac{nRT}{V}$, where pressure depends on three variables V, and n for a gas, i.e. $P = f(T,V,n)$. There are some other important algebraic functions used in chemistry such as polynomial functions, odd functions, implicit and explicit functions. All the non-algebraic functions are called transcendental functions. They include (i) logarithmic functions, (ii) exponential functions, (iii) trigonometric functions, (iv) inverse trigonometric functions, (v) hyperbolic functions and (v i) inverse hyperbolic functions. The mathematics dealing with both algebraic and transcendental is important not only for plotting the graphs but for understanding and learning the derivation of numerous equations and calculations spread in chemistry texts. In teaching the topics that involve such equations most of the lecture time is taken by explaining these functions otherwise the chemistry therein is simple.

**Logarithm** is important in chemistry in many ways. Relations between variables involved in chemical process are expressed in the form of logarithmic equations. This makes equation simple and easy to plot on a graph. The concentration and activities of ionic species in solution are usually expressed in p-scale, which is –log of the molar concentration or activity of the species. pH scale is more familiar to students which is –log $[H^+]$. Both the common logarithm ($\log_{10}$) and natural logarithm ($\log_e$ or ln) are important. The 'e' represents an irrational number having value 2.71828...Inter conversion of logarithm is easily done, and it follows the equation;
$\log_{10} x = \frac{\ln x}{\ln 10} = 0.4343 \ln x$. Logarithms whether natural or common are part of many equations in chemical sciences. Examples that appear in freshman chemistry texts include the equation for pH, the integrated rate equation for the first-order reaction, the relation between standard free energy change and equilibrium constant, the Clausius-Clapeyron equation, Arrhenius equation, and the Nernst equation. With the exception of the equation for pH these examples employ natural logarithms in their derivations. Typically in the last step a conversion to common logarithm is performed. Log. and p-scales are important in all the branches of chemistry, the solution chemist can not work without the tool of these scales. For example the Debye-Huckel equation for the activity coefficient determination and the solution speciation use these scales. For complicated systems commercial speciation software are available for use with computer.

**Differential Calculus and Ordinary Differential Equations:** Transformation of matter and energy are associated with physical and chemical changes. The quantitative relationship between the changes and the rate of change are of concern to chemist. The change is usually represented in science by symbol $\Delta$ (capital delta), thus $\Delta x$ means a change in *x*. But in chemistry we are concerned with molecular level changes, which are infinitesimal, and such changes are represented by another symbol $\delta$ (small delta), thus *x* means very small change in *x*. The chemistry texts also use *dx* similar to calculus for small change in *x*, which is read as "differential of *x*". When one function '*y*' changes with respect to another '*x*', then their ratio $\frac{dy}{dx}$ is called derivative of *y* with respect to *x*. Differential calculus uses methods to find $\frac{dy}{dx}$ in an equation of variable functions. Let us consider two functions *u* and *v* along with *y* being functions of *x* and present the simple rules of differentiation applied to the different forms of equations.(Table-2). In this table, *u* and *v* are functions of *x* and the values n, c and e are constants. n can assume any value except zero, c can have any value including zero, and e is equal to 2.71828...Applications of the rules of differentiation in chemistry, collected from chemistry texts are described by Sayyar[4]. For finding differentiation of function of a function, *Chain Rule* is used.

**Table-2:** Derivatives of algebraic and trigonometric functions.

| EQUATION | DERIVATIVE |
|---|---|
| $y = c$ | $\frac{dy}{dx} = 0$ |
| $y = cu$ | $\frac{dy}{dx} = c\frac{du}{dx}$ |
| $y = cu^n$ | $\frac{dy}{dx} = cnu^{n-1}\frac{du}{dx}$ |
| $y = u \pm v$ | $\frac{dy}{dx} = \frac{du}{dx} \pm \frac{dv}{dx}$ |
| $y = uv$ | $\frac{dy}{dx} = u\frac{dv}{dx} + v\frac{du}{dx}$ |
| $y = \frac{u}{v}$ | $\frac{dy}{dx} = \frac{v\frac{du}{dx} - u\frac{dv}{dx}}{v^2}$ |
| $y = \sin(u)$ | $\frac{dy}{dx} = \cos(u)\frac{du}{dx} = \frac{1}{\sec(u)}\frac{du}{dx}$ |
| $y = \cos(u)$ | $\frac{dy}{dx} = -\sin(u)\frac{du}{dx} = -\frac{1}{\csc(u)}\frac{du}{dx}$ |
| $y = \tan(u) = \frac{\sin(u)}{\cos(u)}$ | $\frac{dy}{dx} = \frac{1}{\cos^2(u)}\frac{du}{dx} = \sec^2(u)\frac{du}{dx}$ |
| $y = \log_e u$ | $\frac{dy}{dx} = \frac{1}{u}\frac{du}{dx}$ |
| $y = \log_a x$ | $\frac{dy}{dx} = \frac{1}{u}\log_a e\frac{du}{dx}$ |
| $y = e^u$ | $\frac{dy}{dx} = e^u\frac{du}{dx}$ |
| $y = c^u$ | $\frac{dy}{dx} = c^u(\log_e c)\frac{du}{dx}$ |
| $y = u^v$ | $\frac{dy}{dx} = vu^{v-1}\frac{du}{dx} + u^v\log_e u\frac{dv}{dx}$ |

**Ordinary differential equations** contain only one independent variable and as a consequence, total derivatives. They represent a relation between dependent variable (*y*), its various derivatives and functions of the independent variable (*x*). The *order* of a differential equation is the order of its highest derivative. If the highest derivative $\frac{d^n y}{dx^n}$, occurs in the equation, then the order of equation is *n*. The *degree* of the differential equation is the power of the derivative of the highest order in the equation after fractional powers of all the derivatives have been removed. The derivative $\left(\frac{dy}{dx}\right)^2$ would be of second degree but first order. Thus the equation

$\frac{d^2y}{dx^2}+\left(\frac{dy}{dx}\right)^2+xy=0$ is of the second order and first degree, while $\frac{d^2y}{dx^2}+\left(\frac{dy}{dx}\right)^{\frac{1}{2}}+xy=0$ is of second order and second degree. If the dependent variable and all its derivatives occur in the first degree and not multiplying each other, the equation is said to be *linear.* Solution of equation of nth order involves n integrations. Since, each integration introduces one arbitrary constant, the final solution for independent variable will contain n arbitrary constants. However a solution in which one or more of these constants are given specific values, for instance the value zero, will also satisfy the differential equation. In view of this consideration two types of solutions of an ordinary differential equation of *n*th order may be distinguished: (i) the *complete* or *general* solution which contains its all of *n* independent arbitrary constants; (ii) *particular* solutions, obtainable from the general one, by fixing one or more of the constants. In any chemical problem we generally use the given conditions to determine the arbitrary constants. Since differential equations contain derivatives, their solution essentially involves integration. Calculation of vibrational frequencies and energies of molecules, electron energy states in atoms and wave equation for electron motion involve differential equations. Teaching the differential calculus and methods of solution of differential equations, is important for understanding the logical basis of the results given in the chemistry literature.

**Partial Differentiation:** Partial differentiation and partial differential equations are common in chemistry. When there are more then one independent variables in an experiment and the change in the dependent variable is determined simultaneously by all the variables, then the method of partial differentiation is used to find *dy*. In other words it is the method of differentiation of function of several independent variables. The science of thermodynamics is the study of the laws that govern transformation of energy during physical and chemical changes. The quantitative physical variables that characterize the thermodynamic system include pressure, volume, temperature, internal energy and entropy. It is not always possible to vary such quantities at will, but specification of some, results in definite values for others. The method of partial differentiation then becomes appropriate[5]. Consider a function *u* of two independent variables. The functional notation is $u=f(x,y)$. The partial derivative of the variable *u* with respect to keeping constant is $\left(\frac{\partial u}{\partial x}\right)_y$ and similarly the partial derivative of *u* with respect to *y* keeping *x* constant is $\left(\frac{\partial u}{\partial y}\right)_x$. The total differential of *u* given by the fundamental theorem of partial differentiation is $du=\left(\frac{\partial u}{\partial x}\right)_y dx+\left(\frac{\partial u}{\partial y}\right)_x dy$. The partial molal quantity of a thermodynamic system is given by $G=f(T,P,n_A,n_B\ldots)$. Its total derivative is given as:

$$dG=\left(\frac{\partial G}{\partial T}\right)_{P,n_A,n_B,\ldots}dT+\left(\frac{\partial G}{\partial P}\right)_{T,n_A,n_B,\ldots}dP+\left(\frac{\partial G}{\partial n_A}\right)_{T,P,n_B,\ldots}dn_A+\left(\frac{\partial G}{\partial n_B}\right)_{T,P,n_A,\ldots}dn_B+\ldots$$

Looking through various chemistry texts (6, 7) it is obvious that students are asked to solve problems that involve partial derivatives early in the course.

Partial differential equations frequently occur in chemistry texts. In the study of structure of atoms and in spectroscopic studies, one uses the wave equations like the Schrödinger equation or the equation for vibrating string, which are the partial differential equations. Making use of the method of separation of variables such equations are solved. In teaching quantum chemistry and chemical thermodynamics, the lecture material mostly is partial differentiation and the solution of partial differential equations. The importance of it is thus evident, for learning the chemistry in these subjects and understanding the basis of the relationships in the texts.

**Integration:** Integration is a method of summing or adding a sequence of small changes or small parts. It is the reverse of differentiation. Indefinite and definite integral are the two types we find in chemistry texts. When the variable has given limits it is called definite integral and integral without limits is known as indefinite integral. The solutions are simple and some basic rules of integration are given in Table-3.

**Table-3.** Basic antiderivatives.

| |
|---|
| $\int dx = x + c$ |
| $\int x^n \, dx = \frac{1}{n+1} x^{n+1} + c$ |
| $\int x^{-1} dx = \ln x + c$ |
| $\int e^x \, dx = e^x + c$ |
| $\int e^{ax} \, dx = \frac{1}{a} e^{ax} + c$ |
| $\int a^x \, dx = \frac{a^x}{\ln a}$ |
| $\int \ln x dx = x \ln x + x + c$ |
| $\int \log_a x dx = \log_a e(x)(\ln x - 1)$ |
| $\int \cos x dx = \sin x + c$ |
| $\int \sin x dx = -\cos x + c$ |
| $\int \sec^2 x dx = \tan x + c$ |

In Table-3, c is the constant of integration, which cancels out in the case of definite integrals, $\int_a^b y dx = f(b) - f(a)$ and is not written. Examples of application of the methods of integration found in elementary texts are: relation for entropy from its changes in an ideal gas, free energy of ideal gas, integration of Clausius-Clapeyron equation for the calculation of enthalpy change, enthalpy change from variation of the equilibrium constant, calculation of free energy using the Arhenius equation, solutions of the rate expressions etc. Definite integral is widely used in thermodynamic and kinetic studies of the chemical reactions.

For finding integrals of simple problems, just the rules of integration given in Table-2 are applied, but the complex problems are first brought in a form fit for the application of the rules. Depending upon the nature of the equation the methods used are: algebraic simplification, substitution, integration by parts and integration by partial fractions. These methods provide tools to solve complicated integral equation, found in the chemical kinetics, chemical thermodynamics, quantum chemistry, electrochemistry, surface chemistry, statistical thermodynamics, analytical chemistry, etc. texts. The mechanism of a chemical reaction for example, is determined from the kinetic study of the reaction. Where the rate of reaction, rate constant and the order of reaction are important. Methods of integration are used in the derivation of kinetic expression and for treatment of the experimental data for determining mechanism of the chemical reactions, thus its teaching is important, without which the students will not be able to investigate the reaction and understand its mechanism.

**Mathematical series:** A sum of terms is known as series. If finite terms are present then the series is named as finite series and if infinite terms then it is called infinite series. A series having increasing powers of a variable is called geometric series. If in the geometric series each of the successive higher power of the variable has a multiplied coefficient then it is a power series. The power series may be finite or infinite depending upon the number of added terms. Power series are used to obtain numerical approximations for the value of an integral that cannot be evaluated in terms of standard functions. For example given the problem of determining $\int_0^{0.2} \frac{(e^x - 1)}{x}dx$, the student might first seek, in the tables of integrals, the antiderivatives of $\frac{(e^x - 1)}{x}$. None will be found. However an approximate evaluation of the integral can be had by replacing in the integrand by perhaps the first three terms of the infinite series $e^x = \sum_{n=0}^{\infty} \frac{x^n}{n!} = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots$ Having done so, we see that solution of $\int_0^{0.2} \frac{(e^x - 1)}{x}dx$, is as easy matter. Power series are also used in the solution of **linear differential equations** in cases where it is possible to express the function by means of a power series. A power series may be written as $f(x) = \sum_{n=0}^{\infty} c_n (x - x_0)^n = c_0 + c_1(x - x_0) + c_2(x - x_0)^2 + \ldots$. Here $c_0$, $c_1$, etc. are called the coefficients of expansion. As an example of the series application in solution of linear differential equation we can take the case of finding the possible values of the energy and shape of the corresponding wave functions in the case of Harmonic oscillator, where the method is used for solution of the differential equation[8] $\frac{d^2H}{d\xi^2} - \frac{2\xi dH}{d\xi} + \left[\left(\frac{\alpha}{\beta}\right) - 1\right] H = 0$. Power series method is also needed in solution of differential equation for finding possible energy and wave functions of electron in hydrogen atom. This mathematical method is thus also important to be known to chemistry students for overcoming the difficulties involved in theoretical derivations of some very important expressions.

**Determinants and Matrices:** A ***determinant*** is an arrangement of quantities or elements $a_{ij}$ in rows and columns in which the number of rows is equal to the number of columns.

$$\det A = |A| = \begin{vmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn} \end{vmatrix}$$

The determinant has *n* rows and *n* columns, and thus is the *order* of the determinant. In chemistry applications, the elements of the determinant are numbers or functions(real or complex), the determinant itself will also be a number or function whose value or form is determined by certain combination of its elements. Whenever a determinant such as det A = 0, we say the matrix A is *singular*, otherwise, A is called *nonsingular*. Students of chemistry should be familiar with the use of determinants in the solution of *n* linearly independent equations with *n* unknowns.

A ***matrix*** may be defined as a two-dimensional array of elements that obey a certain set of rules called matrix algebra. The elements may be real or complex, are arranged in rows and columns. Unlike determinants, matrices may be square or rectangular and also a matrix does not have a value. An example of an arbitrary matrix A is the following.

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn} \end{bmatrix}$$

Matrix A is said to be an *m* x *n* matrix, since it has *m* rows and *n* columns. The general *element* of matrix A is written where the subscript *i* identifies the row and *j* identifies the column. When *n* and *m* are equal then A is called *square* matrix; when $n = 1$ and $m > 1$ then A is a *column* matrix.; when $n > 1$ and $m = 1$ then A is called a *row* matrix. When the matrix has , then the matrix is called rectangular matrix.

Introduction to the concept of a matrix and matrix algebra enables the students to find solution of simultaneous equations in a more systematic way and to express the result more compactly. Matrices are also used to describe transformations from one coordinate system to another. Familiarity with the matrix method is essential for the application of the symmetry and group theoretical methods, to the molecular problems.

## References

1 ADLEMAN, L. M., (1994). *Science*, 266: 1021; GIFFORD, D.K., (1994). *Science*, 266, 993.

2 BOYER, C. B. (1985). A history of mathematics. Princeton University Press, Princeton, Chapter 25.

3. J. Phys. Chem. Ref. Data, (1973), 2(4): 741; PILAR, F. L.(1990). Elementary quantum chemistry. 2nd ed., McGraw-Hill Pub. Co. New York.

4. SAYYAR MOHAMMAD., (1999). Application of mathematics in chemistry, M.Sc thesis, University of Peshawar.

5. BLINDER, S. M., (1966), Mathematical methods in elementary thermodynamics. *Journal of Chemical Education,* 43 (2): 85-92

6. ATKINS, P.W.,(1994) Physical chemistry, 5th ed., W.H. Freeman. New York.

7. KAUZMANN, W., (1957). Quantum Chemistry. Academic Press, New York. Pp. 203-304.

8. MARGENAU, H., MURPHY, G. M., (1956). The Mathematics of physics and chemistry. D. Van Nostrand Co. New York.

9. MCQUARRI, D. A., SIMON, J.D., (1999) Physical chemistry, a molecular approach. Viva Books Pvt. Ltd. New Delhi.

10. KLEIN. D. J., RANDIC. M. eds., (1990). Mathematical chemistry. Proceedings of the 3rd International conference on mathematical chemistry. Galveston, TX (USA). March 1989.

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# MEASURING COMPETENCIES IN EDUCATIONAL SETTINGS

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## Summary

As in many countries with educational reform movements there is a debate going on in the Netherlands about the quality of education. The whole system is undergoing a change: from Primary Education to Secondary Education (general and vocational) up to Tertiary Education.

The main issue in the political debate on Primary Education is the age at which children enter compulsory education.

The main point of change in Secondary Education is the didactic system and the role of the teacher.

In academic education the educational framework will be renewed by the introduction of the bachelor-master structure.

This paper focuses on the changes in Secondary Education and the function and role of assessment as an important tool of quality control.

One of the main reasons for the reform of Secondary Education is the high percentage of dropouts in Tertiary Education (about 30%) due to a lack of such skills as planning, applying creative solutions, communication, investigation, etc.

I will elaborate on the changes in Secondary General Education and in Secondary Vocational Education. The core objectives of both changes can be summarized as follows:

- stimulating a broad development of students' knowledge, skills and attitudes;
- creating active and independent students;
- taking into account different styles of learning.

Modern society needs employees who are capable of planning their own activities, who can manage their job independently, who are capable of finding necessary information, etc. In short, the ability to apply integrated skills is more important than the possession of atomized knowledge.

Changes in syllabuses have to be accompanied by changes in assessment procedures and assessment tools. In the paper I will discuss portfolio assessment, measuring competencies and the introduction of the so-called Quality Monitor® as part of a system.

## 1 Introduction

One of the main reasons for the reform of Secondary Education is the high percentage of dropouts in Tertiary Education (about 30%). Students in Tertiary Education lack such skills as planning, applying creative solutions, communication, investigation, etc. Moreover, students in secondary education are not used to monitoring the progress of their studies.

One of the core activities of Cito group, the Dutch National Institute for Educational Measurement, is the production of nation-wide school-leaving examinations in Secondary General Education (4 levels, two each at 16+ and 18+, all subjects). In Secondary Vocational Education there is a school based examination with a completely different involvement of Cito. Its main activities in vocational education consist of training staff and teachers in organizational matters of evaluation and in the development of item banks. It is in this field of education that the development of competency measurement and the Quality Monitor® has taken place. The need for competency driven education (a competency is more than a skill) arises from several circumstances:

- there is a growing demand in society for competencies rather than qualifications based on knowledge and skills alone;
- knowledge is changing so rapidly that is not so important to know all kinds of facts but better to know where to find them;
- there is a significant influx of adolescents from foreign countries and they do not have all the qualifications society demands; this means competencies are becoming more important;
- in order to have better chances of employment, people have to be more flexible in coming up to society's ever-changing demands.

The Inspectorate has to control the system. Especially the qualities of the exams of Secondary Vocational Education are not what they should be. Therefore the system is going to be changed. This will involve using the specially developed Quality Monitor®, which is aimed at improving the quality of the educational system.

## 2 Secondary General Education

The changes in upper secondary education have been effective since 1999. The reform movement was introduced with the slogan 'from teaching to learning', expressing the necessity for students to become more responsible for their own study progress and learning activities than they were in the then current system.

The core objectives of the change can be summarized as follows:

- stimulating a broad development of students' knowledge, skills and attitudes;
- creating active and independent students;
- taking into account different styles of learning.

Modern society needs employees who are capable of planning their own activities, who can manage their job independently, who are capable of finding necessary information, etc. Integrated skills are more important than atomized knowledge.

Every subject in the syllabus contributes to a set of integrated skills, which the student has to acquire. In the syllabuses of all the subjects, the first domain of attainment targets consists of 'general skills'. It includes objectives concerning language skills, computational skills, communicative skills, information skills, problem solving skills, research skills and technical skills. The other domains describe the subject specific attainment targets.

At the end of the course in Dutch secondary education, there is a centrally organized written examination and a school based part. This school based assessment largely consists of portfolio assessment. During the last two or three years, students compile their portfolios. There are general guidelines for the compilation of portfolios, but each school has a large amount of freedom to specify the tasks that the students have to perform. The school is responsible for the specification of the SBA (School Based Assessment) containing detailed information concerning the content of the SBA, the schedule of assessment activities, procedures, etc. These specifications are handed out to the students and have to be sent for approval to the Inspectorate. The Inspectorate check that the programs for SBA contain all the necessary information, and they guard the level of the assignments per school.

Each portfolio contains four different types of assignments:

- written tests (paper and pencil)
  The written tests make up 60% of the portfolio mark. Written tests come under the responsibility of the teachers themselves. Most of these tests are produces, set and marked by the teachers. They also develop their own marking schemes.
- practical assignments
  The main purpose of practical assignments (PAs) is to test general skills such as described. This is done

within a subject specific context. The PAs account for 40% of the portfolio mark. PA's are small research projects (10-20 hours) to be carried out in a few days or weeks. Not all the elements of a research cycle need to have equal weight in a PA. Sometimes more emphasis can be placed on the gathering of information, sometimes on the analysis of data. Students have to include at least two PAs per subject in their portfolios. A PA is not assessed by its (end) product only. The process and the presentation both play an important part in the assessment. The student has to write a small project log to enable the teacher to assess the process. Presentations can be in the form of a written report, an article, an oral report, a demonstration, a poster presentation, an audio-visual presentation, a presentation using information technology, etc. There are three assessment categories: general skills, subject specific skills and the presentation. The assessment complies with criteria set in advance. It is recommended for the criteria to be set by the school as a whole and not by individual teachers. It is also recommended that the students be informed by what criteria they will be assessed.
The students must make sure that their portfolios cover different types of research and different forms of presentation. One of the PAs must be carried out in a group of at least three persons.
- profile assignment
  The profile assignment is a large PA (40-80 hours). The students work on their profile assignment in the final year. It covers a full research cycle. Its purpose is to integrate the skills and the knowledge of two subjects from the profile (i.e. one of four fixed sets of school subjects) that a student has chosen. Just as with the PAs the product and the process will be assessed. The assessment will not result in a mark but should be at least satisfactory; otherwise the student is not able to get his schoolcertificate. The assessment is mentioned separately on the students' certificates.
- miscellaneous assignments
  This last part concerns small assignments like participating in field trips, theatre visits, career guidance activities, etc. They are not marked as such, but the portfolio should indicate that a student has taken part in a prescribed number of activities.

A major complaint of teachers concerning the implementation of the new curriculum is lack of time. That is why Cito group has developed models for evaluating the students' products and processes. Teachers can use these models and adjust them to their own needs if they like. The model for the organization and assessment of the profile assignment includes four different phases:
- the orientation phase and the period of making choices (about 12 hours);
- the research phase: gathering information and experimenting (about 36 hours);
- the phase of preparing the presentation or making the design (about 28 hours);
- the presentation itself (about 4 hours).

The time allotted to each period should be seen as indicative, not prescriptive! One student will use more time for orientation and making choices, while another student needs more time for formulating the research questions and hypothesis. Yet another one will need most of the time for experimentation or making creative design. But in order to achieve satisfactory results, all the phases should be gone through.

The separate phases are distinguished to facilitate following the flow of progress and process. Completing one phase and entering the next can be used as an anchor point. Each phase requires its specific activities of the students. Each anchor point can be seen as a moment of reflection and can be used for assessing the students on the basis of different criteria separately, resulting in a *go/no go* decisions (see appendix 1). If the student is allowed to continue with the next stage, it is not possible at a later moment in time to ask the student to redo work which was done during the proceeding phase. If a *no go* decision is taken, the teacher has to give instructions about what should be done. This is to make sure that a student has ample opportunity to repair work which is not satisfactory. A student cannot continue with the next stage before a satisfactory result has been obtained for the previous one. The model uses a three-point scale:
1. unsatisfactory: the aspect is either not present or it is present but is not worked out properly;
2. satisfactory: the aspect is present and reasonably worked out;
3. good: the aspect is present and worked out well.

The last assessment may develop into a final discussion involving reflection and evaluation. It must be clear to the student that the assessment is finished before this final discussion. The function of this last session is to emphasize the active involvement and personal responsibility of the student.

The next table shows the different aspects of the discussion sessions.

| Phase | Discussion subjects | Length of the discussion | Discussion partners | Kind of discussion | Information sources | Assessment tools |
|---|---|---|---|---|---|---|
| Orientation and choice | Subject title | 10 minutes | Teacher and student | Guidance | The subject, the first planning of the research | |
| Research and gathering information | Research questions and planning | 20 mins | Two teachers and student | Judgement | The (research)plan and projectlog | Assessment procedure 1 |
| | On the basis of the projectlog | 10 mins | Teacher and student | Guidance | Planning, log and different sources | |
| Preparation of the presentation | draftreport | 20 mins | Teacher and student | Judgement | Planning, log and different sources | Assessment procedure 2 |
| | Continuing writing or preparation of the presentation | 10 mins | Teacher and student | Guidance | Planning, log, different sources and draftreport | |
| Presentation | Presentation | 10 - 20 mins, depending on the kind of presentation | Two teachers and student | Judgement | presentation | Assessment procedure 3 |
| | Reflection and evaluation | 10 mins | Teacher and student | Reflection | | |

Because this system is not obligatory it is not possible to show any results of trials, but during discussion we can mention the different ways teachers have used the evaluation sets and their reactions to them. The results are promising.

## 3 Secondary Vocational Education

In the vocational part of Secondary Education a change was effected in 1997. The Ministry of Education prescribed all the attainment targets and the schools had to make a program for the assessment of all these targets. It is required now that at least 51% of the targets be externally legitimized. Schools have to send all the tests and other evaluation materials to special examination centers for legitimizing. This means a lot of work and involves much discussion about the way of legitimizing. For the benefit of improving the evaluation materials and processes Cito group offers a full and detailed schooling program. It involves training management and middle management in organizational matters and the main features of making and judging tests and training teachers in producing all kinds of evaluation materials. This ranges from the construction of the well known written questions till the evaluation of what is called: professional vocational training. This latter part is especially important because vocational education leads towards jobs in society.

In recent years suggestions have been made towards the development of attainment targets described as competencies. The system of attainment targets is composed of a lot of qualifications demanded by several branches of industry. This influence on the goals being set is very strong and because of the dissatisfaction with the results of education there is a strong movement for changing the system into a competency driven system. In education there is increasing emphasis on the point of view that students have their own responsibility and should be able to cope with all kinds of problems. This means that it presents groups of students with problems and they have to solve them. The problems must be context-orienting. This should be the basis of the examinations too. The development of instruments for measuring the students' competencies is the next step. A current topic of discussion is whether it is possible to measure the competencies of youngsters at the age of about 16 - 18 years.

A competency is made up of several components (see definition below). A competency test should cover all these elements and should reflect the method of education. A competency test is set in a rich context (the sum being more than just an addition of the component parts) and does not only consist of a summative test but has a lot of formative elements in it too.

**Definition of competency**

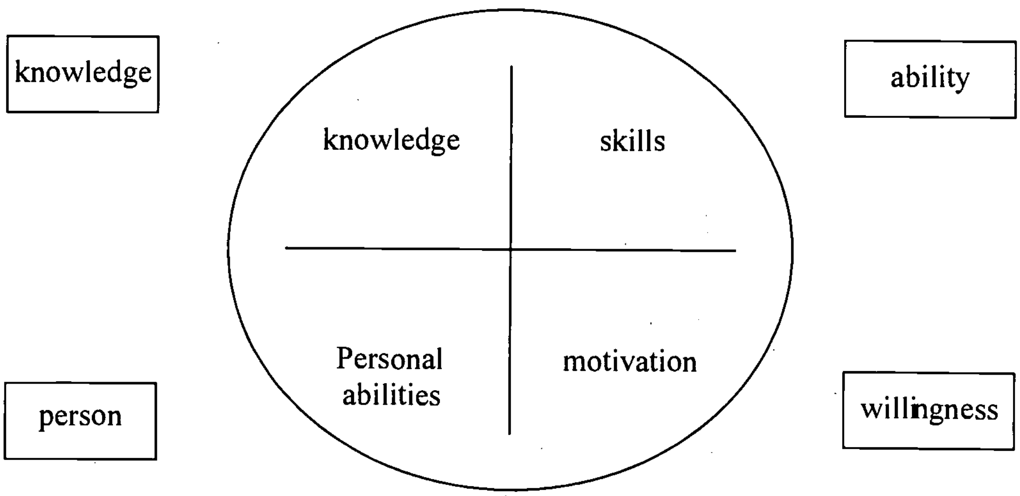
In daily practice such words as competencies, qualifications and skills are used as synonyms. This is not correct. In the literature (Bos 1998) the following definition is used:

A competency is competency only if it provides information concerning the following components:

- a classification component which states what the competency is about;
- a context in which the competency is shown;
- skills needed for showing the competency;
- knowledge needed for showing the competency;
- personal abilities for monitoring the performance of the competency;
- criteria of behavior.

So competencies are more than skills, they are more complex and more inclusive. A competency is shown in a specific context and by means of specific behavior. Judging a competency has to build in these two conditions.

The below figure (Schipper, Jie a Joen, de Kleer, 1999) shows the composition of a competency. The component 'Personal abilities' is subdivided into personal abilities and motivation.




Missing in the figure are the context in which the competency should be shown, the criteria of behavior and the results that should be measured.

**How visible is a competency?**

For the development of a competency it is not only important to look at the ability of the starting workers, but also to pay attention to their motivation and the quality of performance. Motivation is the foundation of an individual competency.

Values, vision on oneself and others and creative and productive knowledge and experiences are also important components of a competency. Especially these personal abilities are difficult to learn. In a lot of cases they are not visible either and so are not measurable.

They can be made visible by eliciting behavior, forcing choices and next asking to explain the behavior and reflect on comparable situations.

In the literature a competency is compared to an iceberg of which only the tip can be seen *(Bergenhenegouwen, 1998).*

Personal abilities set limits to the competencies that can be developed.

**Competency driven education and evaluation**

In vocational education competency driven education is gaining more and more momentum. This means a shift in the teaching process from teacher centered to student centered education. The traditional educational concept is changing from knowledge-based to competency-based. Students are more responsible for their own educational process (Schlusmans & Slotman in Jochems, W. en Schlusmans, K., 1999).

In their view of education four concepts are essential:

- integration;
- a real life context;
- reflection;
- self responsible students.

Dividing vocational qualifications into several disciplines leads to traditional education. Instead, qualifications have to be formulated in terms of competencies. Knowledge and skills are still important, but only in relation to real life context. This kind of education is only successful if it is followed by a new type of evaluation. Education and evaluation are not two separate issues but should be integrated. This involves a diversity of assessment tools. Formative evaluation will play an important role in the whole educational system. In this system it is quite normal for students to make the wrong decisions. But this is part of the learning process and making errors should not be penalized. This process should be part of the judgement about competency. Evaluation plays a role in activating and guiding the learning process (de Bie, 2000). It is even imaginable that all the results of formative evaluation should make summative evaluation unnecessary.

But it should be borne in mind that the instrumentation used should always meet all the usual test criteria such as validity, reliability, transparency, etc. There should also be a balance between the intensity (in time) and the number of assessments conducted to show the competency.

Cito group was asked to participate in a project in one of our big cities (Rotterdam) to develop competency tests because the traditional evaluation system is leaving too many students uncertified, especially in the lower grades. Assessment in a real life situation was expected to solve this problem. So we developed a number of specific competency tests as part of the education system used (see appendix 2). Until now we have not been able to try out the material.

**The Quality Monitor®**

At this moment the Inspectorate is not satisfied with the quality of the examinations in spite of the efforts made at legitimizing them. Consequently, a political discussion has started about how to improve the whole system of education. As part of this quality discussion Cito group has developed a monitoring system (the Quality Monitor®) that can be used as a tool for improvement.

To work on quality, a school has to know what is the state of the art, what do we want to undertake and what is the final stage. Schools have to produce a quality report every two years and the data from the monitoring can be used for it. Here Cito group comes in. We offer schools a counseling program in which the management and/or teachers are helped in the whole quality process. It involves a step-by-step process towards the final stage.

The Quality Monitor® has the following starting points:

- improving the examination process;
  Quality requirements for examinations have been formulated. These criteria are contained in checklists in the Quality Monitor®.
- Step-by-step improvement;
  Because of the complexity of the exam system improvement should be brought about in phases. Four phases are defined in the Quality Monitor®.
- Ease of application;
  For quality members of schools it is important to establish in an efficient way where the school stands in the process and what should be the next steps for improvement.
- Contribution to the quality report;
  The outcomes of the Quality Monitor® can be easily used as a contribution to the report that has to be made every two years. The outcomes can also help the management to formulate the school policy. Thus it is a systematic way of controlling the quality of the exam system.
  The Quality Monitor® consists of three parts: a matrix, checklists and activity plans. It is available in a paper version and a digital one. The digital version allows easy mouse-click selection of the different aspects of the quality system.

For a quick overview the matrix is shown below. It is divided into themes relevant for the examination and the four phases. These four different phases start with 'incidental management policy', followed by 'starting management policy' and 'complete management policy', and end with 'integrated management policy'.

To show how it is built up a few cells are filled. In the complete matrix every cell is filled and can offer checklists and activity plans for reaching the next phase.

The Quality Monitor® was constructed together with three schools and has been used as a pilot. During this pilot study is has shown its value and schools are eager to use it.

| Cito groep | | Quality Monitor® | | | |
|---|---|---|---|---|---|
| | | Phase 1 | Phase 2 | Phase 3 | Phase 4 |
| Test construction | Proce-dures | Teachers are making their tests individually | A group of teachers are working together in making tests | There are special test constructors | A test construction procedure is established |
| | Criteria | | | | |
| | | | | | |
| Determining Tests | Training | Teachers have not had any training in making tests | A few teachers have been taught how to make tests | A test making policy is determined | The test making policy is evaluated every year |
| | | | | | |
| | | | | | |
| Documents | | | | | |
| | | | | | |

### Assessment

As shown in these examples from Secondary Education, assessment should play a major role in the quality improvement of educational systems.

When setting up new educational programs, whether for teacher education or for the education of students of whatever level, the evaluation of what is happening or what has happened is usually forgotten. If you are lucky, some attention is paid to evaluation at the end.

The examples show that the process of developing new educational material, new educational systems and implementing these materials or systems without paying attention to evaluation/assessment is 'a missed chance'. Educationalists/teachers working together with evaluators/assessors will save time and make implementation better, cheaper and more pleasant for all.

## 4 Literature

Bergenhenegouwen, G. (1998) Kerncompetenties, competenties en competentie ontwikkeling. In: Opleiders in Organisaties, Capita Selecta, nr. 36. Kessels, Smit, Paps-Talen (red).

Bie, de D.(2000). Een Gewichtig tussenstation. Toetsen en het beoordelen van competenties in dienst van het leren. Onderwijs en Gezondheidszorg, 24, 2, p15-17.

Bos, E.S. (1998). Competentie; verheldering van een begrip. OTEC rapport 98/R01. Heerlen, Open Universiteit.

Jochems, W. en Schlusmans, K. (1999). Competentiegericht onderwijs in een elektronische leeromgeving. In: Competentiegerichte leeromgevingen (2) Schlusmans, Slotman, Nagtegaal, Kinkhorst (red). Utrecht: Lemma.

Kroft, van der, G. & Sinkeldam, R. (1999). Environmental topics as a tool to change the Dutch Secondary Educational System, IOSTE 9 Proceedings, vol.2, pg. 605-615, 1999, Durban, South Africa

Krogt, van der, M., (1998) Cito, The Netherlands The school based Portfolio-Assessment, (Dutch title: Eindverslag Netwerk Examendossier)

Schipper, E., Jie a Joen, N., de Kleer, E. (1999), Ned Tijdschrift voor Bedrijfsopleidingen, november

Simons, P.R. (1999). Competentiegerichte leeromgevingen in organisaties en hoger beroepsonderwijs. In: Competentiegerichte leeromgevingen (2) Schlusmans, Slotman, Nagtegaal, Kinkhorst (red). Utrecht: Lemma.

Sinkeldam,R., (1998), Cito, the Netherlands Teacher- and student-guide Profile Assignment, (Dutch title: Handleiding Profielwerkstuk)

Wiggins, G. (1998) Educative Assessment; Designing Assessments to Inform and Improve Student Performance. San Francisco, Jossey Bass Publishers.

## Appendix 1

### 1 Assessment I

| | For each aspect circle the number in the column under the category of your judgment | | | | | |
|---|---|---|---|---|---|---|
| | **Aspects to be judged** | **unsatisfactory** | **satisfactory** | **Good** | | **Agreements/ remarks** |
| **1.** | Is the integration of the two disciplines reflected in the subject (title)?<br>*Think about:*<br>• *Recognition of the disciplines*<br>• *does it fit the profile* | **no-go** ➡ | **2**<br>(1) | **3**<br>(2) | → | |
| **2.** | Is the discipline-content adequately represented in the research question?<br>*Think about:*<br>• *clearness and level of the research-question*<br>• *originality* | **no-go** ➡ | **2**<br>(1) | **3**<br>(2) | → | |
| **3.** | Has the student split up the research-question into relevant sub-questions?<br>*Think about:*<br>• *evel of discipline-content*<br>• *concreteness of the questions*<br>• *solvability*<br>• *relation with the main question*<br>• *marking out and restriction*<br>• *terminology* | **no-go** ➡ | **2**<br>(1) | **3**<br>(2) | → | |
| **4.** | Has the student set hypotheses or expected outcomes?<br>*Think about:*<br>• *relation with theory*<br>• *is the hypothesis in line with the research-question* | **1** | **2** | **3** | → | |
| **5.** | Is there a realistic 'plan of approach'?<br>*Think about:*<br>• *necessary activities are mentioned*<br>• *logical sequence of activities*<br>• *realistic planning in time*<br>• *clearness of the plan* | **no-go** ➡ | **2**<br>(1) | **3**<br>(2) | → | |
| **6.** | Does the plan of approach provide answers to the research-questions?<br>*Think about*<br>• *the research-method*<br>• *proposed experimental set*<br>• *safety and environment* | **no-go** ➡ | **2**<br>(1) | **3**<br>(2) | → | |
| **7.** | Has the student get a good overview of the various information-sources?<br>*Think about:*<br>• *completeness of info*<br>• *topicality of info*<br>• *validity of info*<br>• *variety of info* | **1** | **2** | **3** | | |
| **8.** | How independent is the student?<br>*Think about:*<br>• *has made right decisions*<br>• *anticipates and thinks with group members*<br>• *has worthwhile ideas* | **1** | **2** | **3** | | |
| **Subtotal assessment I** | | | | | ... | |

## Appendix 2

| Building assistent (junior vocational education)<br>Competency test 'Adjusting a section' |
|---|

**Competency**
Under supervision the student is able to adjust a section of a building construction together with a colleague. She/he can use the design of a building construction for brickwork.

**Construction**
The construction work has to be done at school or, if possible, at a real building place. Depending on the place of construction students are assessed by their teachers or by their tutors in practise.

The student gets instructions on a plan with designs. With the plan of designs she/he has to decide what and how many materials and tools she/he needs. In good cooperation with another student she/he has to adjust the section.

The students can elucidate their actions and results on a paper with questions.

The professional attitude appears from:
- acting according to a plan;
- taking into account her/his own safety and that of others;
- a good pace of work;
- independence;
- cooperation;
- communication skills and being friendly;
- working conscientiously;
- taking initiative.

**The assessment**
The aspects are assessed on a two-point scale (0 if the aspect is unsatisfactory or doubtful and 1 if it is satisfactory or good). Weighting of the different parts such as preparation, etc. is found at the bottom end of the instrument. The column 'details' can be used for notes.

*Student instruction*

Assessment of 'adjusting a section'

**What will be assessed?**
Adjusting the section with the aid of a design.
Cooperation with another student.

**Where and by whom are you assessed?**
During a term of probation you are assessed by the tutor. When working at school you are assessed by your teacher.

**What do you have to do?**
Read the instructions and follow them precisely.

**What will your attendant pay attention on?**
She/he will look at the way you prepare and carry out the plan.
She/he will also look at your professional attitude. This means, for example, that she/he will assess your pace of work, safety, the extent to which you cooperate. The discussion at the end of this 'test' is part of the assessment.

**Assessment tools**

*A: preparation*

| Nr | Description | 0 of 1 | Details |
|---|---|---|---|
| 1 | Writes on the instruction card what and how many materials and tools are needed | | |
| 2 | Puts everything ready to hand in order of use | | |
| 3 | Consults with the teacher or tutor about a suitable place | | |
| 4 | Together with the other student decides the sequence of actions and the change of persons | | |
| | **Total** | | |

*B: execution*

| | | | |
|---|---|---|---|
| 5 | Using appropriate section parts | | |
| 6 | Nailing the section | | |
| 7 | Keeping the section level | | |
| 8 | Clear instructions to the helper | | |
| 9 | Adjusting the section parts | | |
| 10 | Checking and re-adjusting the section | | |
| 11 | Cleaning up materials and tools | | |
| | **Total** | | |

*C: evaluation*

| | | | |
|---|---|---|---|
| 12 | Answering the questions on the card of instruction | | |
| 13 | Elucidating the answers | | |
| 14 | Is able to point out what was good and what was wrong | | |
| 15 | Points out what improvement is possible | | |
| 16 | Uses the right vocabulary | | |
| 17 | Shows sufficient professional knowledge | | |
| | **Total** | | |

## Appendix 2

| Building assistent (junior vocational education)<br>Competency test 'Adjusting a section' |
|---|

**Competency**
Under supervision the student is able to adjust a section of a building construction together with a colleague. She/he can use the design of a building construction for brickwork.

**Construction**
The construction work has to be done at school or, if possible, at a real building place. Depending on the place of construction students are assessed by their teachers or by their tutors in practise.

The student gets instructions on a plan with designs. With the plan of designs she/he has to decide what and how many materials and tools she/he needs. In good cooperation with another student she/he has to adjust the section.

The students can elucidate their actions and results on a paper with questions.

The professional attitude appears from:
- acting according to a plan;
- taking into account her/his own safety and that of others;
- a good pace of work;
- independence;
- cooperation;
- communication skills and being friendly;
- working conscientiously;
- taking initiative.

**The assessment**
The aspects are assessed on a two-point scale (0 if the aspect is unsatisfactory or doubtful and 1 if it is satisfactory or good). Weighting of the different parts such as preparation, etc. is found at the bottom end of the instrument. The column 'details' can be used for notes.

*Student instruction*

Assessment of 'adjusting a section'

**What will be assessed?**
Adjusting the section with the aid of a design.
Cooperation with another student.

**Where and by whom are you assessed?**
During a term of probation you are assessed by the tutor. When working at school you are assessed by your teacher.

**What do you have to do?**
Read the instructions and follow them precisely.

**What will your attendant pay attention on?**
She/he will look at the way you prepare and carry out the plan.
She/he will also look at your professional attitude. This means, for example, that she/he will assess your pace of work, safety, the extent to which you cooperate. The discussion at the end of this 'test' is part of the assessment.

**Assessment tools**

*A: preparation*

| Nr | Description | 0 of 1 | Details |
|---|---|---|---|
| 1 | Writes on the instruction card what and how many materials and tools are needed | | |
| 2 | Puts everything ready to hand in order of use | | |
| 3 | Consults with the teacher or tutor about a suitable place | | |
| 4 | Together with the other student decides the sequence of actions and the change of persons | | |
| | **Total** | | |

*B: execution*

| | | | |
|---|---|---|---|
| 5 | Using appropriate section parts | | |
| 6 | Nailing the section | | |
| 7 | Keeping the section level | | |
| 8 | Clear instructions to the helper | | |
| 9 | Adjusting the section parts | | |
| 10 | Checking and re-adjusting the section | | |
| 11 | Cleaning up materials and tools | | |
| | **Total** | | |

*C: evaluation*

| | | | |
|---|---|---|---|
| 12 | Answering the questions on the card of instruction | | |
| 13 | Elucidating the answers | | |
| 14 | Is able to point out what was good and what was wrong | | |
| 15 | Points out what improvement is possible | | |
| 16 | Uses the right vocabulary | | |
| 17 | Shows sufficient professional knowledge | | |
| | **Total** | | |

*D: professional attitude*

| | | | |
|---|---|---|---|
| 18 | Works according the plan | | |
| 19 | Takes into account own safety and that of others | | |
| 20 | Works independently (doe not ask the help of the attendant more than twice) | | |
| 21 | Cooperates well | | |
| 22 | Debates with the helper and gives clear instructions | | |
| 23 | Is friendly | | |
| 24 | Is conscientious | | |
| 25 | Has a good pace of work | | |
| 26 | Works tidity | | |
| 27 | Shows initiative | | |
| | **Total** | | |

**Weighting of the parts and conclusion**

All aspects are scored 0 or 1.

0 = unsatisfactory or doubtful

1 = satisfactory or good

For the parts Preparation(A), execution(B) and evaluation(C) you can get a maximum of 17 points. The minimum a student has to get is 11 points (65%).

For the part Professional attitude (D) you can get a maximum of 10 points.

The minimum a student has to get is 6 points.

Mutual compensation among parts is not possible. If a student meets the minimum requirements, she/he has passed. If one of the parts is below the minimum, she/he has failed.

# 107 IDEOLOGIES IN SCHOOL SCIENCE TEXTBOOKS CONFRONT STUDENTS: HARMONY AND INDIFFERENCE

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## Introduction

The work presented in this paper aims to investigate how science textbooks construe reality, scientific knowledge and the student as receiver in discourses on 'energy'. Critical text analysis is carried out on text samples used in the mandatory science course in upper secondary school in Norway. In individual, semi-structured interviews, students read text samples and were asked questions in a close contextual frame ('what is this text about?') and in a wider institutional frame ('what is the purpose of science education in your experience?').

The work presented has origins in an effort to identify ideologies regulating school science discourses (Knain 1999, 2001). There are several reasons why this is interesting. Learning science in school is never only about learning about the natural world. Students also learn how the *social* world is perceived, including how to think about themselves and behave in matters involving science. Science education practices have a potential for socializing students into various relations that involve power and autonomy, say between expert knowledge and lay citizens, or condition citizens' abilities to influence decisionmaking (Fourez 1988, Östman 1995). From a cultural perspective, science education is considered as making meaning within the context of a cultural milieu. In this perspective, students with different *world views* attend science classes; the contextualization of science may be in conflict with their cultural background, and so they may choose to ignore science (Aikenhead 1996, Cobern 1996).

## Framework and method

Critical text analysis is conducted within a social semiotic framework based on Halliday's functional grammar and stratified semiotic planes so that meaning at the cultural (ideological) level could be deduced from meaning at the lexicogrammatical level (Halliday 1994, Halliday, Martin 1993). We know something about what to expect in a text when we know the situation. This co-variation between text and context is called *register.* By identifying the register in terms of lexicogrammar (words and grammar), and drawing on the context of school science, ideologies regulating the discourse may be inferred. The text analysis follows a methodology from Fairclough, with *text description*, *text interpretation* and *text explanation* corresponding to stages in analysis and levels of context (Fairclough 1989).

A few notes on the text description. In Hallidays framework, language has components of meaning that are always simultaneously present in language, that is, components that are

> manifestations in the linguistic system of the two very general purposes which underlie all users of language: (i) to understand the environment (ideational), and (ii) to act on the others on it (interpersonal). Combined with these is a third metafunctional component, the 'textual' which breathes relevance into the other two (Halliday 1994, xiii).

Halliday's framework is rather complex, and so only three aspects of his functional grammar were used for empirical work, within three different metafunctions: *i)* grammatical processes (sorting out and ordering experiences), *(ii)* modality (the area of meaning that lies between 'yes' and 'no', 'true' and 'false'), and *(iii)* conjunction (cohesion across sentence boundaries). All images in the samples were also analyzed in grammatical terms (Kress, van Leeuwen 1996). *A grammatical process* consists of the process itself (verbs), participants in the process (nouns), and (possibly) circumstances associated with the process. For instance, in

"Kelly watched the stars", 'Kelly' and 'the Stars' are participants in the mental process (sensing) realized by the verb 'watch'.

Learning 'concepts' means not only to learn static 'words'. 'Words' and 'grammar' cannot be clearly separated in this social semiotic framework. A goal of learning is that students learn to construct meaning flexibly in various situations, using semantic relationships that Lemke has called 'thematic patterns' (Lemke 1990, 91). Furthermore, these words are often metaphors for processes, action going on in the physical world. For instance, 'stargazing' is a *nominalisation* where an act of sensing ('Kelly wached the stars') is turned into a 'thing ('stargazing')'. Halliday has pointed out the importance of grammatical metaphor as kind of coupling and decoupling between a plane of semantics, interfacing with the world of human experience, and a grammatical plane as a theory of experience. Scientific knowledge has evolved as a kind of metaphorical reconstrual of experience, in which nominalizations are important in expanding, transcategorizing, compacting, distilling and theorizing (Halliday 1998, 228).

Texts on the topic of 'energy' used in the eleventh grade (age 16), the first year of upper secondary school in Norway were analysed. Texts were sampled to include both the field of mechanics in physics (force and energy), and discourses on energy in society (use of energy, environmental issues). Two books are included in the present analysis; one is for the 'general track' (for students preparing for college and university), the other for vocational education, the 'vocational track'. The topic that was chosen for analysis is included in both tracks.

Semi-structured interviews were carried out with students in the target group for the analysed texts. The interview guide was structured to identify relationships between their views on the purpose of school science, interpretations of specific texts in the sample, and their use of science textbooks. In the social semiotic framework underpinning the study, students' interests are important for their interpretation of texts and their use of textbooks. Furthermore, these interests are rooted in a wider cultural milieu, which may be at odds with the culture of school and/or the culture of science.

Six boys attending the same class in the vocational track were interviewed in one school, and three girls and three boys attending the same general track class were interviewed at another school. The interviews are analysed both across cases (focusing on students' background and interests) and within cases (focusing on relationships between background and interpretation for individual students). Two levels of coding arise in both instances, conceptual and theoretical. Texts and interviews are analysed using ATLAS software for qualitative data analysis.

## Results

First some aspects of the critical text analysis will be presented and discussed. Then the student interviews will be presented.

## The Mechanics sections

As noted above, in an Hallidayan framework, an uncommon sense understanding of physical processes concerning energy is constructed in the mechanics sections in the science textbooks. This (re) construction of meaning is realized by lexicogrammatical (words and grammar) processes. The topics that are treated in the mechanics part are force, energy, and energy transfer.

The mechanics text and the vocational text treat the topic differently, suggesting that these texts construe their purpose and their ideal reader in different ways. Below the general track text ('A') and the vocational track text ('B') will be compared.

### Text A – general track

Text A introduces the chapter on energy with a narrative that unfolds in historical time on how energy stored in gasoline has origins in fusion processes in the Sun. The concept of 'energy' is then introduced, the term's Greek origin is briefly mentioned, before students are reminded of previous encounters in school with this subject.

Then the main thematic patterns in the text unfold: energy is transferred either by heat or by work. This is the largest section in the text. Details in this development will be investigated later.

Next, students are reminded of different types of energy that they may have heard of, such as chemical energy, nuclear energy, solar energy, radiation energy, and so on. These concepts, the students are told, are used in various contexts or situations. In this text it turns out that they are a kind of surface phenomena, as there are only two fundamental types of energy: kinetic[1] and potential[2] energy. This development is first given in the projection 'Physicists will say that <projection>':

> It can be hard to determine which label we should use for a type of energy. Physicists will say that in reality there are only two kinds of energy: [bevegelsesenergi], which is also called kinetic energy, and [stillingsenergi], which is also called potential energy. Other types of energy are combinations of [bevegelsesenergi] and [stillingsenergi] (Text A, 104-105).

This passage has a different 'flavour' than the rest of the sampled text. There are some markers of modality ('can', 'should') in addition to verbal processes that are metaphors for relational processes (realized by 'called'). 'In reality' is a translation of 'egentlig', which creates a tension in meaning together with the projection: This is how the world really is – according to physicists. In a yellow background following this passage, this notion is restated without the projection, now stating the fact. The tension has now disappeared. It is a fact lifted out of the social context that made it so, standing alone as a fact of nature. By this move, the context of the scientific community is removed. It is not only a notion that is held by physicists, it is a fact of nature. This shift is interesting for several reasons. First, how scientists struggle to understand nature and how their critical negotiations result in (eventually) established and uncontested knowledge is omitted. These historical and epistmological aspects are not the issues in this text. Furthermore, the premise is that "since the physicist say that.".then it follows that this is how the world really is. This again presupposes that the students trust the phycisists. It is however clear that this is not for the students to decide; this is factual knowledge that school want them to learn. By being offered in a school textbook the content has the authority to demand that students believe it, or at least make an effort to accept it as true.

At this ideological level, what matters most is that the choices made, explicitly or implicitly, are related to the purpose of the sender, a purpose that is related to the purpose of science education. This text is foremost about establishing conceptual knowledge in mechanics. It is not intended to be used for teaching about nature of science, for instance.

Still, the passage quoted above is *there*. The context of physics is made visible and compared to everyday contexts. The overall message is this, I suggest: 'Physicists provide true knowledge about nature. In nature, there are really only two types of energy, kinetic and potential. There are only two types of energy in every context, as every context is part of nature. However, in everyday contexts we experience phenomena which make different aspects of energy and energy use relevant, and so we use other words that we find more appropriate than the physicists technical term'.

1 The term usually used in Norwegian is 'bevegelsesenergi' – literally meaning 'energy from movement'. Technical terms ('kinetic' and 'potential') are also used, especially in higher grades.

2 'Stillingsenergi' in the Norwegian text, literally meaning ('energy from position'). All translations are done by the author.

Text A is building up a taxonomy on energy, as shown in the diagram below:

| | | | |
|---|---|---|---|
| | | – nuclear | **Text A – general track** |
| | – kinetic | – solar | |
| energy | | – electric | |
| | – potential | – sound | |
| | | – chemical | |

However, this is not the primary intention of this text. Within the genre of the scientific report (Martin 1993), this text is foremost *explaining*. The various types of energy are listed rather summarily ("You have heard of various types of energy. These may be..") after 'energy sources', 'energy' chain and 'energy transfer' are discussed. We will look at how this explanation goes on in some detail below.

> In all the examples above [how to warm water] the kettle is *energy receiver*. During the heating, an energy transfer takes place from the energy source to the energy receiver. This energy transfer is manifested by an increased temperature in the water.
>
> The hot cattle then becomes the energy source for the water, and the water is the energy receiver. During the heating, energy goes from the cattle to the water. This energy transfer makes the temperature increase in the water. (Naturfag, 5-timerskurs, 102)

Above, energy receiver (energimottaker), energy source (energikilde) and energy transfer (energioverføring) are nominalizations. They are distilled meaning from a full process, lacking not only participants, but also 'action'; the verb.

In this passage, students meet scientific knowledge as a kind of metaphorical reconstruction of experience. But what kind of 'reality', more precisely, is offered? In lower grades in school, scientific reality is compatible with a kind of 'naïve realism', or better (as everyday thinking is extremely complex, rather than 'naïve') everyday, common-sense reality (Knain 2001). This means that the fundamental mechanisms of the world are of the same kind as the mechanisms that we experience in everyday life. In the present text on energy, however, an intermediate level of reality is introduced. Lexicogrammatically it is constructed by abstract material processes that puts action back into the technical distillations. For instance, in the clause 'an energy transfer takes place', the material process 'takes place' puts action back into the 'energy transfer' grammatically. The text on energy transfer mentioned describes not merely everyday actions and theoretical knowledge, but rather actions in an abstract world. It is realized by a change of lexicogrammar that implies not only a reconstrual of reality, but also an introduction of a *new kind of reality* that can be traced back all the way to Galileo:

> [But] We can see in Galileo's practise, if not in his words, a most important intervening layer emerging between theory and the brute world – the realm of theorized objects. These are natural objects as *conceived and described by* the relevant theoretical concepts. Planets and falling apples have colour, texture, irregular surfaces, heat, solidity and any number of other properties of relations. But when they become the subject matter of mechanics they are merely point masses with specific accelerations; [.].they are no longer natural objects, but theoretical objects (Matthews 1994, 125).

This means that eleventh-grade students, taking the last compulsory science course, are meeting a discourse that is typical of the physical science some of the students will encounter in university or college courses.

To conclude on text A, this text is foremost an explanatory type, the actual classification below potential and kinetic energy is secondary. Furthermore, this text also addresses the student more directly, and in some instances even highlights a difference between scientific and everyday contexts.

**Text B – vocational track**

Text B for the vocational track students has a similar field to text A by seeking to help students develop thematic patterns on types of energy and energy transfer. The focus of this text is however different from the general track text. The paragraph headings are clear indicators of this. Whereas the headings in text A are pointing out elements in the thematic pattern, the headings in text B are different types of energy. This text is a *classificational* one. Developing a physical understanding is secondary. The classification comes before the energy transfer section in this text. In text A it is the other way around, and the section on different types of energy is contextualized ('you may have heard of.') and made less real compared to the "true" categories of kinetic and potential energy. There are no contextual clues in the text for vocational track students, and the student is never addressed directly by a 'you' as he or she is in the A text.

Text B starts with the heading "Types of energy". Then it is stated that the word 'energy' has origins in greek and means 'ability for action' ('handlekraft'). Then, between two red lines, it is stated that "Energy is an object's ability to do work". Confusingly, this statement which is marked as important by the layout is not related to the thematic development, as 'work' is not mentioned again until several pages later. Then follows the paragraphs mentioned above, each consisting of a few sentences explaining the concept. This structure is implicated by the headings:

**Text B – vocational track**

| | |
|---|---|
| | – kinetic |
| | – potential |
| | – heat |
| energy | – electric |
| | – chemical |
| | – nuclear |
| | – radiation |

We see that this taxonomy is flat; there is no intermediate layer as in text A. This is an important difference, because it is a result of a different aim of this text. It does not attempt to address a physical reality 'beneath' the different types of energy. It does not differ between physical and everyday contexts. In fact, kinetic and potential energy is just another type of energy along with electric energy and so on.

A confusing element in this taxonomy is the term 'heat energy'. This term is explained as 'inner energy' in the text. The problem with this thematic pattern is that it overlaps 'heat'. 'Heat' is not 'inner energy' in physics; heat is *transport* of energy from a location with high temperature (high inner energy) to locations with lower temperature (less inner energy). There is no further mentioning of heat. When students are supposed to learn about energy transfer, heat in its proper physical meaning is not a participant in the explanation.

As noted above, the A text is an *explanation*. Things are going on in the physical world. Energy goes from one object to another and each object's role in the process is explained. Text B is a *classifying* text, almost like a dictionary. Apparently it is simpler than A, because the student at first is not asked to understand what goes on at a more fundamental level (in nature). Eventually, the energy chain is introduced. What is meant by 'energy chain' is explained in general terms. Then examples follow on energy transfer. But the student is not given much help in relating the general principles to actual phenomena. Apparently in order to avoid a technical discourse that might be too difficult, there is no explanation of 'energy chain' in the manner of text A, where each participant in the process of energy transfer is carefully identified, both as an everyday object and as a theoretical entity. Text B states the general laws, then a few examples are provided.

So, in the situational context, this text is problematic. It is not clear whether the ideal reader is someone that should be able to recognize what various words with 'energy' in them 'means', or whether the ideal reader is someone that should be able to use the thematic patterns of physics with understanding in a flexible manner.

Also in the cultural context this text is problematic. The students are not given any bridges between physics and its application or relevance in everyday situations. In fact, the general track text ('A') addresses the reader more explicitly. It seems that at a cultural level, text B do not try to reach out to the students. Simply put, it seems that this text become difficult at a metacognitive level as a result of the attempt to make it 'easy' cognitively!

## Types of students

Making meaning is a rich and dynamic process, in which those who take part negotiate on which contextual frames should matter in the situation. The categories discussed below cannot predict which meanings students actually derive from a given text, and so they are unable to catch the dynamic and immediate aspects of meaning making. At best the categories may give some expectation of how the student will meet the subject. In any case, knowledge about genre is a set of more or less specified expectations to a given text. The categories referred to below belong to this contextual level above the specific social situations in which the texts were used. Students' interests, plans for further education, and what they think of school can be considered more or less stable across situations. Interpretations of information students gave on their interests, career plans, how they liked school and science suggests that these categories are usable, but may need refinement by future analysis.

Aikenhead has used the work of Costa in which five categories of students were related to how easily students appeared to negotiate transitions into the culture of their science classes. According to Aikenhead 2001, 181:

1. *Potential Scientists*, whose transitions are <u>smooth</u> because the culture of family and friends is congruent with cultures of both school and science.
2. *Other Smart Kids*, whose transitions are <u>manageable</u> because the culture of family and friends is congruent with the culture of school, but inconsistent with the culture of science..
3. *"I don't know students"*, whose transitions tend to be <u>hazardous</u> because the cultures of family and friends are inconsistent with the cultures of both school and science.
4. *Outsiders*, whose transition are virtually <u>impossible</u> because the cultures of family and friends are discordant with the cultures of both school and science.
5. *Inside Outsiders*, whose transitions are <u>frustratingly difficult</u> because the cultures of family and friends are irreconcilable with the culture of school, but are potentially compatible with the culture of science

These categories represent degrees of ease at crossing cultural borders into school science. In the article cited above, Aikenhead has included a new category, *"I want to Know" Students*, but this category does not seem to fit any of the interviewed students in the present study.

Briefly put, the students in the general track were Other Smart Kids, whereas students in vocational studies tended to be "I don't Know" Students or Outsiders. One of the vocational students appeared to be an 'Inside Outsider'. He showed an interest in science for practical purposes and enjoyed experiences in nature, but was indifferent to school science. The textbook meant little to him; he read only the books he considered interesting on his own terms.

Of course, one cannot conclude whether these students are typical from these interviews alone. There are reasons to believe these students may be typical of their class, or even their school. Because of to the sampling procedure, the 12 students interviewed were not as diverse a group as one might have preferred.

These categories, then, say something about how the student might experience the encounter with school science, at a cultural level. In the following this will be explored in more detail. What does this mean for students' attitude to and use of the science textbook?

## Student conceptions of science and the science textbook as institution

The school context is more important than the context of science for the interviewed students when they talk about the textbook. The 'Other Smart Kids' drew on the school context before personal interests or everyday life; hence, these students talked about the textbooks in terms of how effective it was for learning purposes at school. They seem to have a pragmatic view of science. Science is 'OK' if it is clear to them what they need to learn and how to learn it and if they get good grades. On the content side of science, they tend to prefer practical knowledge over abstract knowledge. This may be related also to school science, because this is possibly perceived as knowledge that is more easily learned in terms of learning goals.

Most of the students seemed to see the objective of science studies in school as providing a foundation for further studies; thus they tended to prefer textbooks that were restricted to factual knowledge. Other aspects of science, such as political and ethical issues, "one could think out for oneself" on the basis of the facts.

In conclusion, the 'Other Smart Kids' did not experience serious difficulties crossing the cultural border into science education, because the interests of the school and those of academic science overlapped. These students accepted that the structure of science was necessary to learn because it would prepare them for further studies, not in science, but in other areas in which scientific knowledge would be needed.

### The 'pure' scientific text – and the alienated students

The vocational text studied seems to build on a notion of a 'pure' scientific text, with as little text and as few 'distractions' as possible. In order to be simple, a short description is given for each type of energy, as discussed above. Structured like a dictionary, with different energy types as headings, it is a *classifying* text. As such, and because of factual errors, it will likely not provide – and does not seem to aim for – an understanding of the physics involved. But what, then, *is* the purpose of the text? As a side effect of its being 'short and simple', this text is actually difficult to use for learning purposes. Furthermore, it might be argued that as most of the interviewed vocational students seem to be outsider to the cultures of science as well as school, the 'distractions' in terms of bridges between the contexts of school science and other, everyday contexts might be precisely what would be needed if these students were to find school science more relevant for their perspectives on the world and their ambitions in life.

Both the general track and the vocational track students are satisfied with their books, but for different reasons, and the reasons mentioned by the vocational track students give cause for concern. The analysis of the interviews of these students reveals a situation in which these students are not addressed in the textual culture of school science, but they don't ask to be included, either. This is a profound challenge, and the textbook is only part of its solution.

### References

Aikenhead, G.S. (1996) Border crossings into the subculture of science. *Studies in Science Education*, **27**, 1-52.

Aikenhead, G.S. (2001) Student's ease in crossing cultural borders into school science. *Science Education*, **85**, 180-8.

Cobern, W.W. (1996) Worldview theory and conceptual change in science education. *Science Education*, **80**(5), 579-610.

Fairclogh, N. (1989) *Language and power.* London and New York: Longman.

Fourez, G. (1988) Ideologies and science teaching. *Bulletin of Science, Technology, and Society*, **8**, 269-77.

Halliday, M.A.K. (1994) *An Introduction to Functional Grammar. Second Edition.* London and Melbourne: Edward Arnold.

Halliday, M.A.K., Martin, J.R. (1993) *Writing Science: Literacy and Discursive Power.* London and Washington, D.C.: The Falmer Press.

Knain, E. (1999) *Naturfagets tause stemme. Diskursanalyse av lærebøker for natur- og miljøfag i et allmenndannelsesperspektiv.* (*The silent voice of science. Discourse analysis of school science textbooks.* PhD thesis.) Avhandling for graden dr. scient. Oslo: Unipub forlag og Det matematisk-naturvitenskapelige fakultet, ISSN 1501-7710 Nr. **27**.

Knain, E. (2001) Ideologies in school science textbooks. *International Journal of Science Education,* **23**(3), 319-29.

Kress, G., van Leeuwen, T. (1996) *Reading Images. The Grammar of Visual Design.* London and New York: Routledge.

Martin, J.R. (1993) Literacy in Science: Learning to handle text as technology. In Halliday, Martin (1993), 166-202.

Östman, L, (1995) *Socialisation och mening. NO-utbildning som politiskt och miljömoraliskt problem.* Uppsala Studies in Education 61.

## Analysed textbooks used by the students

Naturfag 5-timerskurs. Oslo: Aschehoug (2000). (General track).

Naturlig nok. Oslo: NKI-forlaget (2000) (Vocational track).

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# HOME TECHNOLOGY AND CHILDREN'SCIENCE EDUCATION

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**Abstract**

The purpose of this paper is to present an ethnographic study ( Cardoso, 1999) involving six primary school pupils and doing simple experiments with everyday home equipment in the context of learning science.

The hands-on science activities were carried out by children with the help of their parents. Results showed that children learnt at home and that home-background factors influenced children's educational development.

Parents preferred practical aspects of science to theoretical. This was reflected in their comments about their own science learning at school, when they compared it with their children's. Data about home activities, such as cooking, indicated that all children had already helped their parents. Cooking also provided us with several good practices of experimentation, as did weighing, floating or sinking and making cheese. We conclude that carrying out simple experiments at home spreads public understanding of Science via parents and also improves the science learning of children. One reason that may explain both conclusions is that the family environment was embedded in experiences that respected the children's own values and social identity (home culture).

## 1. Introduction

This paper reflects on the results of the ethnographic study (Cardoso,1999), in which the main purpose of this research was to study six Portuguese families who carried out hands-on activities with their children at home. These activities, related to the Portuguese National Curriculum, were implemented twice a term throughout the school year and based on the methodology in the participant observation.

Thus, the data collection involved *simple science experiments* for primary school children to do with their parents and/or other family members at home. One of the children's activity was called *Science in the kitchen* and all that was necessary was: 1 potato, 1 apple and 1 basin with water.

The activity sheet (SHIPS Project, 1992) gives instructions for *feeling* the weight of the apple and the potato in the children's hands, for *thinking* which one floats and for *observing* both of them in the water.

The activity is divided into three parts. The first involves a whole apple and potato and the second small pieces of apple and potato. Because the children tend to say that *heavy things sink and light things float*, in this activity they find out that pieces of different sizes of apple always float while potato pieces always sink. The third part helps them to see what can be done when a *silly cook* mixes the pieces of apple and potato. He should use the bowl of water to separate them because all the apple pieces float and all the potato pieces sink. So children make this suggestion for themselves.

As we, know, things which float in water have a greater *density* than water, but this is a very difficult idea for children. Thus, the conclusion is that, for their size, potatoes are heavier than water and, for their size, apples are lighter than water.

After a week, the children's work was brought back to the school for discussion with the teacher and the class.

Essentially, the results showed that a simple hands-on activity could be carried out successfully in the home by the children with their parents' helping. The children learnt from the activity, whether or not their parents were knowledgeable about science.

Also, the *home culture context* was considered as the more important aspect in this study, rather than the gender and the social class comparison. So, from the study data, we see that there is variation between the parents attitudes and it may suggest that in each home their members produce their own culture. For instance, in Jane's home, the hands-on activities suggest some aspects of the family religious life when it is said that the silver bracelets are from her baptism and her father is not present because of the father's religious activities. In Phil's home there are small wood toys made by his grand-father and father who are carpenters. In contrast, in Mick's home there are many mechanical toys, such as boats and he said that the family goes sailing on the weekends. But it is different in Alex's home, in which the country situations of killing a pig and playing mandoline like his uncle, are family activities. In Bob's home there is another kind of conversation, namely about the steam during the bath or the drops of water inside the window in winter because his mother is a teacher. Finally, in the Neil's home, the child shows great initiative and responsability for what is happening during the hands-on activities. He also is quite independent, such as his mother who obtained her independence too early because her parents lived in a small village without school and she went out to study early. So that, in her opinion you do not need to get help in order to have confidence in own ability because it makes it easier for survive.

Home can be considered the socio-cultural world of each family, in which the child-parent interactions, the roles, strategies and attitudes, as well as the kind of the materials used in the course of the hands-on activities by the children and parents are expressions of their social identities. These aspects of the family life can be a new way of interpreting why the six case-study families vary according to the concept of the home-culture.

## 2. A brief historical view of science education in Portugal

We describe the development of the Portuguese Education System with regard to science education in primary school, in order to understand the teachers', parents' and children's attitudes to science, i.e whether their schooling is related to their attitudes to science teaching in the early years.

The 1960s there were difficult times because an authoritarian regime was in place and political centralization in the country resulted in centralization of the Portuguese educational system. Some papers have been written about the Salazarist primary school, in which *the school tried to train children rather than to educate them.* Of course, in such closed system there is not much educational development.

In the 1970s, the system was expected to contribute to economic growth. In this context, Marcelo Caetano, the head of government from 1968 until the 1974 democratic revolution of 25 April, introduced some reforms, for instance, an important educational reform by the Minister of Education, Law nº 5/73, known as the Veiga Simão Reform, in which would be increased the period of compulsory school from six to eight years. He writes (1972): *Our first concern is rural and industrial environments, where every encouragement should be given to the institution of kindergartens, in close collaboration with other Ministries and private bodies".* About the system of training of teachers he writes (op. cit: 110): o*n the one hand we are setting up Higher Teacher Training Schools and, on the other, we are making it possible for (graduates) to enter Education departments in the universities, (directed) by the National Institute* of *Pedagogy*. Such a system obviously had repercussions on the teaching of science, which had been neglected.

The lack of scientific education in Teacher Training Colleges, as well as in compulsory schooling may have affected the teachers' and parents' attitudes in the context of parents helping their children to learn science at home. In compulsory education, the science curriculum consisted mainly of the study of living things and at secondary school the teaching/ learning of science was a body of established knowledge, in which sciences were taught almost entirely by mechanical rote-learning of facts. However, in this study the practical work plays a central part, in which the activities are carried out with simple everyday equipment. The practice depends on the particular circumstances created by what the parents and children do during the hands-on activities.

With the 1974 revolution, changes in curricula, new forms of pedagogy and school organization - either to aid the building of a socialist society or to create the *socialist school* - were made in the 1976 Portuguese Constitution, both the extension of the Veiga Simão Reform and the attempts at new forms of socialist education were suggested. By 1978 programme (ME, 1978) a new direction in scientific method and the subjects *Man and Nature, Man and Society* were introduced, at the primary level.

In the 1980 Programme (ME, 1980), there is an important note about the importance of other areas besides *writing* and *mathematics*, such as social and natural sciences (but Biology and Ecology only).

In 1980, the first centenary of Faria de Vasconcelos' birthday is commemorated in Castelo Branco (his birthplace and the location of the present study), and he is considered the man who planned education for the future. He refers to the relevance of studying all the sciences in primary school, to the children's understanding of everyday life and their own development as future citizens. However, his educational contribution as an agent of change and innovation was not realised because the political situation was still unfavourable to its implementation. Only in the 1990 Programme (ME, 1990) was physics introduced. We can see the connection between systems of schooling and the wider society; it is necessary to educate for the jobs which require scientific expertise and technical and technological know-how.

Thus, we might point to the instability of the Portuguese Educational System and the very recent liberalisation of science education in Portugal, especially with regard to science teaching in primary schools. As a result, Portuguese teachers are insecure in science teaching, because they had no training in science before the 1990s. However, children have to learn science in primary school now. So, the following questions arose:

- How can hands-on activities carried out at home by children with the help of their parents make a favourable contribution to the development of science education in primary school ?
- How does the child learn at home and at school ?

In 1986, a ratification of the Basic Law of the Educational System was made by the Parliament and a new educational reform cycle began, apparently with a view to decentralisation and autonomy, in which is introduced curricular components of the regional and local type such as the 'Area School', where parents could participate.

According to the Portuguese Education Act (1986), some objectives of basic education are involving families, a conscious and responsible involvement in their surroundings (Article 7h), and participation in the process of educational information and guidance in collaboration with the family (Article 7m). However, Portugal has not yet developed systems of involving parents in their children's learning, similar to the projects on parental partnership in the UK and USA.

Also, some Portuguese teachers still believe that parental involvement contributes to widening the already existing gap between less and more favoured groups, i. e that the most powerful groups have superior capacity of organization and pressure as well as greater ease in profiting from the direct contact with schools in order to improve their children's learning. These problems must be carefully analysed before any programme of home/school partnership is designed. It raises some questions:

- How do school and family partnerships make sense with a view to benefiting children's learning, development and success in school?
- What new strategies are required for the school to work with families?

## 3. Reflection on the research results

This reflection is a further understanding of the contexts that parents and children create when they carry out hands-on activities at home.

### 3.1. The parents respect children's individual differences

The study findings show that the children's opinions, ideas, rhythm and willingness are considered by the parents. Also, the interaction between the child and the parent at home is usually one-to-one, as well as the child's and the parents' roles being reversed; the children often take an organising role.

Thus, the parent-child interactions at home can be considered as a particular way of the parents respect the children's individual differences. The parents treat children differently from how teachers treat them, in which the parents can give more individual attention and have a more intimate relationship with the child than the teacher.

Of course, the opportunities for individual attention are much greater at home than in school where the teacher has to share his/her attention with a greater number of different children. From a sociological and an educational perspective, the teacher should not treat all children the same. Some children are able to exploit home opportunities better than school ones. This was especially evident in the case of Mick, who is not well adjusted to school. If the clash between power relations at school and at home can exert *symbolic violence* (Bourdieu and Passeron, 1977) on the child, the home learning situation is able to remedy this. So the education system needs to recognise the value of working in partnership with parents. Schools should provide a constructive communication between teachers and parents, because learning from one-to-one (home) and in large groups (school) can be important contributions to the children's education.

**3.2. The children distinguish between home and school contexts**

The study findings reveal informal and emotional aspects of parent-child conversation in the course of the hands-on activities at home, in contrast to the formality in the relationship with the teacher in school. So the children, who daily crossed two different social contexts - home and school, have to adjust their meanings to those of the *significant others* to whom they are talking (Mead, 1967).

School and home can be two different worlds for children's learning. For example, in the work of Donaldson (1978), she differentiates between *embedded* (home) and *disembedded* (school) contexts. For the six children, the home environment is embedded in experiences that respect their own values and identities, in contrast to the general patterns of the teacher' subjugation that occur at school. Some children can experience difficulties when s/he is embedded in contexts of great emotional meanings at home, such as Mick, who is not well adjusted to the teacher who plays out in an opressive way, and sometimes he does not want to go to school after passing an uneasy night. He is timid and lacking self-confidence in the presence of the teacher, but at home he feels safe and he is a naughty boy with his brother. From the teory of Berger and Luckmann (1967) we know that: *primary socialisation takes place under circumstances which are highly charged emotionally.* Thus, the value of the home environment has to be considered as an essential part of the learning process and this can be described as the most important one for some individuals (Alexander, 1997; Silverstone, 1994; Solomon, 1994).

So learning in the context of parents helping their children with hands-on activities makes the home a place of great meaning for children.

**3.3. The children want the parents to help them as *parents***

The findings support that the children want their parents to help them as *parents*, i.e the children want their parents go on being *parents'* at home and not teachers. The adoption of atypical roles by the children's parents brings about irritation or anger in some children and they try to persuade their parents to break off the *teacher* role. In the informal and emotional situations of the home, the children speak more openly with their parents than with the teacher, who speaks and acts more formally with pupils in the classroom. It served to accentuate a new home situation, in which the children are much more active than in school and where they try to legitimate their identity as a family member.

The children distinguish between home and school contexts: the functions of each one must be distinct. As is the case also with Alexander's (op. cit.) view: *It would be quite wrong to 'professionalise' parenting through training, assessment and qualifications and thus increase the pressures on parents.* The author, as a lecturer in a Teacher Training College, argues that teachers as educational professionals should take account of children's different home contexts and differences between learning at home and at school. Of course, this professionalism cannot make teachers more powerful in relation to parents, but might decrease the gap between home and school learning. So the basic educational system can promote knowledge, skills and personal competence for all children, using both places of learning - home and school, as well as different roles- parent as a parent and teacher as a professional.

Thus, this research claims present a model of home as a place of learning taking opportunities for learning science into the home so that the parents can help their children to learn science without relinquishing their role as parents.

**3.4. The children learn in the context of carrying out the hands-on activities with their parents' help at home**

The findings show that the children learn through the hands-on activities carried out at home with their parents helping. The children's answers to the test in the classroom at the end of the school year, are on the basis of the children's learning in their homes. The child's quality of remembering in terms of explanation or description of the phenomena is related to the carrying out of hands-on activities at home with their parents' help, and this may also suggest that the children do not keep home and school knowledge totally separate. This provides some support for Vygotsky's view(1978) that the parent involvement on the child's learning must be regarded as embedded in social interactions, which underly mental processes, such as remembering.

Thus, thinking about the concept of the home culture demands that the teacher takes account of home as a place of learning in terms of cultural differences rather than cultural deficits, and should value both forms of knowledge - home and school. More work has to be done on bringing home into school and learning from parents and children.

**3.5. The parents hold positive attitudes to their children's activities**

The study findings show that the parental influence comes from action and does not arise from compulsion, but the parents support their children's activities, behaving in a spontaneous and enthusiastic way.

The parents in this study were aware of the importance of their contribution to the child's educational development and they considered helping their children to learn school science by doing simple experiments at home was important. The parents preferred the practical aspects of science experience at school, when they compared their education with their children's.

So the hands-on activities with everyday materials allow parents and teachers to become involved within a common framework, which is valuable to the child, in terms of creating a bridge between home and school.

Thus, decision making on the basis of partnership between schools, families and community should play an essential part in educational settings within a wider political framework in Portuguese policy, and in the research agenda of parental involvement, such as suggested by the Minister of Science and Technology, at the Ciência Viva (Science Alive) conference, in May 1999.

**3.6. Each home is different in the way that the parents conduct the hands-on activities**

The study findings support some kind of interdependence in the nature of knowledge acquired at home and at school via science activities because the children bring both experiences together for answering test questionnaire. Interesting evidence from the study is that the hands-on activities take place in the kitchen in general, but sometimes in the sitting-room or garden, through which the identity of each family is understood and the materials used to carry out the activities are different and peculiar to each family. This points to the importance of the social environment. The parents seem to reproduce their home culture in the hands-on activities of their children when they help their children to learn science.

From this study the relationship of the child and the parent within the home context of parents helping their children to learn science should be understood as embedded in the home culture. The child-parent interactions should develop an understanding of the different roles, strategies and attitudes that the children and their parents adopt in the course of the hands-on activities, as a special way of giving meaning to their family's home cultures.

## 4. Some implications of the study for the teaching/learning process

The child is a member of the two social worlds and can learn at home and at school, but the learning process is different in each situation. We find that this research study provided some relevant findings for understanding the relationship between home and school environments, in particular home as a place of learning in the context of parents helping their children to learn science.

This study conceptualises children's educational development in terms of Vygotsky's theoretical view, which emphasises cognition as a sociocultural process. At the end of their school year, the children can remember what they learnt through the hands-on activities carried out at home with the parents helping and the quality of the children's remembering may be the result of parental influence.

The findings in this study also revealed that the children, who daily crossed between two different social contexts - home and school- learnt to adjust their meanings to those of the *significant others* to whom they are talking (Mead, 1967). For example, the children distinguished between home and school contexts and they use an informal and emotional conversation with their parents and a formal one with the teacher in the classroom. The parents enthusiastically helped their children with hands-on activities and so could make learning much easier.

The present study also reveals some relevant findings from an educational perspective in science. The children learn in the context of carrying out the hands-on activities with their parents' help at home and the parents also learn, as shown in the parents' comments of their remembered enjoyment of science at home, when they compared their education with their children's.

The *everyday* practical science, which is common feature in the life of both parents and children, can present a new aspect of science, and the results of this study implied that parental interest and supported would be accessible and valuable to the child in primary science. In fact, the parents seem to prefer the practical aspects of science to the theoretical ones and this is reflected in their comments about their own science experience at school when they compared their education with their children's.

When the school science activities enter the home and the activities have direct meaning for the family, this provides opportunities for the parents and children to share in the schools' work. The children who carried out the hands-on activities with their parents' help thought that their parents did *science* experiments at home and that they were part of daily life. However, the children who did not carry out the hands-on activities at home did not share the ideas of science as being a human activity located in everyday life. In his book *The culture of education*, Bruner (1996) argues that children show a strong *predisposition to culture* and he writes that *they are sensitive to and eager to adopt the folkways they see around them*. So the children who carried out the activities with their parents helping them are able to relate home life to science. Thus, the relationship between home and school can help to make links, connecting primary science to everyday life, and taking into account the children's home culture.

The hands-on activities were less a form of instruction, more a combined discovery. Afterwards the parents made links with other everyday phenomena, e.g. practical science (not theoretical). So the hands-on activities were a way of enhancing some kind of familiarity with science. It linked directly with other phenomena observed in nature. Thus, it is possible that if the school extended too strongly, as an institution, with its own practices into the home, it could damage the natural relations between parents and children.

The parents consider that helping their children to learn school science by doing simple experiments at home is important and they are aware of the importance of their contribution to the child's educational development.

Finally, the study findings support the diversity of cultures in the homes. This can have implications in pre- and in-service training courses for teachers' work with children and their families. So, in conjunction with my actions as a teacher educator, it seems important to include on the curriculum the understanding of the education for diversity. Teacher training courses have to do more to prepare teachers for working with children and to value their sociocultural differences. It is important to encourage forms of parental involvement, especially through a constant dialogue and an intense respect for parents, in particular, those that are from non-dominant cultural backgrounds.

Teachers as professionals should learn from studying parents and children interactions at home and use the school as a resource for supporting the home as a significant aspect of a child's learning life. More studies into parental involvement are necessary to:

(a) the bringing of home experiences into school, and
(b) the building of home as a special place of learning.

## Bibliography

ALEXANDER, T. (1997) Learning begins at home: Implications for a learning society. In. COSIN, B. and HALES, M. **Families, Education and Social Differences**. London: Routledge.

BERGER, P. and LUCKMANN, T. (1967) **The social construction of reality. A treatise in the sociologie of knowledge**. London: Penguin Books.

BOURDIEU, P. and PASSERON, J-C (1977) **Reproduction in Education, Society and Culture**. London: SAGE Publications, 5.

BRUNER, J. (1996) **The Culture of Education**. Cambridge and London: Harvard Univ. Press.

CARDOSO, L. (1999) Relationship between home-background factors and children's educational development in science. Unpublished thesis. Univ. of Oxford.

DONALDSON, M. (1978) **Children's Minds**. London: Fontana Press.

SHIPS Project (1992) School Home Investigations in Primary Science. SOLOMON, J. and LEE, J. Hatfield: ASE.

SILVERSTONE, R. (1994) **Television and everyday life**. London: Routledge.

SOLOMON, J. (1994) Towards a notion of home culture: Science education in the home. **British Educational Research Journal**, 20 (5): 565-577.

VYGOTSKY, L. (1978) **Mind and Society**. Cambridge: Harvard Univ. Press.

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# CLASSROOM DEBATES ON BIOTECHNOLOGY IN AGRICULTURAL EDUCATION

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**Abstract**

Debates on biotechnology applications often lead to dilemmas because of uncertainties as to the risks involved. Our aim is to help students contribute to the debates. The objective of the present work is to encourage students to develop a critical approach to scientific statements on the repercussions of biotechnology applications. In this contribution we compare students' arguments in role-playing and debating situations.

A role-playing scenario on animal transgenesis has been developed around the production in a seaside village of giant transgenic salmon expressing a foreign gene for the growth hormone. The local population is very concerned about the project and the mayor has thus decided to organise a public debate. The role-playing was then compared with a conventional debate on the same topic. Our study was conducted in two classes at an Agricultural Lycée with students in their 2nd year of upper secondary vocational education geared to scientific subjects. All the dialogues were recorded on audio and video tape and transcribed in full. In this paper, we analyse the discursive method used by students during the debating situations. A macroscopic analysis of the discussion dynamics and a microscopic analysis of argument episodes were done. We identified the spheres of knowledge or social references on which the students had based their arguments and evaluated the validity of the arguments used.

During the formal debate, students spoke for a longer time and their argumentation was more complex (there were 1.07 interventions per minute as opposed to 3.18 in the role playing scenario). The argumentations were more developed and based on validated information. In the role playing students intervened for shorter periods of time, the argumentation strategies were simple and sometimes based on invalid information (since the students had incorrectly understood the information with which they had been provided in the description of the role they had to play). During the formal debate students used 35 multiple argumentation strategies whereas for the role playing they only used 8 multiple strategies. In the role playing situation the students made more use of rhetorical techniques involving irony or provocation (24 rhetorical techniques for 35 minutes of role playing as opposed to 2 for 94 minutes of formal debate). In this case they were acting and playing their role as best they could. Their arguments were superficial, having been constructed to bolster up their role rather than to support their point of view. They did not necessarily agree with the opinions of the person they were pretending to be. Dynamics and topics are affected by the teacher's interventions and by the kind of debate organised (role playing or classical formal debate). The formal debate would appear to foster reasoned argumentation, while role playing is a mix of rhetorical techniques. Further research should be done on debating situations created in the classroom on socio-scientific issues, thus enabling more precise analysis of argument in action in order to better evaluate the effect of training on argumentation.

## 1. Aims and theoretical frame

Biotechnology applications raise questions in several areas, including ethics, sociology, economy, ecology, regulation and politics. Debates often lead to dilemmas because of uncertainty as to the risks involved. Our aim is to help students to contribute to debates so that they understand that decision-making can be complex when important social issues are involved , for example, economic, ethical and other issues.

Debates generate difficulties for students, since they find themselves in a situation of potential inter or intra-subjective conflict. Moreover students are not used to debating in school activities. Debates generate difficulties for teachers too, in that they have to learn how to chair them, instead of being 'one of *those who know*'.

Some authors hold that argument is an integral part of present-day communication, originating in classic rhetoric (Breton, 1996). Others deal with the subject from a linguistic point of view (Adam, 1992). Others again address argument at several different levels in science teaching: as a means of improving the understanding of concepts, promoting a better grasp of epistemology in science, developing investigative skills (particularly in practical work), or improving the quality of decision-making on socio-scientific subjects (Geddis, 1991, Solomon, 1992, Ratcliffe, 1996, Driver and Newton, 1997, Jiménez Aleixandre *et al.*, 2000a, 2000b, Duschl and Ellenbogen, 1999, Mortimer and Machado, 1999, Osborne, 1999).

In analysing different means of persuasion, it is possible to distinguish, in theory at least, between manipulation, propaganda, seduction, argumentation and demonstration. Actually, situations relying purely on seduction, argumentation or demonstration are very rare, a fact which accounts for the development of rhetoric. In France, rhetoric ceased to be taught in schools and universities at the end of the 19th century, and even became discredited as a corpus of knowledge. This seems to be linked with a conflict between a culture based on evidence, drawing on advances in science and positivist theory, and a culture based on argumentation (Breton, 1996). Interest in rhetoric came to the fore again in the 1960s, with a growing awareness of the impact of media technology. In 1967, Blanché, in his *Introduction à la logique contemporaine* stated that 'evidence is no longer a guarantee of soundness'. Advances in science are driven by debate and disagreement: there is therefore a need to understand the role of controversy in modern science, and its rhetorical functions in handling uncertainty (Osborne, 1999). The objective of the present work is to encourage students to develop a critical approach to scientific statements on the repercussions of biotechnology applications.

Studies on argumentation in science education also draw on research in linguistics. Working from a theoretical typology of text sequences, Adam (1992) defines several prototypes: narrative, descriptive, argumentative and explicative sequences, and dialogue. The following diagram shows how Adam (1992) defines his prototype argument sequence. The pattern of the argument rests on linkages that are made between '*data*' and a '*conclusion*'. These linkages may be implicitly or explicitly supported (by the '*guarantor*' and the '*material*') or opposed (by '*refutation*' or '*exception*').

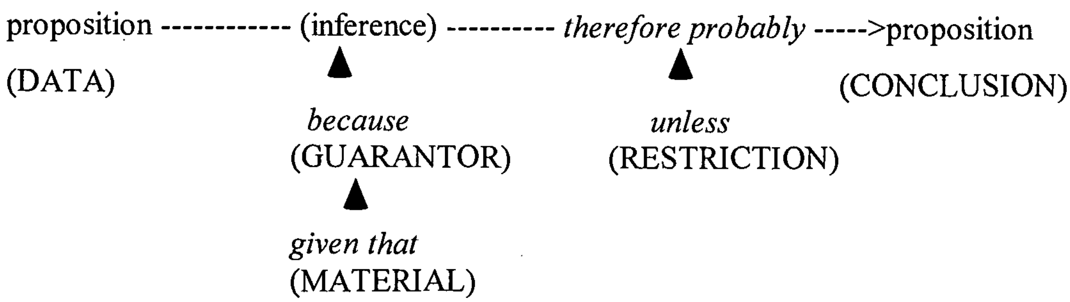


**Diagram 1** : Adam's pattern of argument

Conscientious readers or interlocutors will be attentive to linguistic clues, which lead them to expect some kind of argument. From the point of view of the cognitive treatment of a text, it seems that the understanding of schematic prototype representations that subjects develop over time has an impact on the way they store the information they have considered while coming to grips with a discourse, and on the way they look for blocks of information through a process of anticipation (Adam, 1992).

Analysing an argumentative text is a new subject in the teaching of French as a first language in upper secondary school. The importance attached to it has to do with its ultimate social purpose, which is related in particular to students' perceptions of citizenship. However this topic is rarely, if ever, taken up in science teaching. Moreover, in French teaching, what is taught is determined by a standard division of descriptive reference theories, and does not touch on the question of values – although this is crucial to the study of argument. Furthermore the main media used in these activities is textual and not oral.

In science education studies, many authors refer to Toulmin's layout of arguments (Toulmin, 1958, Pontecorvo and Girardet, 1993, Kelly *et al.*, 1998, Jiménez Aleixandre *et al.*, 2000a, 2000b, Diaz de Bustamante and Jiménez Aleixandre, 2000, Sonora Luna *et al.*, 2000). This layout is very similar to Adam's pattern of argument. A representation of this layout is shown below. Toulmin characterised the components of the argument as follows: "*Data*" are the facts the proponent of the argument explicitly appeals to as a foundation for the claim. The "*claim*" is the conclusion based on the merits 'established' by the argument. The "*warrant*" consists of the rules, principles or inference licence that demonstrate that the step from the data to the claim is a legitimate one. The strength of the warrant may be indicated by modal "*qualifiers*". The "*rebuttal*" indicates the circumstances for which the general authority of the warrant is merited. The "*backing*" establishes the general conditions which give authority to the warrants.

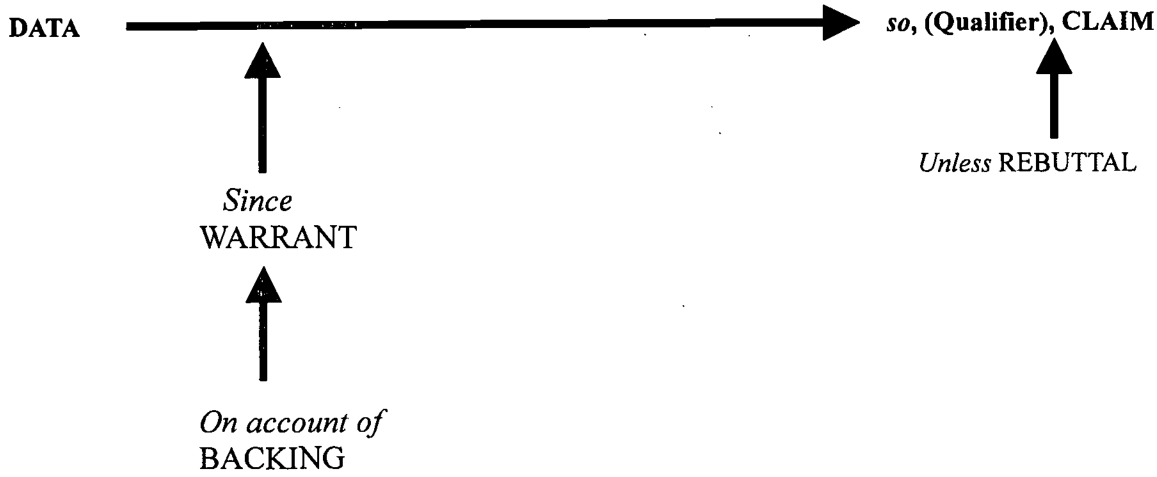


**Diagram 2 :** Toulmin's pattern of argument

The objective addressed in this paper is to compare students' arguments in role-playing and debating situations.

## 2. Methods and sample

A role-playing scenario on animal transgenesis has been developed around the production in a seaside village of giant transgenic salmon expressing a foreign gene for the growth hormone (Simonneaux, 1997). The fish are dubbed 'Sumotori salmon' after the Japanese wrestlers. The local population is very concerned about the project and the mayor has thus decided to organise a public debate. The role-playing was then compared with a conventional debate on the same topic. Our study was conducted in two classes at the Agricultural Lycée in Auch (Gers *département* in South-West France), with students in their 2nd year of upper secondary vocational education geared to scientific subjects. All the dialogues were recorded on audio and video tape and transcribed in full. Although a formal debate, the debating situation (17 students) was organised in exactly the same way as the role-playing (18 students).

In the role-playing scenario, the teacher played the role of mayor. She introduced the scenario and was responsible for the timing. At the end the teacher (the mayor) asked the students to vote.

During the debating situation, the teacher explained the issue being debated by making an analogy with the citizens' conference that took place in France on the subject of biotechnology applications, and set out the aims of the debate, i.e., to reach a decision through argument, explaining that the first task was to discuss the economic, political, ecological and human health aspects of the issue. The teacher remained neutral, leaving the students to take up the various points spontaneously. If one or more aspects were neglected, the teacher asked for their opinion on them. Next, the teacher prompted a debate on the various topics addressed in the role playing scenario, unless they had already been taken up spontaneously by the students. For instance, an increase in livestock productivity, increasing overproduction, technology transfers to the developing world, famine reduction, disruption of the ecosystem, risks to human health, labelling and consumer reactions, patenting living organisms and company monopolies. As the debate proceeded, the teacher supplied the information that was available in the role-playing scenario. The analysis of students' opinions on the Sumotori fish farm is developed in Simonneaux (2000). In this paper, we analyse the discursive method used by students during the debating situations.

The experiment protocol is shown in table 1.

**Table 1.** Experiment protocol

| | |
|---|---|
| Role playing | Debate |
| Pre-test opinions | ditto |
| Introduction to the history of domestication and chronology of the transfer of the growth hormone gene | ditto |
| Presentation of the role playing<br>Written essay by students on the installation of a Sumotori fish farm (opinions to be supported) | Presentation of the debate<br>ditto |
| Role playing performed | Debate |
| Post-test opinions<br>Written essay by students on the installation of a Sumotori fish farm (opinions to be supported)<br>Students explain under what circumstance(s) they might change their opinions. | ditto<br>ditto<br>ditto |

Different methods for analysing argument have been proposed for scientific education. None of them appear to be suitable as is. This paper describes the way in which we have adapted them and the particularities of our approach. Our intention was not to suggest a statistically reliable method.

We were not trying to identify universal characteristics of the way students argue about biotechnology, but rather to compare the effect of different teaching situations (role-playing, debates) on the quality of students' discursive and debating skills.

We see our method as an example that would need to be adapted for specific contexts in further studies.

As noted by Dumas-Carré and Weil-Barais (2000) debate transcripts may be used 'for analysing from different perspectives'. Microscopic analysis of episodes during which a 'subject' is being debated and macroscopic analysis which allows for a description of discussion dynamics and for choosing episodes for microscopic analysis.

We did this in several stages.

Stage 1 involved writing a synthesis of discussion dynamics by identifying major debate topics.
Stage 2 involved microscopic analysis of argument episodes.
Stage 3 concerned the teacher's role.

The argumentation in the two debating situations was compared gradually during the three stages. A certain number of indicators were quantified: the duration of discussion, the number of interventions, the number of interventions per minute, the number of times the teacher intervened, the number of 'message units'. The higher the number of interventions per minute, the less detailed were the arguments. The messages units are units of linguistic meaning that reveal the ways actors construct their actions in a conversation.

It is worth describing the methodology used for the second stage in detail, as it turned out to be the most difficult stage. We first used the Toulmin model, completed successively by Resnick *et al.* (1993), Kelly *et al.* (1998), Sonora Luna *et al.* (2000). Resnick *et al.* added 'the challenge' to the argument components defined by Toulmin, Kelly *et al.* added 'empirical data' and 'hypothetical data', Sonora Luna *et al.* added 'opposition' and 'concession'. As we gradually developed our analysis of the argument episodes, we changed and completed our conceptual argument system in order to take into account the rhetorical techniques used. We perceive debate as being a socio-discursive interactive event. Within this conceptual framework, language is considered as an activity. We use the concept of "*a linguistic action which integrates and links up the representations of the production context and theme content* parameters" Bronckart, 1996. In order to be able to analyse the complexity of debates we used different argument components borrowed from the authors we have just referred to as well as terms we ourselves had introduced: 'declaration' (equivalent of Toulmin's 'claim'), 'question', 'rejected question or declaration' (equivalent to the 'opposition' of Sonora Luna *et al*), 'critical question' (equivalent to Resnick *et al's* 'challenge'), reformulated question', 'restarting', 'answer', 'hypothesis,' 'objection', 'agreement', 'avoidance', 'revealing gaps or uncertainty', 'value judgement', etc. Each linguistic action can support another action. For instance, a declaration can support an opposition, an agreement, a question,..From rhetorical procedures we selected the following components, 'provocation', 'suspicion', 'promise', 'irony'.

We identified the spheres of knowledge or social references on which the students had based their arguments and evaluated the validity of the arguments used. We analysed the argumentation strategies by making a distinction between simple arguments based on only one bit of evidence from multiple strategies consisting of several encapsulated bits of evidence or linear evidence.

## 3. Results

The summaries of discussion dynamics reveal recurring themes which correspond to the topics debated in the classroom and which were controversial. Recurring themes are discussions which students have spontaneously repeated several times. For the role-playing the topics are biodiversity, consumption, labelling, human health and economic implications. For the debate they were economic, ecological and political repercussions in a context of First World/Third World relationships.

The following table compares the different criteria used to analyse students' discussions

**Table 2 :** Comparison of different criteria

| | **Debate** | **Role playing** |
|---|---|---|
| Duration in minutes | 94 | 55 |
| Number of interventions | 101 | 175 |
| Number of interventions per minute | 1. 07 | 3.18 |
| Number of times the teacher intervened | 35 | 16 |
| Number of student message units | 242 | 296 |
| Number of arguments<br>Number of multiple strategies | 36<br>35 | 35<br>8 |
| Number of invalid arguments (with respect to scientific disciplines or to information provided) | 2 | 8 |
| Number of rhetorical procedures | 2 | 24 |

During the debate, interventions were longer and more complex (the number of interventions per minute was 1.07 as opposed to 3.18 in the role playing). The arguments were more developed and based on valid data. In the role playing students spoke for shorter periods of time, arguments were simple and sometimes based on invalid data (students incorrectly interpreted the information with which they had been provided in the description of their role). During the debate the students used 35 multiple argument strategies, i.e. including several encapsulated or linear justifications whereas in the role-playing, the students only used 8 multiple strategies.

In the role playing students tended to use more rhetorical procedures including irony and provocation (24 rhetorical procedures during 55 minutes of role playing as opposed to 2 rhetorical procedures for 94 minutes of debate). They were acting a role as best they could. Their arguments were superficial and were not based on their own point of view but on the description of the role they were playing. They do not necessarily agree with the opinions of the individual they were playing.

There is some discussion on the existence of a prototype argumentation text pattern as defined by Toulmin and Adam. This pattern, if one does exist, could be an argumentation teaching aid. Toulmin and Adam's patterns have been criticized (Brassart, 1987; Golder, 1996) because among other reasons, they do not integrate dialogue. Our analysis supports this criticism; we have not been able to identify a canonic typical argument. Looking at dialogue has led us to identify various types of linguistic actions that take place in exchanges (question or rejected declaration, critical question, reformulated question, reminder, answer, objection, agreement, avoidance, revealing gaps or uncertainty), rhetorical procedures as well as axiological (value judgements) or prescriptive statements. Argumentative discourse cannot be reduced to a series or organisation of linguistic components which are the same in all situations (Golder,1996).

## 4. Conclusion and Implications

This work showed how difficult it is to analyse classroom debating situations. A methodology had gradually to be adapted to deal with the complexity. Analyses from different perspectives are complementary. Macroscopic analysis highlights discussion dynamics and the topics debated, in particular recurring themes. Dynamics and topics are affected by the teacher's interventions and by the kind of debated implemented (role-playing or formal debate). The quantified criteria show that in formal debates students' arguments are more structured and valid. A formal debate appears to encourage well-founded reasoning. Role-playing is mixed with rhetorical expressions. But of course, each debating situation is different depending on the context, the topic, interlocutors..It is a socio-discursive interactive event.

Microscopic analysis best reveals the complexity of discussion. Evidence for this is the significant number of argumentation elements which we identified. Of course debates do not unveil canonical argumentative approaches, as there is some interference from the communication situation itself. Analysis of a debate in action requires drawing on at least two theoretical disciplines, linguistics and communication.

The study of classroom debates on controversial social issues should be continued in order to refine analysis of argument in action and to evaluate the effect of training on argumentation. How to train students to develop argument on controversial knowledge? Teaching them a pattern of argument or helping them to analyse controversial discourses. In the latter case, analysis could be focused on the social and physical situation (who is speaking? What are the stakes?.).and on argumentation itself (kind of argument, validity, strength, justification,.).

## References

ADAM, J.M., (1992). *Les textes: types et prototypes.* Paris: Nathan - Université.

BLANCHÉ, R., (1967). *Introduction à la logique contemporaine.* Paris :PUF.

BRASSART, D.G., (1987). *Le développement des capacités discursives chez l'enfant de 8 à 12 ans : le discours argumentatif (étude didactique).* Thèse pour le Doctorat de Sciences Humaines. Strasbourg.

BRETON, P., (1996). *L'argumentation dans la communication.* Paris : Ed. La Découverte.

BRONCKART, J.-P., (1996). *Activité langagière, textes et discours. Pour un interactionisme socio-discursif.* Paris : Delachaux & Niestlé.

DIAZ de BUSTAMANTE, J., & JIMÉNEZ ALEIXANDRE, M.P. (2000). Communication in the laboratory sessions and sequences of arguments, paper presented in the 3rd ERIDOB Conference, September 2000, Santiago de Compostella.

DRIVER, R., & NEWTON, P. (1997). Establishing the norms of scientific argumentation in classrooms, paper presented in the ESERA Conference, 2-6 September, 1997, Rome.

DUMAS CARRÉ, A., & WEIL-BARAIS, A. (2000). Analyse du travail de jeunes élèves au cours d'activités scientifiques; dynamique des échanges et conceptualisations des élèves, paper presented in Journées d'étude franco-quebecoises – Didactique des disciplines: Recherches sur les pratiques effectives, 5-6 October, 2000, Toulouse.

DUSCHL, R.A., & ELLENBOGEN, K. (1999). Middle school science students' dialogic argumentation, paper presented in the ESERA Conference, Kiel.

GEDDIS, A., (1991). *Understanding Scientific Reasoning.* (3rd ed.) Fort Worth, TX: Holt, Rinehart and Winston.

GOLDER, C., (1996). *Le développement des discours argumentatifs.* Paris : Delachaux et Niestlé.

JIMÉNEZ ALEIXANDRE, M.P., PEREIRO MUNOZ, C., & AZNAR CUADRADO, V. (2000a). Promoting reasoning and argument about environmental issues, *Research in Didaktik of Biology.* Göteborg: IPD. 215-230.

JIMÉNEZ ALEIXANDRE, M.P., BUGALLO RODRIGUEZ, A., & DUSCHL, R.A. (2000b). " Doing the lesson " or " Doing science ": Argument in High School Genetics, *Science Education*, 84, 757-792.

KELLY, G.J., DRUKER, S., & CHEN, C. (1998). Students' reasoning about electricity: combining performance assessment with argumentation analysis. *International Journal of Science Education*, 20, 849-871.

MORTIMER, E. F., & MACHADO, A.H. (1999). Mediational tools and discourse interactions in science classrooms, paper presented in the ESERA Conference, Kiel.

OSBORNE, J ., (1999). Promoting rhetoric and argument in the science classroom, paper presented in the ESERA Conference, Kiel.

PONTECORVO, C., & GIRARDET, H. (1993). Arguing and reasoning in understanding historical topics. *Cognition and Instruction*, 11 (3&4), 365-395.

RATCLIFFE, M., (1996). Adolescent decision-making, by individual and groups, about science-related societal issues. In Welford., G., Osborne, J., Scott, P. (Eds.) *Research in science education in Europe: current issues and themes.* London : Falmer.

RESNICK, L.B., SALMON, M., ZEITZ, C.M., WATHEN, S.H., & HOLOWCHAK, N. (1993). Reasoning in conversation. *Cognition and Instruction*, 11 (3&4), 347-364.

SIMONNEAUX, L., (1997). Sumotoris in Unit 11 Transgenic animals, on

SIMONNEAUX, L., (2000). Comparison of the impact of a role playing and of a classical discussion on students' argumentation concerning an issue in animal transgenesis, paper presented in the 3rd ERIDOB Conference, September 2000, Santiago de Compostella.

SOLOMON, J., (1992). The classroom discussion of science-based social issues presented on television: knowledge, attitudes and values. *International Journal of Science Education,* 14 (4), 431-444.

SONORA LUNA, F., GARCIA-RODEJA GAYOSO, I., & BRANAS PÉREZ, M.P. (2000). Discourse analysis: pupils' discussions of soil science, paper presented in the 3rd ERIDOB Conference, September 2000, Santiago de Compostella.

TOULMIN, S., (1958). *The uses of argument.* Cambridge: Cambridge University Press.

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