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ABSTRACT

The second Utrecht/ICASE Symposium brought a variety of European colleagues together to discuss scientific literacy which has played an important role in curriculum development for the past 25 years. This proceedings contains papers presented at the symposium. Papers include: (1) "Teaching for scientific literacy: An introduction" (Elwin Savelsbergh, Onno de Jong, and Art Alblas); (2) "Environmental literacy: Re-examining the justifications and objectives of environmental education in the context of a risk society" (Marjan Margadant-van Arcken); (3) "Science Education for contemporary society: Problems, issues and dilemmas" (Jonathan Osborne); (4) "Development of a prototype module: An example of a new vision on an A-level Chemistry curriculum" (Hanna B. Westbroek, Astrid M.W. Bulte, and Albert Pilot); (5) "Mathematical and scientific literacy in PISA: The OECD program for international student assessment" (Steven Bakker); (6) "Making a place for newspapers in secondary science education" (Billy McClune and Ruth Jarman); (7) "Effectiveness of teacher-developed scientific and technological literacy materials" (Miia Rannikmae); (8) "A problem-posing approach to teaching for scientific literacy: The case of decision-making about packaging waste" (J. Kortland); (9) "Contextualizing Biodiversity" (Daan van Weelie); (10) "Science and the senses: An educational experiment at the Utrecht University Museum" (Erik Plomp); (12) "Ciencia Viva: An initiative for scientific and technological culture" (Carlos Catalao); and (13) "Towards teaching for scientific literacy: Reflections after the symposium" (Harrie Eijkelhof). A list of participants is also included. (YDS)

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Onno de Jong, Elwin R. Savelsbergh,
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Teaching for Scientific Literacy

Context, Competency, and Curriculum

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Teaching for Scientific Literacy

Context, Competency, and Curriculum

Proceedings of the 2nd International Utrecht/ICASE Symposium
11-13 October 2000

edited by

Onno de Jong
Elwin R. Savelsbergh
and Art Alblas

Utrecht University, Centre for Science and Mathematics Education

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Preface

In the autumn of 2000, the 2nd Utrecht/ICASE Symposium brought together a variety of European colleagues to discuss about *Teaching for Scientific Literacy*. Why did we select this theme? During the last 25 years staff members of the Centre for Science and Mathematics Education have been involved in a series of curriculum development projects in which scientific literacy played an important part, be it that the term itself was seldom used. We spoke of efforts to relate science to the life world of the pupils, to prepare pupils for democratic decision making, to involve pupils through realistic mathematics education, to raise awareness for environmental issues and to promote insight into the nature of science. Curriculum projects included physics education (PLON), environmental education (NME-VO), general science education (ANW), mathematics education, and currently chemistry education (Westbroek, Bulte & Pilot, this volume). In more detailed empirical studies we have built an understanding of how these goals could be attained for specific topics, such as radioactivity, biodiversity (Van Weelie, this volume), and environmental decision making (Kortland, this volume). Recently the group of Margadant (this volume) joined us with their work to give environmental literacy a firm scientific basis. So an exchange of views and experiences with colleagues from elsewhere on curriculum development and research would be in itself a good reason.

Another consideration to opt for the theme of scientific literacy deals with the development of a new Master programme on communication and education which will be effective from August 2002 onwards. It is likely that this Master programme will include streams on teacher training and informal science education, the latter including an academic training to work as environmental or health educator, science writer, science information officer or staff member at a science museum. Here the boundaries between formal and informal science education are becoming less distinct as it may be expected that pupils in future will use more and more out-of-school sources to learn science, especially when aims of scientific literacy are concerned.

Which brings us to the final reason: the fact that scientific literacy appears to be an important factor in the revision of science education at the compulsory school age levels.

During the symposium, we had some lively discussions, and an inspiring exchange of ideas and suggestions concerning the presentations. This book brings together the papers presented at the symposium, augmented with feedback from the audience. I would like to thank all presenters and participants for their contributions to this inspiring meeting, especially those who travelled long distances to this university in order to participate. Finally, I am glad that we have colleagues such as Onno de Jong, Elwin Savelsbergh and Art Alblas who have been willing to put their effort into organizing this meeting and I thank them on behalf of all participants.

Harrie Eijkelhof
director of the Centre for Science and Mathematics Education

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Teaching for scientific literacy: An introduction

Elwin R. Savelsbergh, Onno de Jong, and Art Alblas
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In science education research we aim toward giving the students a better understanding of science, be it mechanics, catalysis or ecology. But should all students learn mechanics, catalysis and ecology, and if so what should they learn about it, and to what end? To put it differently, is there a global rationale behind our secondary science curricula, and how should this rationale affect teaching? These were the central questions we tried to answer at the year 2000 edition of the biennial Utrecht/ICASE Symposium.

Of course, different stakeholders, such as universities, employers, teachers, or students will have different answers to the above questions, and answers might differ for different branches of education. However, it is widely felt that science plays a role in everybody's lives, and that therefore the general public should have a basic understanding of science. The AAAS' curriculum reform initiative Project 2061 put it like this:

> *Education has no higher purpose than preparing people to lead personally fulfilling and responsible lives. For its part, science education – meaning education in science, mathematics, and technology – should help students to develop the understandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on. It should equip them also to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital*
>
> *[T]he science-literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes (Rutherford & Ahlgren, 1991).*

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Science literacy, or as many people say, scientific literacy (SL)[1], is thus considered vital to participation in modern society. However, that is about the end of the agreement as scientific literacy is a fuzzy concept that masks many different meanings (for an overview, see Laugksch, 2000). For instance, the term SL has been used to refer to content knowledge, communicative competency, science theory, and cultural and ethical perspectives. Its fuzziness doesn't keep people from disagreeing with the idea. Shamos (1995), for instance, pleads for the less ambitious goal of *science appreciation*, because he believes the essential scientific knowledge needed for political decisions goes far beyond the reach of the school curriculum.

The stance taken by Shamos, not only reflects a belief about science (and about school), but also a view about society. According to this view scientists are knowledgeable individuals, and one has to put trust in the proper individuals. An alternative worldview is to see society as characterized by complexity, provisionality, uncertain and occasionally contradictory scientific knowledge, and an absence of general standards and values. In such a society, individuals and institutions must reflect on risks and uncertainties (Beck, 1992; Giddens, 1991). Where one view calls for trust and appreciation, the other sees participation and empowerment as central goals for science education. These are very different, albeit not mutually exclusive, goals for science education. One aspect that might be missed here is the practical relevance science and technology have to an individual. In contrast to Jonathan Osborne's belief, expressed at the symposium, that his generation must be about the last who could use their physics knowledge to fix their cars, the UNESCO/ICASE project *Scientific and Technological Literacy for All* produced learning materials that put an emphasis on the practical relevance of science and technology, such as how to avoid malaria (Holbrook, Mukherjee, & Varma, 2000). In this volume, Marjan Margadant and Jonathan Osborne are most explicit about the relation between literacy and society.

The views described above are at an abstract level and provide no direct hold to evaluate the level of scientific literacy a group or an individual has achieved, or to compare the effectiveness of an educational program or intervention towards improving SL. For both political and scientific reasons it could help to have a valid means to make such comparisons. There have been several attempts to construct such instruments, and several of these instruments evoked fierce debates between pro and con. This is not without reason, because a generally accepted test can have a strong influence on what will be taught and how it will be taught, and poor assessment could easily work against SL. The need for a valid assessment and the threats of poor assessment are recurrent issues in this volume. Currently, one of the most extensive programmes for SL assessment is the OECD sponsored PISA project. In this volume, Steven Bakker reports on how scientific literacy test items were developed in the PISA project, and on the operational definition of SL that underlies these items.

[1] In this volume we take *scientific literacy* as a general term to subsume closely related terms like science literacy, public understanding of science, science culture, environmental literacy, and science and technology literacy.

From the perspective of the symposium, a view on what SL ought to be, and a means to assess the current level of SL provide just a starting point. A successful reform requires knowledge about current practice, and an understanding of how this came to be and why it is sustained. Anecdotal evidence about a few exceptional teachers is not enough as a basis for systemic reform. Some efforts are being undertaken to get an insight in what is going on in the normal science classroom. An interesting initiative in this direction is the TIMSS-R video study, where hundreds of science lessons from several countries are being compared. In this volume, Billy McClune and Ruth Jarman focus on one aspect of classroom practice that might have particular relevance for SL, namely the use of newspapers. They investigated newspaper use in the science classroom, and the goals teachers have in mind when they use newspapers in class. It appears that most teachers use newspapers for motivational and illustrative purposes, and that it is a small minority who uses newspaper reports to evoke critical thinking. Among other reasons, they argue that teachers who are willing to use newspapers for critical thinking find little support in curriculum materials and examination programs.

The same must be true for other SL learning goals, and therefore, an important step should be to develop teaching approaches to support SL. That is what most of the volume is about, where teaching is to be taken in a broad sense. Teaching thus involves the curriculum level as well as concrete teaching materials, and it includes classroom teaching as well as informal education.

The contributions by Jonathan Osborne, and by Astrid Bulte, Hannah Westbroek and Albert Pilot deal with the curriculum level. Osborne first argues that current teaching practice is based on a number of fallacious assumptions. Next, he presents recommendations for future content and structure, and for the implementation process. Bulte et al. start from the interdependence between content, pedagogy and philosophy of science in the Chemistry curriculum. They propose that the philosophical starting point should be *science as a social enterprise*. Next, they describe how this view affects both content and pedagogy. Finally, they discuss the design of a prototype teaching-module based on this viewpoint.

The contributions by Koos Kortland and by Daan van Weelie both describe teaching materials with a focus on decision-making and participation in societal debate. Kortland discusses a teaching unit at lower secondary level about the waste issue. Van Weelie discusses a teaching unit at upper secondary level about biodiversity.

The projects described by Carlos Catalão and by Erik Plomp both aim at a positive attitude and interest in science. Catalão describes Ciência Viva, a project, initiated by the Portuguese Ministry of Science and Technology, to stimulate *science culture* among larger parts of the population. Plomp describes the development of Science Exhibits to evoke an interest in science among lower secondary students

Finally, the materials Miia Rannikmae developed in cooperation with teachers are more geared towards the practical uses science can have. In her contribution she stresses the importance of gradual change, small scale development and teacher involvement.

Clearly, there is a variety of perspectives and emphases: some authors advocate radical change, others promote gradual change; some take top down approaches, others start from grass root reforms; some promote critical thinking, others promote a positive attitude, and finally, some authors start from specific contents, whereas others take more generic teaching methods as their starting point. In a concluding paper, Harrie Eijkelhof compares the merits of the different approaches and identifies common trends, pitfalls and opportunities for further research and development.

We found it illuminating to have this group of people together at the symposium, and, later on, to see their papers grouped together. Clearly, there is no single answer to the question of how to teach for SL. Nevertheless, there are shared concerns, and there are common elements in our ideas about how to proceed. Although scientific literacy may be a fuzzy concept, the reading of these papers makes clear that it is not an empty concept.

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Environmental literacy: Re-examing the justifications and objectives of environmental education in the context of a risk society

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This article focuses on the various justifications that have been offered for environmental education. Following a brief outline of the origin and development of the concept of environmental literacy, both the environmental and political justifications and the traditional pedagogical justification for environmental education are critically discussed. From this discussion it follows that a pedagogical justification needs reformulation if it is to represent the characteristics of contemporary society and guarantee the pedagogical imperative of freedom of thought in education. Based on a conceptual analysis of sustainable development and some recent work on teaching children about a pluralistic view of nature, this article offers directions to solve the problems surrounding a pedagogical justification for environmental education, and to pay more attention to the societal and political dimensions of environmental and scientific literacy.

Introduction

Until now, the environmental and political justifications for environmental education have outweighed the pedagogical justification. By *justification* I mean the grounds on which we assume that we have the right (or the obligation) to teach children about environmental issues. Environmental education, with its goal of environmental literacy, gained importance first and foremost because of the expectation that environmental literacy would contribute to the resolution of environmental issues and lend support to environmental policies, not because of its potential to contribute to the democratic and emancipatory development of mankind. The latter has traditionally been the core theme of a pedagogical justification. However, an emancipatory pedagogical justification that aims to promote independent and critical thinking in individuals has been criticized as far too ambitious and representative of either a bourgeois, old-fashioned attitude or a modernist view of society.

While I continue to struggle with the problem of the justifications and objectives of environmental education, in this article I wish to sketch a possible pedagogical justification that is appropriate in a society characterized by a pluralism of lifestyles

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and individualization on the one hand and globalization of social structures on the other. First, as a historical backdrop, I briefly describe the origin and development of the concept of environmental literacy.

Origin and development of environmental literacy

When I was preparing this text, I dug up all my articles on environmental literacy, and I found some reviews on the roots and evolution of the concept. Roth (1992), for instance, writes that he was the first to use the term environmental literacy, in his article for the Massachusetts Audubon in 1969. This article was partly reprinted in a Sunday edition of the New York Times. A year or so later, the term *environmental literacy* cropped up in several of President Nixon's speeches. The speechwriter, who had read the New York Times reprint of the article, had worked with Roth in the field of environmental education.

This anecdote shows that environmental literacy (and education as a whole) is not *above* politics. Of course, we very commendably try to protect freedom of education and freedom of thought against political pressures. But we must recognize that education has already been politicized. As educators, we need to take the political use of the concept of environmental literacy more seriously. Purely political debates tend to specialize in oversimplifications (Bruner 1996), but education – and scientific and environmental literacy in particular – is not a simple issue.

Environmental literacy continues to be the primary goal of environmental education, with the term *literacy* in its broadest sense meaning: well-educated or knowledgeable. Roth originally stated that environmental literacy was:

> *[E]ssentially the capacity to perceive and interpret the relative health of environmental systems and take appropriate action to maintain, restore, or improve the health of those systems.* (Roth, 1992, p. 1)

This definition was refined and developed by a number of authors (for instance, Hungerford, Peyton & Wilke 1981; Michaels & O'Connor 1990), who generally endorsed the statements and documents of the United Nations' summits on environmental issues (see also Van Weelie, this volume, on the connection between Agenda 21 and the political pressure to devote more attention to biodiversity in environmental education). Clearly, the expectation was that environmental literacy would contribute to the resolution of environmental issues and lend support to environmental policies.

Critique on environmental and political justifications

For over fifteen years, I have defended a pedagogical justification for environmental education, as opposed to environmental and political justifications. From an emancipatory and pedagogical point of view, the goal of education is to form independent and critically-minded citizens, who can make a meaningful contribution to a working democracy. Environmental and political justifications usually reduce the goal of environmental education to forming a support base for environmental

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policy making and regulations among the general public and changing people's behaviour. This approach to environmental education may be classified as instrumental. In my view, an instrumental approach contradicts the whole notion of education and the notion of a democratic society in which citizens do not blindly mimic or adopt behaviour determined by experts, but instead act as critical and emancipated citizens who assume the role of watchdog by checking government policies and actions. From a pedagogical perspective, it is undesirable that the goals of environmental education be determined by external authorities who are not an integral part of the community of learners taking centre stage in the educational process. In other words, the question is not what young people should know or be capable of doing—the embodiment of authoritative thinking and top-down management. Instead, the question is: how do young people learn; what do *they* want to know and learn; which knowledge and which skills should not be kept from them in their attempts to give shape and meaning to their own lives? (Margadant 1997; Margadant & Wals 1998).

The general view of environmental education that is widely supported by both educators and policy makers is that it is a multidisciplinary form of education that focuses on nature, environment and society as interdependent and inseparable entities. There is a growing consensus that limiting the scope of environmental education to any subset of these components would not reflect the characteristics of environmental issues. Hence, environmental education must lean heavily on humanities and social sciences as well as on natural science.

The literature that I dug up devotes quite a lot of attention to the considerable overlap and parallel development of scientific literacy and environmental literacy. However, little consideration is awarded to the contribution of the humanities and social sciences. In 1992, Roth complained:

> *To my knowledge the social sciences community has not yet undertaken to define literacy in terms of the various social sciences. Thus it is not possible to look at how such literacy, or literacies, might be considered in terms of relationship to environmental literacy.* (Roth, 1992, p. 7)

He also suggested a series of possible objectives.

In my view, social scientists have certainly contributed to environmental education, but not in the way that Roth expected. Various social scientists (for instance, Jickling 1991; Sauvé 1999) have been critical of the scientific and political bias in environmental education. Recently, Ashley stated the case for environmental education as follows:

> *The National Curriculum for England and Wales, in its present form, was conceived by this same government [Major's conservative government at the time, M.M.] which, grounded in modernism, promoted the notion of science as the ultimate authority. Yet as Giddens ... illustrates, this is a lay-person's view of science, it is not the informed view of the community of scientists who are generally far more realistic about risk, uncertainty*

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> *and the limits of science than politicians whose understanding of science as often as not is gained from the media or even their own memories of school science.* (Ashley, 2000, p. 271)

As for environmental education, the problem of the scientific and political bias may be illustrated by the following example. In the United States, the Independent Commission on Environmental Education (1997), a group of ten specialists in the areas most often covered in environmental education carried out an evaluation of the teaching material used in American schools. The Commission was particularly concerned about complaints that teaching material for environmental education was factually inaccurate, superficial, and designed to persuade rather than to inform. In several cases, these complaints proved to be valid. One of the most troubling findings of the Commission was the superficial way in which environmental education is dealt with in high school textbooks.

Critique on the traditional pedagogical justification

An emancipatory pedagogical justification for environmental education, with its traditional objective of fostering independent and critical thinking, has been criticized as far too ambitious – particularly for *black schools*, which have a majority of children from various ethnic backgrounds – and as representative of either a bourgeois, old-fashioned attitude or a modernist view of society (see, for instance, Bolscho 1998; Jans & Wildemeersch 1999). According to postmodern philosophers and educators, emancipatory pedagogical justifications reflect the ideals and values of the Enlightenment (justice, equality, humanity, rationality, emancipation, democracy, etcetera), that bring to mind Kant's ethical philosophy.

It pains me to hear this kind of criticism and Jansen (1994) considers it too absolute. In spite of their specific historical ties, the ideals and values of the Enlightenment have not lost their validity. However, they do need to be reformulated in the context of a society characterized by pluralism of lifestyles and individualization on the one hand and globalization of social structures on the other. In this respect, the social theories of Giddens (1991) and Beck (1992) are particularly valuable. According to Giddens and Beck, modern-day society is characterized by complexity, provisionality, uncertain and occasionally contradictory scientific knowledge, and an absence of general, shared moral standards and values. Beck speaks of a *risk society*, which centres not on the distribution of prosperity, but on the distribution of risks: Who decides what is dangerous or not? Who is held responsible for catastrophes? Who decides which risks are socially acceptable? Who decides who runs which risks? A risk society that is characterized by these questions force people and institutions to reflect on uncertainties such as food safety (for example, BSE, genetically modified food), nature exploitation (for example, drilling for gas in the Dutch Waddenzee, which is rich with marine life), xenotransplantation, and so on. This kind of reflection requires scientific and environmental literacy in every citizen, even those who do not pursue an academic education.

Sustainable development and the need for reflection

The problems surrounding a pedagogical justification for environmental education became even more clear when the concepts of sustainability and sustainable development are analysed. Following the UNCED conference in Rio de Janeiro, which resulted in the publication of Agenda 21 (UNCED, 1992), sustainable development became the core theme of environmental literacy.

The Dutch government asked us to provide a conceptual analysis of the idea of *learning for sustainability*, and to develop appropriate educational methods (see Lijmbach, Broens, Hovinga in cooperation with Margadant, 2000). In our conceptual analysis, we reviewed national and international policy documents and educational literature. We found that the concept of sustainability was initially reduced by most authors to *ecological* sustainability, which can be scientifically delineated and poses limits to societal developments. Alternative interpretations of sustainability were hardly considered. Subsequently, sustainable development was defined as the sum of ecological sustainability *plus* economical development *plus* societal development. Berryman (2000) has dubbed this combination the *new mythical Trinity*—an appropriate term in the sense that the interrelations between the three are not entirely clear.

Nevertheless, there is a growing consensus among government policy makers and captains of industry that reflects this mythical Trinity. For government and industry, sustainable development means scientific-technological and economic-ecological development aimed at the modernization of production and consumption. This consensus has been attacked from three different standpoints, namely, an alternative political view, according to which the current political power relationships are part and parcel of sustainability problems; an eco-centric view, that states that sustainability problems are caused by our anthropocentric, controlling attitude towards nature; and a view derived from the social theories of Giddens and Beck. These views have been translated into various approaches to environmental education, which usually reflect the environmental and political justifications that I criticised above. In our opinion, the view based on the social theories of Giddens and Beck is the only view that allows a reformulation of the pedagogical imperative of freedom of education and freedom of thought.

According to Giddens and Beck, the interpretation of sustainability and the formulation of solutions are entirely societal problems that are intertwined with other societal problems. It follows that different institutions and social groups will define sustainable development in different ways. It is precisely this difference of opinion that should be the starting point for discussion *and* leads the way to possible solutions. Because of the complexity of the problems and the uncertain and occasionally contradictory scientific knowledge that is available to us, governments and scientists are unable to provide ultimate solutions. Citizens joined in sub-political groups need to reflect on the uncertainties of and possible solutions for sustainable development.

This kind of reflection may be designated as *social learning*, as it implies the process of learning in and with groups. However, social learning is not a form of education, certainly not in a formal sense. According to Jansen (1999), social learning bridges the gap between social activation and education. In social learning processes, people become aware of the knowledge and skills they need to analyse problems and find solutions. This approach is needed in environmental education: learning is achieved not in the old-fashioned, authoritative way, but in a demand-driven way.

Environmental literacy and lifelong learning

A demand-driven approach to education must be workable within the strict frames of a school curriculum. Therefore, the objectives of environmental literacy must be reconsidered in the light of existing practices in the schools. Current curricula were developed primarily with the goal of selection for university entry (Ashley 2000; Millar & Osborne 1998), but – as I remarked above – not every pupil goes to university. For the majority of people, therefore, living in a risk society requires a different kind of environmental literacy than is currently taught at school. A student who becomes a cashier at a supermarket, for instance, has to form a view on the sense and nonsense concerning *eco-products*. However, this is not only the cashier's problem. The manager should be more knowledgeable about the eco-products on sale and, if the supermarket is part of a chain or a holding, the board of directors should be even more informed. In effect, the whole food producing industry has an obligation to inform the consumers at large. In a risk society, it is no longer acceptable for the food producing industry that offers genetically modified products to dismiss consumer criticism about 'Frankenstein food' as irrational fears. It should be part of the ethics of those working in the food industry to attend to these fears and supply comprehensible information.

I have used this example to show that society as a whole, and not just the educational system, is responsible for the scientific and environmental literacy of its citizens, notwithstanding the attempts of governments to politicize and oversimplify the issue and lay the burden entirely on the shoulders of the schools. If environmental literacy is to become a matter of lifelong learning, then the focus of school curricula will have to change. The goal of forming literate people (in the sense of educated or knowledgeable) should shift to a focus on creating empowered citizens.

Millar and Osborne (1998) and Bruner (1996), among others, have argued for a narrative form of science education. Bruner proposes that science education should focus from start to finish on the lively process of *making* science, rather than dishing up *dead science* as depicted in current textbooks. This implies that the focus must shift from an exclusive concern with nature *as-it-is-out-there* to a concern with a *search* for nature, that is, nature *as-we-construct-it* (Bruner 1996, pp. 126-127). This approach is in line with the social theories of Giddens and Beck. Both implicitly and explicitly, this approach also contains an introduction to the cultural boundaries of science and the ethical responsibility of the scientist. But is this the solution? Will

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this approach help us to formulate the goals for the kind of environmental literacy that people need in a risk society?

It seems to me that approaching the problem of environmental literacy from a theoretical level will only result in yet another table of abstract objectives that are usually ideologically biased or so open-ended that they encompass almost everything. In line with the Utrecht phenomenological tradition, therefore, I have approached the problem the other way round and taken as a starting point *the things themselves* (zu den Sachen).

The problem of pluralism

We recently completed an action research project in which we developed a theoretical framework that formed the foundation for four sets of teaching modules representing a pluralistic view on nature (Margadant & Van den Berg, 2000). In this project, researchers from three different disciplines (sociology, philosophy and pedagogy) worked together with curriculum developers of the Dutch National Institute of Curriculum Development (SLO) and teacher-authors of various school textbooks. A scan of current Dutch biology and geography textbooks (Margadant & Wals, 1998) had revealed that many textbooks present a one-sided view of nature. Nature is seen primarily as a resource or sustenance base, or a scientific view of nature is presented, while the diverging views that are embedded in various social contexts and social practices in our society are ignored.

For example: the Dutch government recently decided that our country needs an Ecological Main Structure (Dutch: Ecologische Hoofd Structuur), that is, large nature areas connected by corridors and stepping stones (small nature sites) that allow plants and animals to migrate. Its contours are like a large untidy H running through the Netherlands. Nature is the main 'function' in this structure; housing, industry and agriculture are of minor importance and in some areas even prohibited. However, since the Netherlands is the second most densely populated country in the world after Bangladesh, this Ecological Main Structure has inevitably caused tremendous tension in various social contexts and settings. The issue has forced those who live and work in this area to reconsider their views on nature and the environment.

In a pluralistic society, it is important that people have the ability to live and interact with other people and groups of people who think and behave differently. Hence, environmental literacy should focus on teaching students to discuss their views of nature with each other so as to develop a collective perspective that transcends individual behaviour.

We developed the theoretical framework and teaching modules with this in mind. The teaching modules were used in a tryout with teachers in regular classes, observed by one of the researchers. Our analysis of the results revealed that the classroom discussions were generally limited to an inventory of pupils' views and interests regarding a particular nature issue, and that the discussion ended there. This problem of 'discourse paralysis' may be due to prevailing views in education that

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attach considerable significance to the development of the pupil's *own* values and opinions. With this focus on personal value development and autonomous thinking, the social and political context in which values and ideas are developed is ignored (Lijmbach, Margadant, Van Koppen & Wals, in prep.).

Another reason why the classroom discussions did not progress beyond an inventory of pupils' own views and interests regarding nature, relates to the disciplinary frameworks (geography and biology) in which the modules were developed. Biology and geography lessons on the subject of nature aim primarily to develop pupils' knowledge and understanding. Teachers have been educated in their teaching subject and they are trained to transfer this knowledge. Teaching pupils about issues such as policy making, conflict resolution and problem solving is not part of traditional biology and geography curricula. Although environmental education is multidisciplinary, in this case it is embedded in the monodisciplinary subjects, namely, biology and geography. However, environmental education also involves teaching pupils about the social and political issues that concern nature and environment. To biology and geography teachers, these issues may be incompatible with their monodisciplinary curriculum. Monodisciplinary biology and geography curricula and multidisciplinary environmental education may be complementary when an understanding of the relationship between science and society is considered an integral part of teaching scientific and environmental literacy (*ibid.*). Several authors have recently defended this view (i.e., Ashley 2000, Bruner 1996, Millar & Osborne 1998).

Conclusion

In my view, the problem of reformulating the pedagogical justification and objectives of environmental literacy in the context of a risk society boils down to two main issues. First, environmental educators, researchers in education, curriculum developers and teachers need to take a much more critical stand towards policy makers, who implicitly or explicitly require environmental education to provide a support base for their environmental and sustainable development policies. Secondly, more attention must be paid to the societal and political aspects of environmental and scientific literacy in order to develop teaching practices that truly represent the characteristics of contemporary societies and guarantee the pedagogical imperative of freedom of thought in education. In my opinion, these issues can only be tackled through the close collaboration of social scientists and natural scientists, researcher in education, environmental educators, curriculum developers and (science) teachers.

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Science education for contemporary society: Problems, issues and dilemmas

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Traditionally, science education has been a preparation for a scientific career. Yet if science is merely a gateway to a set of limited career options, it merits no higher status than any other optional subject, and this reason alone is insufficient to merit universal compulsion and a place at the curriculum high table. In addition, existing practice in science education rests on a number of fallacies or myths which inhibit change and are open to many substantive challenges. Such values have led the traditional science courses to provide only minimal treatment of the other three pillars on which any public understanding of science rests – the processes of science, an analysis of risks and benefits, and a knowledge of the social practices of science – knowledge which is necessary for the future citizen. Including these aspects will require a course that approaches the content, not from a foundational perspective where the final holistic picture is only accessible for those who complete a full education in science, but rather from an approach that emphasizes the major explanatory stories that science has to offer. Such a course would seek to emphasize the development of an appreciation of science as a cultural activity rather than an extensive knowledge of its content. It will, however, be argued that any new curricula must make science education more relevant to contemporary students—developing an awareness that science is both an interesting and important activity, and the capacity of students to engage with science in a positive and enthusiastic manner. However, a number of obstacles to reform exist. The introduction on standards has reinforced the dominance of easily assessable content and the attempt to make the important measurable, has made only the measurable important. The imposition of such frameworks has undermined teachers' sense of commitment and professionalism, and many are now resistant to change. These issues, examples of new approaches, their implications and more are explored in this paper.

Science Education and its problems

It is Collins (2000) who most aptly points to the horns of a trilemma on which science education sits. That is that science education attempts to wrestle with three mutually contradictory requirements. On the one hand it wants to demonstrate the

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tremendous liberatory power that science offers—a combination of the excitement and thrill that comes from the ability to discover new knowledge, and the tremendous insights and understanding of the material world that it offers. Yet its mechanism for achieving this aim is to rely on a dogmatic, authoritarian and extended science education where students must accept what they are told as unequivocal, uncontested and unquestioned. Only when they finally begin practising as scientists and enter the inner sanctum will the workings of science become more transparent. Moreover, its foundationalist emphasis on basic concepts rather than the grand ideas of science means that any sense of its cultural achievement is simply forgotten. The consequence, as argued in the report *Beyond 2000*,was that:

> *We have lost sight of the major ideas that science has to tell. To borrow an architectural metaphor, it is impossible to see the whole building if we focus too closely on the individual bricks. Yet, without a change of focus, it is impossible to see whether you are looking at St Paul's Cathedral or a pile of bricks, or to appreciate what it is that makes St Paul's one the world's great churches. In the same way, an over concentration on the detailed content of science may prevent students appreciating why Dalton's ideas about atoms, or Darwin's ideas about natural selection, are among the most powerful and significant pieces of knowledge we possess.* (Millar & Osborne, 1998, p.13)

The outcome is that science education is, in a non-too trivial sense, science's worst enemy leaving far too many pupils with a confused sense of the significance of what they have learnt and, more seriously, an enduring negative attitude to the subject itself (Osborne & Collins, 2000; Osborne, Driver, & Simon, 1996). None of this matters for the traditional education of the scientist – Collins' second horn – which demands a lot of routine and rote learning to acquire the basics of the domain.

The result, however, is that such an education ignores or neglects the third horn of its trilemma, the requirement to provide its students with some picture of the inner workings of science. Knowledge, that is, of science-in-the-making (Latour, 1985)—knowledge which is essential for the future citizen who must make some judgement about reports about new scientific discoveries and applications. Contemporary society, it is argued (American Association for the Advancement of Science, 1989; Jenkins, 1997; Jenkins, 1998; Millar, 1996; Millar & Osborne, 1998), requires a populace who have a better understanding of the workings of science enabling them to engage in a critical dialogue about such issues and arrive at considered decisions about the political and moral dilemmas posed by science. New developments in science will, for instance, require the ability to distinguish whether an argument is sound; to differentiate evidence from hypotheses, conclusions from observations and correlations from causes.

Another aspect of concern is the gulf between science-as-it-is-practised and science-as-it-is-taught in schools. The growing gulf between these two is well-illustrated by our recent research (Osborne & Collins, 2000). Many pupils expressed antipathy to topics such as the periodic table. Not only did they experience difficulty in

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memorizing the constituents of the table, but they also failed to perceive its relevance to their everyday lives at present or in the future:

> Edward: It doesn't mean anything to me. I'm never going to use that. It's never going to come into anything, it's just boring.

Similar sentiments were expressed about the inclusion of the blast furnace in school science:

> Roshni: The blast furnace, so when are you going to use a blast furnace? I mean, why do you need to know about it? You're not going to come across it ever. I mean look at the technology today, we've gone onto cloning, I mean it's a bit away off from the blast furnace now, so why do you need to know it?

The lack of perceived relevance to pupils' lives of such topics was a recurring theme throughout these discussions in all groups, either for continuing education in science and/or career aspirations. For instance, it was argued by a boy not continuing with science post-16 that 'I won't need to know all the equations or the chemicals'. Without the essential ingredient of relevance, sustaining interest is difficult, if not impossible.

The emphasis of school science on consensual, well-established science, means that there is no space for any consideration the science that dominates contemporary society—the science and technology of informatics, CD-ROMs, mobile phones, lasers, health and disease, modern cosmology, modern imaging systems using computerized techniques, advances in materials technology and polymers, and least but not last, advances in medical genetics. This is the science that interests adolescents and would be included if the curriculum was, instead, organized around the question 'what makes young people want to learn science?' Yet there is as much chance of finding any contemporary science on the curriculum as there is water in a desert. This is not to argue for a curriculum based totally on contemporary science but simply for some aspects to be included as a vital point of engagement.

More fundamentally, the question needs to be asked how this gulf between school science and contemporary science has emerged. My analysis is that, as currently practised, science education rests on a set of arcane cultural norms which inhibit change and adaptation. These are 'values that emanate from practice and become sanctified with time. The more they recede into the background, the more taken for granted they become' (Willard, 1985). A closer examination, and the insights of contemporary scholarship, expose these norms to be nowhere near the self-evident truths that we may think—what I might choose to call the eight *deadly sins* of science education. For in contemporary society, research would indicate that trust in science is dependent on developing a knowledge not only of its basic concepts and ideas of science, but also *how* it relates to other events, *why* it is important, and *how* this particular view of the world came to be. Any science education, therefore, which focuses predominantly on the intellectual products of our scientific labour – the *facts* of science – simply misses the point. Science education should rest, therefore, on a triumvirate of a knowledge and understanding of:

a) the scientific content,

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b) the scientific approach to enquiry,
c) science as a social enterprise—that is the social practices of the community.

Evidence would suggest that in many countries, normative practice regards school science education as a selection mechanism for the few who will become the future scientists of contemporary society. Consequently the predominant emphasis is on the content of science and consensual well-established knowledge. Contemporary science – the science that interests adolescents – is notable by its absence. The result is a curriculum with only marginal relevance and extrinsic instrumental value for a limited set of career aspirations rather than a discipline valued for its intrinsic interest. Western societies can ill afford the consequent alienation and disengagement with science that such courses generate. First on the economic front, the lack of recruits into science and technology is in danger of undermining economies which are highly dependent of the skills and knowledge of these disciplines. Second, the ensuing lack of engagement and ambivalence to science threatens science's relationship with its publics and public distrust of scientific expertise is in danger of placing unwarranted restrictions on future research and technological development. Fear of the worst is leading the public to demand a naïve application of the precautionary principle to research potentially limiting the advancements that science offers for solving the plethora of problems that face contemporary society. In the UK, for instance, significant pressure groups have argued that all research on genetically modified food should be halted using highly questionable ethical arguments.

What then are the norms that hinder the development of current practice in science education obstructing the development an appropriate understanding of science, a more positive engagement with the fruits of scientific labour, and a critical but constructive understanding of its strengths and limitations? The argument here is that the practice of science teaching rests on eight fallacious assumptions, which are as follows:

The fallacy of miscellaneous information

All too many science courses have attempted to make students memorize a series of dry facts which no practising scientist knows, such as the boiling point of water, the density of various substances, the atomic weight of different chemical elements, conversion factors from one system of units to another, the distance in light years from the earth to various stars (and so on). However, an increasing body of work now shows that knowledge is only one component of the many competencies required of adults in their professional life and, unless it is constantly used, is rapidly forgotten (Coles, 1998; Eraut, 1994).

The foundational fallacy

This is the fallacy that because scientific knowledge itself is difficult and hard won, learning and understanding science requires a similar process where the student's knowledge and understanding are assembled brick by brick, or fact by fact. As a

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consequence only those that reach the end ever get to comprehend the wonder and beauty of the edifice that has been constructed. Current practice, therefore, is rather like introducing a young child to jigsaws by giving them bits of a one thousand piece puzzle and hoping that they have enough to get the whole picture, rather than providing the simplified 100 piece version. In effect, although the pupils can see the microscopic detail, the sense of the whole, its relevance and its value—the things that matter to the pupil (Rowe, 1983) are lost. Chown (1998) offers a good example of a tale which the foundationalist approach offers only to undergraduates or postgraduates taking courses in stellar nucleosynthesis—the grand ideas of science which are reserved only for those who complete the course.

> *But if all these examples of our cosmic connectedness fail to impress you, hold up your hand. You are looking at stardust made flesh. The iron in your blood, the calcium in your bones, the oxygen that fills your lungs each time you take a breath - all were baked in the fiery ovens deep within stars and blown into space when those stars grew old and perished. Every one of us was, quite literally, made in heaven.* (Chown, 1998, p. 62)

Yet there is nothing about such a story which is intrinsically difficult. The failure to communicate such ideas in compulsory science education simply reinforces Claude Bernard's, the famous 19th century philosopher, view that science is a 'superb and dazzling hall, but one which may be reached only by passing through a long and ghastly kitchen.'

The fallacy of coverage

School science is suffering from a delusion that the science we offer must be both broad and balanced. The result is an attempt to offer a smattering of all sciences and to cram more and more into an oft-diminishing pot. Quite clearly, as the bounds of scientific knowledge expand from evolutionary biology to modern cosmology, more and more knowledge vies for a place on the curriculum. However, just as those teaching literature would never dream of attempting to cover the whole body of extant literature, choosing rather a range of examples to illustrate the different ways in which good literature can be produced, has the time not come to recognise that it is our responsibility to select a few of the major *explanatory stories* that the sciences offer? And surely it is the *quality* of the experience, rather than the *quantity*, which is the determining measure of a good science education?

The fallacy of a detached science

Science education persists with presenting an idealized view of science as objective, detached and value free. This is wrong on three counts. First the public, and particularly young people, do not distinguish between science and technology. Second, science is a socially-situated product and the language and metaphors it draws on are rooted in the culture and lives of the scientists who produce new knowledge. Thirdly, those that engage in science are not the dispassionate, sceptical and disinterested community that Merton (1973) portrays. Science is a social practice, engaged in by individuals who share a 'matrix of disciplinary commitments, values and research exemplars' (Delia, 1977). Within the contemporary context, where scientists are employed by industrial companies with vested interests, it is hard to advance a case that science is simply the *pursuit of truth* untainted by professional aspirations or ideological commitments. For these days scientists are judged as much by the company they keep as the data they may gather (Durant & Bauer, 1997).

Finally, the separation of science from technology eliminates all consideration of the societal implications for society. For, as Ziman (1994) argues, if science education fails to make the small step from science to its technological applications, how can it take the much larger step to the implications for the society in which it is embedded?

The fallacy of critical thinking

This is an assumption that the study of science teaches students reflective, critical thinking or logical analysis which may then be applied by them to other subjects of study. It is based on the fallacious assumption that mere contact with science will imbue a sense of critical rationality by some unseen process of osmosis. It is also an assumption questioned by the Wason 4 card problem and the Wason 2, 4, 6 problem (Wason & Johnson-Laird, 1972) both of which require a standard scientific strategy of falsification to determine the correct answer and, which very few, including scientists, use.

Secondly, the notion that science develops generalizable, transferable skills is also an assumption questioned by the body of research which suggests that people's use of knowledge and reasoning is situated within a context (Carraher, Carraher, & Schliemann, 1985; Lave, 1988; Seely Brown, Collins, & Duiguid, 1989) and that detached knowledge is of little use to individuals until it has been reworked into a form which is understood by the user.

The fallacy of the scientific method

This is the myth that there exists a singular scientific method whereas the record of those who have made the important discoveries of the past shows not only that scientists rarely attempt any such logical procedure, but that the methods vary considerably between the sciences. The methods deployed by the palaeontologist working out in the field are about as similar to those used by the theoretical physicist as chalk and cheese.

Yet the science that increasingly confronts the individual in the media, with its focus on environmental or biological issues, is predominantly based on correlational evidence and uses methodological devices such as clinical trials with blind and double-blind controls. Yet where, and when, is there any treatment of the strengths and limitations of such evidence (Bencze, 1996)? Is it not time to give up any notion that there is such a singular entity and turn instead to presenting a range of ideas about science and its working. Moreover, when so much of the science reported in the media is based on epidemiological research and associative findings – probability and likelihood rather than causal relationships and certainty – is it not time to teach about such data, its interpretation and evaluation?

The fallacy of utility

This is the myth that scientific knowledge has personal utility—that it is essential to the mastery of the technology; to remedy its defects; and to live at ease in the culture of technology that surrounds us. For as machines become more intelligent they require less care and thought for their effective use. Even its economic utility is questionable as current employment trends, at least in the UK and USA, suggest that, although we will need to sustain the present supply of scientists, there is no indication that there is any need to significantly improve the number going into science, which remains, as ever, a small minority of the school cohort of around 10–15% (Coles, 1998; Shamos, 1995).

The homogeneous fallacy

Increasingly, in many countries, science education labours under the fallacy that its clientele are an entity who, whilst they might differ in aptitude and ability, nevertheless are best served by one homogeneous curriculum. With their devotion to pure science, a foundationalist approach, and a high-stakes assessment system, the result is a pedagogy based on transmission (Hacker & Rowe, 1997). By the onset of adolescence, the imperative of relevance increasingly challenges the delayed gratification on which such a curriculum rests leading to a lack of motivation and interest (Osborne, Driver, & Simon, 1996). Pupils, therefore, need to be offered a diversity of science courses to meet their disparate needs.

What then are the methods, practices and components of a new vision of science education that might meet these concerns? The broad framework of such a vision has been developed in the report *Beyond 2000: Science Education for the Future* (Millar & Osborne, 1998). In this report, we argued for 10 recommendations, which we saw would address many of the aforementioned criticisms. These were:

1) Science education should be for the majority and should be for scientific literacy.
2) An element of choice should be allowed at age 14.
3) The curriculum needs aims to ensure that its primary purpose is well understood and shared by all.
4) Scientific knowledge can best be presented as a set of *explanatory stories* that would provide a holistic overview of the great ideas of science.
5) Technology can no longer be separated from science as the former is what interests pupils.
6) The science curriculum must give more emphasis to key ideas-about-science.
7) Science should be taught using a wide variety of teaching methods and approaches.
8) Assessment needs to measure pupils' ability to understand and interpret scientific information.
9) Change in the short term should be limited as radical change is undermined by teachers.

10) A formal procedure needs to be established for the testing and trialling of innovative approaches.

However, reforming the science curriculum to meet the challenges of the contemporary society faces a number of obstacles that must be addressed and met. These are the limitations of the qualifications and abilities of the science teaching force; the problems with developing appropriate modes of assessment; the resistance of well-established stakeholders; and the culture of science teaching.

Curriculum Reform

Any new curriculum which gave more emphasis to developing an understanding of the nature and processes of science, would require teachers themselves to have some understanding of these dimension of science. Yet science teachers are the products of an education which has paid scant regard to history, or any examination of its social practices. And for good reason—the dominant ideology within science is one of dogmatism and authority where the tentative nature of the roots of scientific knowledge is excised to present science as a body of certain knowledge which has been the successful, linear progression of the work of isolated great men, devoid of any cultural context. The outcome of such an education is a body of science teachers who have naïve views of the nature of science—seeing it as an empirical process where scientific theories are inductively proven (Koulaidis & Ogborn, 1995; Lakin & Wellington, 1994)

Similarly, Donnelly (1999) has shown how science teachers see their work as one which is dominated by content rather than process, as opposed to the contemporary treatment of history where the history teachers seek to develop an understanding of what it is to *do* history. The significance of empirical work to science, and in the teacher's practice, is such that teachers are endowed with distinctive status by the provision of specialized laboratories. Laboratories in their turn become rhetorical artefacts where the scientific world-view can be used to illustrate the predictability of nature and inspire confidence in its portrayal of nature (Donnelly, 1998). Asking teachers to teach more about the nature of a subject which they themselves only have a limited understanding of will inevitably be problematic.

Attempts to introduce change under the umbrella of the National Curriculum – particularly when those changes were later shown to be based on fallacious models of science – have met with substantive resistance and modification. The 1991 version of the English and Welsh science curriculum introduced a model of practical based investigatory work which was unfamiliar and resented by teachers who failed to share or understand its intentions. The result was a long period of adaptation whilst teachers reworked the curriculum to put into practice work which was a distorted representation of the intentions of the national curriculum document. Many teachers were alienated or disaffected by the process (Donnelly, Buchan, Jenkins, Laws, & Welford, 1996).

The lesson of these problems is one that was clear from previous research on educational change (Fullan, 1991; Joyce, 1990). First, teachers must be dissatisfied with the existing curriculum if the arguments for change are to be heard. Second, if change is to occur, teachers must be supported in developing new practices, new bodies of knowledge and new pedagogic methods. At the very least, that requires the rewriting of curriculum support materials which should seek to provide exemplary illustrations of the ideas to be taught and suggestions for how it can be taught. More substantive support would require a programme of professional development delivered by individuals who are themselves competent and effective teachers who have a good grasp of any new initiative. At the very best, there would be in-situ training provided for all teachers who required it.

Assessment

The second problem lies with reform lies in the role of assessment within existing national and international frameworks. Within the past twenty years, political imperatives have led to the necessity to measure the performance of the educational system. The consequence has been the rise of national systems of assessment based on testing at certain key ages—in the UK these are age 7, 11, and 14. Internationally, we have also seen the rise of comparative assessment between countries which have been used as a measure of the overall quality of education (Beaton et al., 1996). Thus rather than assessment serving as a tool to benefit the child, providing either a formative or summative judgement of their capabilities, it has become a servant of a bureaucratic mentality that seeks to monitor the performance of the system. Whilst, it could be argued that these two aims are not incommensurable, the reality is different.

Similar problems have beset attempts to provide performance indicators in the Health Service, in the privatized railway companies and a host of other public services. A variety of indicators are selected for their ability to represent the quality of the service, but when used as the sole index of quality, the manipulability of these indicators destroys the relationship between the indicator and the indicated. Directing more and more attention onto particular indicators of performance may manage to increase the scores on the indicator, but the score on what it indicates are, in reality, relatively unaffected. Thus whilst measures of children's achievement show year on year improvement, the actual quality of their education remains much the same.

The lesson of history then is that in seeking to make the *important measurable*, only the *measurable* has become *important*. The second problem is that within school science, assessment items are commonly devised by those that have been, or still are, practising science teachers. Just as it is often said that you teach only that that you can teach, so assessment is often based on the normative values of what it is considered possible to assess. Hence the assessment of students' understanding of the processes of science, or its social practices, are not considered because there is no established body of knowledge of how to assess such items. At worst, assessment experts will simply assert that it is too difficult, time-consuming or expensive to assess such understandings and at best, that they do not know how to do so. Thus within such a context generated by the importance of measuring performance of students, teachers and schools, the clear message to teachers is that the lack of any assessment of a given topic implies that it is an extraneous item of no significance.

The single most important message that emerges from this experience is that curriculum reform without a commensurate change in the assessment will be ineffective. Change must be attempted holistically and not in a piecemeal fashion for the intended curriculum is read as much, if not more from the assessment as much as it is from the curriculum. In conclusion, what is evident, is that *science for all* requires a curriculum *for all*. The current flight from science by contemporary youth would suggest that anything else would be a price that neither science or society can afford to pay.

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Development of a prototype module: An example of a new vision on an A-level Chemistry curriculum

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This paper presents a part of our research programme, which aims at supporting and stimulating the discussion on redesigning A-level chemistry education in the Netherlands. The aim of the research discussed in this paper is to develop, through developmental research, an example or prototype of a representative part of a new secondary school chemistry programme. From this prototype a consistent view should emerge to inspire and guide developers involved in a far-reaching curriculum innovation project. In this paper a draft version of a new vision on an A-level chemistry curriculum (students aged 16–18) has been worked out. This offers us guidelines, preliminary design criteria, and design characteristics for the further development of our prototype.

Introduction

Recently, a coordinated effort to redesign the A-level Chemistry curriculum in The Netherlands has been initiated (Bulte et al., 1999; Eenhoorngroep, 2000; Westbroek, Bulte, & Pilot, 2000). Also internationally, a need is felt to reconsider aims and content of the Chemistry curriculum (Black & Atkin, 1996; Pilot & Vos, 2000; UNESCO-workshop, 2000).

Analysis by Van Berkel, De Vos, Verdonk and Pilot (2000) shows that the structure of the current predominant school chemistry curriculum is a rigid combination of a *substantive structure (Sub)* based on corpuscular theory, a positivist *philosophical structure (Phil)*, and a *pedagogical structure (Ped)*, aimed towards training of students as future scientists (Figure 1). Processes of curriculum redesign have so far resulted in a sedimentary structure (De Vos & Pilot, in press) with successive layers of new content, new pedagogy and new philosophy on top of the predominant 19th century basis. The result is an overloaded, rigid, curriculum (Figure 2), which is unable to accommodate new scientific content and recent social and pedagogical developments in the time available for school chemistry for school chemistry. This curriculum is thus very resistant to change with a twofold isolation: school chemistry is both isolated from its social, everyday context and from the latest scientific developments.

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From a basis of
directly observable facts
(objective, independent from human beings),
more complex theories can be induced.
This leads to rational scientific theories suitable
for describing and improving the world.
(Phil)

Corpuscular theories
are the necessary starting point for
the understanding and description
of natural phenomena
(Sub)

Learners are to be
trained as future scientists;
knowledge is directly
transferable to
learner
(Ped)

Figure 1. The existing coherence of the philosophical, pedagogical and substantive structure of 'Normal Chemistry Education' as the currently predominant structure of school chemistry according to Van Berkel et al (2000).

Numerous examples of this twofold isolation can be found in the textbooks for secondary education. For example, for studying the subject of *salts*, textbooks start from the structure of atoms, followed by how atoms are converted into ions, and how ionic substances are built from charged ions. Textbooks continue with the solubility of ionic substances in water. Subsequently more complex ions, such as sulphates and nitrates, are carefully added to the students' repertoire. All these separate parts in the textbooks are accompanied by student-exercises that mainly aim at training the students' ability to reproduce the chemical knowledge presented. It takes quite a number of chemistry lessons before a student will come to a point where the new chemical knowledge may be related to society and the everyday world. Some students indeed start to ask about nitrates and environmental problems. Others never make such a connection. For other subjects, such as organic chemistry, the pathway to study from basic chemical principles towards relevant application (e.g., production of medicines) is even longer. State of the art chemistry has become too complex, and students never come to a point where interesting, relevant themes are dealt with in the classroom, because this can no longer be realised within the (time-)limits of the chemistry curriculum. The pedagogical structure therefore results in problematic learning processes for students: school chemistry is difficult, abstract and irrelevant.

A superficial scan of the textbooks may give the impression that everyday context has been added to the curriculum. Several student-exercises contain information about contaminants in a river, such as lead-salts, acid-base indicators in plants or food additives for preservation of e.g. wine. However, textbook and teacher aim at

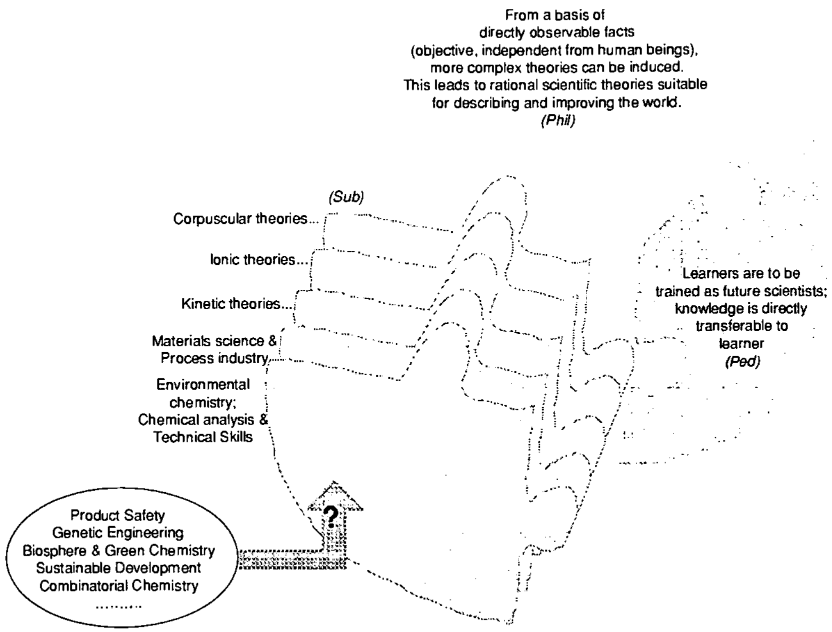

Figure 2. The overloaded chemistry curriculum with a sedimentary structure according to De Vos & Pilot (2000), still with the predominant rigid structure described by Van Berkel (2000). Besides, new layers of the pedagogical structure, that have occurred since the 1960s and that have intertwined with the substantive structure, makes the sedimentary structure even more obscure (this is not expressed in the drawing).

reaching the 'right' answer, for example the recalculation of the concentration of an additive given in gram per litre into parts per million (ppm's). Students pose different questions: how many glasses of wine can I drink before I will get sick, what is the effect of alcohol on my body, why is the addition of sulphite important, is the same fact true for red wine? Or even further: shouldn't the government prohibit the addition of sulphite? At the moment students become personally involved in subjects that relate to chemical knowledge, the student-activities in the present curriculum (*the pedagogical structure*) are not adequate to deal with questions that are relevant to their own life and their own society. Such confusing implicit shifts between several curriculum emphases described by Roberts in several papers (1982; 1988; 1995) then lead to confusing messages in textbooks about what should be learned and why school chemistry is relevant (Westbroek et al., 2000).

This leads to the conclusion that the predominant coherent combination of the philosophical, the pedagogical and the substantive structure as it has emerged from the 19th century and further been developed throughout the 20th century, can no longer offer adequate chemistry education. Therefore, it is necessary to start a

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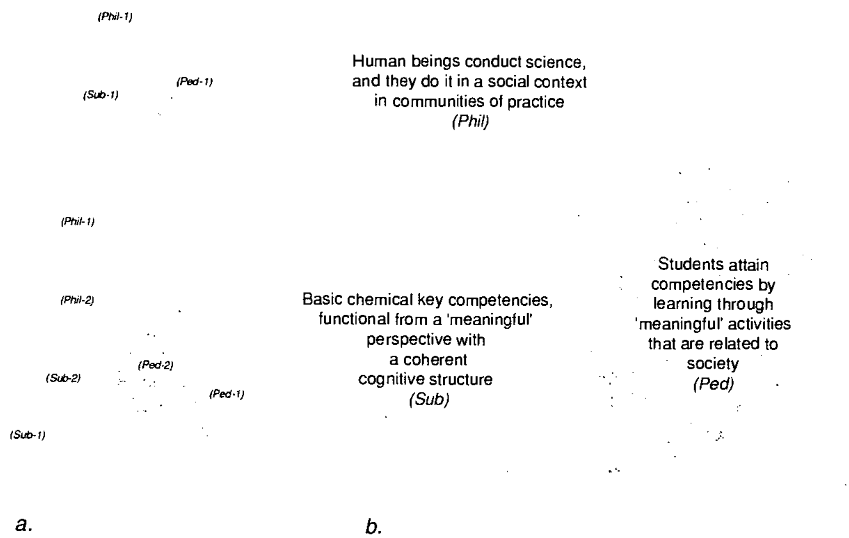

Figure 3a) For a new coherent relationship between philosophy, pedagogy and scientific content these three structures should be changed simultaneously. b) A new vision to be consistently worked out in an exemplary prototype.

process to design a new coherent combination of a chosen philosophical, pedagogical and substantive curriculum structure (see Figure 2 and 3). Changing only one piece of the puzzle is not enough: the curriculum must be changed in three structures simultaneously in order to connect to modern developments, and at the same time make it coherent again.

Towards the construction of a new consistent vision

In order to bridge the two-fold gap that isolates school chemistry, firstly from the everyday context of society, and secondly from state of the art chemistry, we need to revise the philosophical, pedagogical and substantive curriculum structure. The resulting structures should fit together again (see also Figure 3). In the following paragraphs, the outline for such a coherent redesign of philosophy, pedagogy and substantive structure is presented.

Philosophy of science (Phil)

In our daily lives, chemistry (or science in general) is one of the perspectives in viewing the world around us. Among other perspectives, such as the psychological perspective, the economic perspective and the political perspective; the chemical perspective offers a view on the materials and substances we use, that we are made of, and that constitute the material world we live in. A chemical perspective enables us to understand certain phenomena and may offer us possibilities to improve our circumstances. This philosophical part of the new structure bases on the view that the central starting point for learning chemistry must be human activity and society, in which chemistry and chemical knowledge may serve our daily lives, thereby making chemistry *meaningful* to everybody. Scientific development is thus interrelated with society: science can offer solutions to problems in society, scientific activity is part of our culture and new results of science may have ethical implications. This relationship with society makes science itself meaningful.

In a scientific discipline, knowledge is constructed through human activity. Scientific development takes place because scientists perform their work in communities of practice. Within and between groups working in a specific domain, results, conflicting ideas and theories are discussed; scientific knowledge is finally accepted on the basis of the emerging consensus between prominent groups of scientists. In science, novices learn, by participation in a scientific community, the expert's personal knowledge, intellectual passion, faith, trust, tacit understanding, and methodological rules embodied in scientific practices (Jacobs, 2000; Polanyi, 1958). Learners within such programmes become involved in (research) problems that are *meaningful* within the (research) programme, and therefore become meaningful for the learner.

Notions of these aspects, chemistry (science) as a perspective to deal with societal issues and chemistry (science) as a human activity, are of importance for secondary education. Scientific *facts* are generated by groups of humans, are subject to change and involve uncertainties. Chemistry education should emphasise that such scientific facts often are a basis in democratic decision-making.

Pedagogical design (Ped)

This philosophical starting point must be brought in agreement with relevant principles of the pedagogical design. Based on a social constructivist perspective on thinking and learning, we think students construct knowledge through their interactions with others and their interpretations of these interactions. Fundamental to this perspective are features of *active construction, situated cognition, community* and *discourse* (Anderson, Greeno, Reder, & Simon, 2000; Boekaerts & Simons, 1995; Rivet, Slinger, Schneider, Kraijick, & Marx, 2000). Through discourse, students should become familiarised with the common language of chemistry as a perspective on the world. The design of learning tasks must stimulate students to realise that they *need* this perspective. A new perspective on chemistry education should explicitly aim at putting students in a position where they themselves *want* to extend their conceptual network in a direction eventually leading to insightful scientific competence (Klaassen, 1994; 1995).

We prefer to express learning aims in terms of competencies, meaning: knowledge, skills and attitudes as one integrated set of abilities that are to be learnt in order to be able to do authentic tasks in a real world (De Vos & Pilot, in press; Pilot & Vos, 2000).

Substantive structure (Sub)

The scientific content of a new curriculum must be functional for learning a chemical perspective when dealing with societal issues: the core competencies (necessary basic = key chemical concepts, skills and attitudes) must be derived from representative *meaningful* themes and projects. This set of core competencies can be considered a *chemical toolbox*, and must be interrelated and connected to previous knowledge. The traditional content of the present chemistry curriculum, such as the structure of atoms, ionic theory, fundamental acid-base calculations, etc., not necessarily needs to be part of a new chemical toolbox. The knowledge to be attained by students must be easily accessible when needed in approaching complex social scientific problems. The relevance of applying these chemical key concepts to theme assignments is a starting point when choosing the scientific content of a curriculum.

Steps in the research design

Developing an entire curriculum out of a newly chosen vision involves several steps that are impossible to comprehend in one single pathway. The previous text has described the development of a new vision on chemistry education. The next step is to transform this vision into design criteria for an entire curriculum for A-level chemistry (students aged 16–18). Transformation of these criteria directly into a whole new set of curriculum materials would involve the design of a tremendous number of curriculum materials, with large investments in human resource and time. Therefore, these general criteria are firstly further transformed into a pedagogical design for a single representative exemplary module (the third step of Figure 4). The module design should be worked out in educational materials (fourth step, Figure 4), which will be experimentally tested in real classrooms with real teachers and students (fifth step). The attained learning results are evaluated and related to the intentions described as learning aims of the prototype (have students attained the competencies for this exemplary module as an example of the intention described in our vision?). A careful analysis of this exemplary module provides a basis for adjustment and sharpening of our vision on chemistry education (the *feedback* arrows at the bottom of Figure 4).

The prototype module must also make our vision on chemistry education communicable. A vision described in abstract terms (as is necessary in this stage of research) is difficult to comprehend. A prototype tested in a real classroom can then be used as an illustration of the vision .

Transformation from vision to design

The construction of an exemplary module takes place through developmental research (Gravemeijer, 1994). During the design process, continuous evaluation and revision lead to an improved module. Simultaneously, adjustment between criteria, design characteristics and the actual design must be achieved. Finally, a successfully developed module must meet the essential criteria.

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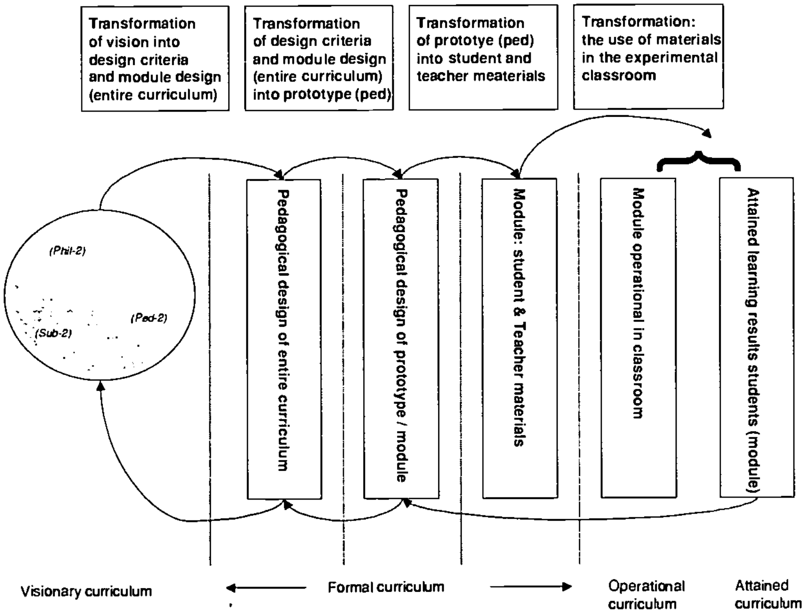

Figure 4. Transformations from a vision on chemistry education into design criteria for an entire curriculum, into an exemplary module, into students and teacher materials, into the operational form in a real classroom, into attained learning results of students. The arrows in the lower part of the figure represent evaluative feedback loops.

The following four questions are the guidelines during this stage of the research:

1. How can this vision lead to a solution for the problems of chemistry (science) education?
2. Is this vision effectively and correctly transformed into the design criteria described (are the criteria valid, precise and complete)?
3. Will the characteristics of the pedagogical design (see section *General characteristics of the module*) lead to a module within which the criteria can be achieved?
4. Is the subject-theme chosen for the prototype appropriate to make the module a representative example for the entire curriculum?

We expect that further development leads to a prototype that meets the most essential criteria, and is an example for a part of a chemistry curriculum with coherence between the philosophical, pedagogical and substantive structure.

Design Criteria

A new coherent vision, as intended and described above, needs to be translated into design criteria, both at a global level for an entire curriculum and at a more specific level for the exemplary prototype. The design criteria concern a large number of aspects. These aspects involve replacing the present curriculum, and implementing a complete new A-level curriculum. Since such a replacement deals with a wide variety of complex processes, it is impossible to define all necessary criteria in one single research project at this stage. In this project, we focus on the development of an exemplary prototype. The criteria most essential for this purpose must be selected.

For this reason, we have identified four categories of criteria that must be taken into account:

1. Learning aims: the competencies students must have attained after working with this module.
2. Learning processes: the desired learning processes in order to finally achieve the learning aims.
3. Situational conditions with regard to teachers and organisation.
4. Criteria necessary for a successful innovation process.

In the development of the prototype module our research focuses on categories 1, 2 and 3 (see overview in the tables 1 and 2). Through a learning process (2) students will achieve the learning aims (1). In the design process of this exemplary module, the emphasis is on the design criteria of the categories 1 and 2. Criteria in the category teachers & organisation (3) are considered as situational conditions here. All other factors (category 4) are considered beyond the scope of this project at the moment now. As for the criteria in category 1, the learning aims refer to the entire curriculum; the prototype module reflects these aims in as far as they are applicable within the module.

In category 1, criterion 1a refers to a match between mainly the philosophical and the pedagogical structure of the curriculum. The philosophical structure should emphasise that science is a human activity, and that science is closely interrelated with society. This aspect is therefore an important part of the pedagogical structure. Criterion 1b refers mainly to the substantive structure. The content of this part should serve criterion 1a, and so the substantive part becomes interrelated with the philosophical and pedagogical structure. In contrast to the present curriculum, in which content is mainly dictated by the academic discipline, here we want to define a content that is functional when dealing with the real world, as it is meaningful for students. Criterion 1c is the central part in which our vision on the philosophical, pedagogical and substantive structure of the curriculum come together.

The categories 1 and 2 are closely related: 2a is necessary for achieving 1a, 2b for achieving 1b, and 2c for 1c, although these interrelations will not be completely be one tot one. With 2c we hope to accomplish learning situations for students in which authentic real life situations are simulated, with teams working together on real (research) themes guided by a team leader (teacher). Both 1b and 1c reflect ideas about situated cognition with meaningful learning activities; *rote* learning is to be avoided.

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Table 1. Overview of design criteria: categories 1 and 2.

1. Learning Aims	2. Learning Process
1a: students have learnt that science is an integral part of our society; science is present in our daily lives; 1b*: students have learnt interrelated key concepts in a coherent cognitive structure connected with previous knowledge 1c*: students know how to apply basic key concepts in different complex social assignments (transferable, integrate C1a and C1b) * reasonable for A-level student (16-18)	2a: learning tasks are focused towards active participation in social practice related to community 2b: learning tasks are such that students gradually learn to build their own coherent cognitive body of knowledge of chemical key concepts closely interrelated and connected to previous knowledge 2c: learning tasks stimulate students (preferably in teams) to apply chemical key concepts in complex social assignments (integrate C2a and C2b) 2d: time investment is reasonable for students

Table 2. Overview of design criteria: categories 3 and 4.

3. Teacher & Organisation	4. Implementation process
3a: the required teacher competence to perform the teacher's task as intended in this module is within reasonable limits 3b: time investment is reasonable for teachers and technical assistants 3c: this science module is feasible within the facilities and organisation of a school environment	4a: the resulted design rules of such a module facilitate the design of new modules 4b: curriculum design by means of this route avoids the traditional rigidity 4c: curriculum design by means of this route makes a regular update of new (modern) theme subjects possible 4d: the module is recognisable and acceptable to teachers, assistants, school management 4e: this module design is suitable for teachers to actively participate in parts of the design in order to develop their required teaching competence

In category 3 the criteria for the development of a prototype are directed towards the situation the prototype is designed for. As has been mentioned the criteria in category 3 must be considered as situational conditions here. The criteria of category 4 will not be evaluated in this research project. As has been emphasised above, the first aim of the development of an exemplary prototype is to make our vision explicit. Real operational educational materials in this stage are a tool to sharpen our preliminary (abstract) criteria for the learning aims and the learning process. The prototype facilitates the communication about such a new vision. Although we do not evaluate the criteria in category 4, aspects of a successful implementation of new chemistry education should be obviously taken into account when transforming vision, design criteria, and characteristics of a module into an operational prototype.

Module Design and Prototype

When authentic tasks dealing with societal themes must become an essential part of the chemistry curriculum, students' activities should involve more than the traditional reception of instruction and making the (instruction-related) student-exercises. Not necessarily should these student-activities be entirely replaced by other activities. Part of the time, however, must be available for project work with a focus on the active participation in a societal theme, involving chemical knowledge, in order to come to acceptable decision-making. Applying chemical key concepts (2c) in a social assignment can be regarded as the central emphasis in the learning process of (groups of) students. This requires that students attain a coherent body of chemical knowledge (a *chemical toolbox*). Chemistry, deals with scientific concepts that are often counter-intuitive and difficult to attain. Therefore, we propose that, not all time should be devoted to thematic projects but part of the school curriculum should be reserved for systematic learning and instruction of the necessary chemical toolbox.

General characteristics of the module

A schematic representation of the characteristics of such a design that combines systematic instruction and project work is presented in Figure 5. This design is based on project-based curricula in Mechanical and Electrical Engineering courses for tertiary education both in Aalborg, Denmark, and at the University of Twente, The Netherlands (Kjersdam & Enemark, 1994; Peters & Powell, 1999). For secondary chemistry education, we propose our module to be part of the total school chemistry curriculum consisting of 3 to 6 module each year. A three-year A-level chemistry curriculum then consists of 9–12 modules, with the total time for one module approximately 6–12 weeks with 20–40 student hours.

Each module consists of three major parts:

I) the introduction to the theme of the module starting by posing a problem related to the theme of the module,
II) a part in which students systematically learn core competencies (chemical key concepts, skills and attitude),

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III) a part in which groups of students work together on assignments within the common theme.

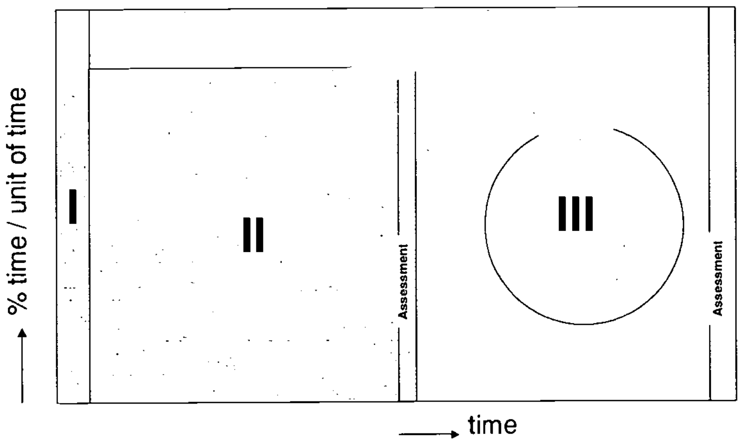

Figure 5. Schematic representation of a module according to the model (Kjersdam & Enemark, 1994). The horizontal line shows the time necessary for this module, the vertical line indicates the percentage of time in a unit of time.

At the end of part II, students' learning results are assessed individually, while assessment in part III is done through a group presentation of the project.

The design criteria 1a and 2a are related to part I of the module design, and the design criteria 1b and 2b to part II. In part III, the three criteria of category 1 and the first three criteria of category 2 must be translated into the planning of student activities. Design criterion 2d and the criteria of category 3 are constraints of the design.

In designing the prototype module, we start by selecting subjects for theme assignments. Necessary core competencies are to be derived (see arrow in Figure 5) from the selected subjects, subsequently followed by designing the required sequence of learning activities in part II. By means of this procedure we expect that the substantive structure can be constructed such that it serves the philosophical and pedagogical structure. We hope to avoid that the substantive structure again will be solely dictated by the academic discipline.

This subdivision of a module into three parts has the advantage that part II can be designed such that it is recognisable as *common* chemistry education to teachers, assistants, school managers and parents. We hope that a part more or less comparable to the present situation will facilitate successful implementation in a later stage.

The prototype and its theme

This prototype module is situated at the start of the A-level curriculum (students aged 16). Apart from practical reasons (the exams are still far away, and the students have not been used to any particular approach to chemistry teaching, which makes innovative experiments more acceptable), we think it is only logical to take this module as the core of what we consider to be *meaningful chemistry education*.

The theme selected for this prototype is *water quality*, mainly because it has proven to be a *rich* theme: it includes many topics that could provide a basis for projects. It is also a theme that potentially could bridge the gap between chemistry and students' experiences. Furthermore, quite a number of internationally well-known chemistry curricula have been developed with *water* as their major theme (for example: (Balaco et al., 1988; Rivet et al., 2000). Experimental research data from these projects can be used as input into our design. Finally, the chemistry of water quality involves basic topics that are suitable to start with, such as: mixture types, concentration, qualitative and quantitative analysis of water mixtures, separation techniques, sampling etc.

In the following paragraphs, the three major parts of the prototype design are presented as a case study with water quality as its main theme. We start by describing part III (projects), because from this part core competencies (part II) are to be derived. Finally, we will give a brief description of the introductory part of the prototype (part I).

Part III

Theme projects may evolve from the question: 'What is considered to be good water quality?' This central question implies sub-questions such as: 'What is the water used for, what are personal (students) needs and requirements for this application? What are the legal specifications? On the basis of what *scientific facts* does the process of legal decision making take place? How do we measure quality, and by whom is it measured? How do we control quality?' These are questions that can only partly be answered by applying science (chemistry); social, political, economic as well as personal considerations also play important roles. Projects can involve investigations into quality of drinking water, tap water, bottled water or the quality of creek water for the ecosystem or for swimming. Effects of contamination on a system may also be included in such chemistry projects.

When students work on such projects, certain learning activities are required that go beyond the learner's capabilities. Therefore, in the design of the theme assignments, certain scaffolds, used in the operational curriculum and facilitating transfer of chemical competences in one situation to another, are necessary (Rivet et al., 2000; Schunk, 2000).

Part II

The derived core competencies concern aspects of health and safety, dose-effect relationship, concentration both qualitative and quantitative, characteristics of

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suspensions and solutions, separation of contaminants, minerals essential to life, chain management: from raw material to product, waste and on to recycling, techniques for analysis, aspects of calibration interpolation and extrapolation, taking representative samples, experimental errors, making contaminants visible by reagentia, and detection limits of techniques. Students must learn these concepts and skills in a cognitively logical sequence, and student activities should be so designed that meaningful and feasible learning processes take place (Boekaerts & Simons, 1995).

Part I

Part I legitimates part II and part III not only from the perspective of the students but also from a social, philosophical, and scientific point of view. This activity must activate previous knowledge. Essential in the design is the integration of the parts I, II and III. Learning aids, hints ensuring the active use of core competencies help induce the desired action of the part of students, teachers and assistants.

Conclusion

A draft description of a new vision on chemistry education has been worked out using the subdivision into three structures of the curriculum: the *philosophical*, the *pedagogical* and the *substantive* structure. In this stage of our research a new possible vision has been transformed into preliminary design criteria for an entire curriculum, and the characteristics of the modules the curriculum should consist of. Subsequently a selection has been made for the exemplary module to be developed as a prototype, and first ideas concerning a possible educational theme, water quality, have been described.

In discussions at the ICASE symposium, there was a general concern that an innovation as intended is quite ambitious; it seems an enormously difficult task to realise. Moreover, participants commented that the preliminary criteria and the design characteristics are difficult to comprehend and to judge in this abstract form. These two main aspects of the discussion support the choice we made to design an exemplary module in order to:

1. Explore the possibilities and constraints on a small scale when working with a new vision in real practice, before large investments are made for an entire curriculum.
2. Enable discussion about the new vision, with the prototype as a practical example of this vision.

The cyclic design process (developmental research) of our prototype must lead to a qualitatively acceptable module, by which students learn key competencies as intended. After having achieved this kind of result, generalisation of our knowledge to other modules and to the entire curriculum will induce a new cyclic process in order to improve the description of learning goals more specifically and the vision on chemistry education in general. By means of this procedure we hope to contribute to supporting and stimulating the process of redesigning the A-level chemistry curriculum in the Netherlands, and possibly in other countries.

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Mathematical and scientific literacy in PISA: The OECD programme for international student assessment

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Mathematical literacy is an individual's capacity to identify and to understand the role that mathematics plays in the world, to make well-founded mathematical judgements and to engage in mathematics, in ways that meet the needs of that individual's current and future life as a constructive, concerned and reflective citizen.

Scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity.

These are two PISA definitions of domains of knowledge and skills, which students are supposed to acquire at some stage, but clearly go beyond the traditional school subjects. The challenge of PISA is to assess to what extent students are *literate* in these domains; to what extent they have mastered some of the skills that are essential for modern citizenship and are associated with maths and science. Obviously this is not about solving quadratic equations or calculation of the molarity of the pH of a sulphuric acid solution. The goal of the present paper is to clarify the ideas behind the PISA interpretation of literacy in science and maths by briefly introducing the frameworks on which the assessment instruments have been built, and giving examples of assessment tasks.

The PISA Maths and Science Challenge

The PISA Maths and Science Challenge – defining these literacies and turning these definitions into tests – is a multiple one. While the concept of reading literacy has been well-established over time and is supported by a consistent and tested theory, mathematical and scientific literacy have been recognized in the sense that some skills belonging to these subject domains are important for all adults, not just for scientists. However, there is not such a thing as generally accepted frameworks for these literacy's, let alone a description of levels. The task of developing assessment instruments for assessing the achievement of students in over thirty countries in these domains raises a wide range of problems. Obviously, the first one to cope with is answering the question: what do maths and science literacy consist of, what kind

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of skills, what kind of knowledge, or in other words: what should be the dimensions of the framework underlying the assessment instruments? The next question would be: in a given framework, what kind of levels of mastery will we distinguish? And then the key question for any test developer: how to operationalize these specifications into assessment items. And how to take into account the conditions that are set by the international nature of the project such as the requirement of the tests being void of any cultural bias.

Since the start of the project, in March 1998, a number of maths and science experts and test developers have been working jointly on these problems. The definitions given above, domain descriptions and a set of field-tested assessment instruments have come out of these efforts. The domain descriptions, elucidated by sample items, were presented in two OECD publications (Measuring Student Knowledge and Skills, A New Framework for Assessment, OECD, 1999, and Measuring Student Knowledge and Skills, The PISA 2000 Assessment of Reading, Mathematical and Scientific Literacy, available on the OECD-PISA website: www.pisa.oecd.org).

This present paper will be dealing with the framework dimensions and the process of constructing assessment instruments, mainly drawing upon the experience in the field of science.

The Dimensions of Mathematical and Scientific Literacy

In the PISA definition, both for maths and science, the term *literacy* is used to indicate the ability to put knowledge and skills to functional use, rather than just to master it within the school curriculum as is done in the traditional item on concentration in Figure 1. *Functional* does not only mean simple mechanical operations, such as working out how much change to give someone in a shop, or calculate how much water is needed to dilute waste water to meet legal requirements, just as in the second concentration item in Figure 1.

It also implies wider uses, including taking positions towards and appreciating things, like in the case of Mr. Green (third item in Figure 1), and to think scientifically about evidence one may encounter, for instance about the effect of eating only chocolate on one's health (see sample questions in the Appendix).

The dimensions of the domains of scientific and mathematical literacy should reflect this broad and functional approach. Basically, both domains are characterized by three dimensions:

1. Processes or skills
2. Concepts and content
3. Context

The processes or skills dimension

The PISA mathematical literacy processes focus on students' abilities to analyse, reason and communicate ideas effectively by posing, formulating and solving

Traditional; tests performing of an algorithm in academic context

You have 2,5 litres of a solution of compound A in water.
The concentration of A is equal to 30 mg.l^{-1}
You want to decrease the concentration of A to 5 mg.l^{-1} by diluting this solution.

- How much water should you add?

Same, daily life context

Each day, Super Picture, a photo film processing plant, discharges 1500 litres of waste water into the river Rhine. This waste water contains 30 mg.l^{-1} of toxic compound A. The law only admits 5 mg.l^{-1} of A. Super Picture wants to comply with legal requirements by diluting the waste water before discharging it.

- How much water should they add to the waste water each day?

Tests using source and previous knowledge for decision-making

A News Report

Frightening Fish Chase Super Film

Serious commotion arose during yesterday's meeting of the Regional Water Board when Frightening Fish, a local group for conservation of river life, accused Super Picture of seriously misleading the public. Super Film, a photo film processing plant, had just proudly announced that the level of toxic compounds in their waste water discharges into the Rhine were now well below the legal maximum. But Frightening Fish's representative Mr. Green argued that Super Picture had merely achieved this by diluting their waste water with fresh river water before discharging it. "In this way, they may well comply with legal requirements, but....."

- Complete Mr. Green's argument.

Figure 1. Three different ways of assessing the concept of concentration.

mathematical problems. Processes are divided into three classes: reproduction, definitions and computations; connections and integration for problem solving; and mathematization, mathematical thinking and generalizations. In general, these processes are in ascending order of difficulty.

PISA tasks are designed to encompass a set of general mathematical processes such as mathematical thinking and argumentation, modelling, handling symbols and formalisms, etc., but no test items are used that assess these skills individually. When doing 'real mathematics', it is necessary to draw simultaneously upon many of these skills.

The scientific processes in the PISA framework emphasize the ability to use scientific knowledge and to know about science. Students should be equipped with understanding the nature of science, of its procedures, of its strengths and limitations and of the kinds of questions that it can, and cannot answer. Students should be able to recognize the type of evidence required in a scientific investigation and the extent to which reliable conclusions can be drawn from evidence. It is considered to be important for students to be able to communicate their understanding and arguments effectively to particular audiences, for otherwise they will have no voice in the matters that are debated in society. These arguments have led to the identification of the scientific processes given in Table 1.

Scientific literacy	
Process	*Includes*
1. Recognizing scientifically investigable questions	• Questions that science can attempt to answer • Which question is tested here?
2. Identifying evidence needed in a scientific investigation	• Identifying or proposing evidence that is required to answer a question or the procedure needed to gather it
3. Drawing or evaluating conclusions	• Relating conclusions to evidence • Which conclusion is consistent with the given evidence?
4. Communicating valid conclusions	• Expressing to a given audience the conclusions that can be drawn from available evidence
5. Demonstrating understanding of scientific concepts	• Showing understanding by applying concepts in situations different from those in which they were learned • Recall of knowledge, showing its relevance, using it in making predictions or giving explanations

Table 1. Scientific processes and scientific literacy

The concepts and content dimension

School mathematics curricula are usually organized in strands, such as geometry, algebra and calculus. These strands do not, however, reflect the complex patterns in the world around us. For this and other reasons, PISA took a different approach and organized content around cross-cutting mathematical themes, referred to as big ideas: change and growth; space and shape; quantitative reasoning; uncertainty; and dependency and relationships. In PISA 2000, only the first two are represented.

The scientific concepts selected in PISA are expressed as broad integrating ideas that help to explain aspects of our material environment. The PISA framework does not attempt to identify all concepts that would meet that criterion. Instead concepts are sampled from a list of main themes, such as structure and properties of matter; forces and movement; physiological change; and the earth and its place in the universe. More important, though, is the application of processes and concepts in relation to problems and issues in the real world. The areas of application of science have been grouped under three broad headings:

1. Science in life and health
2. Science in earth and environment
3. Science in technology

The contexts dimension

Whatever process and whatever content is tested, every test item should create a real life situation, challenging students to bring in their mathematical or scientific knowledge to understand a situation, solve relevant problems, develop a standpoint and communicate findings and opinions.

Sample Questions

The descriptions of the framework dimensions may leave some questions on the essence of the PISA approach unanswered. From these, it may be difficult to visualize the way maths and science skills are contributing to students' 'preparedness to modern life and responsible citizenship'. As usual, such descriptions only become alive when illustrated by specimen tasks. And also the thought: 'First there was The framework, then came the questions' is not true to the facts. Framework and questions were developed together in an iterative process.

The two questions below (see Figure 2 and 3) may serve to get an idea of assessment of the maths competency 'connections and integration for problem solving' and of the maths items in general.

Pizza's

A pizzeria serves to round pizzas of the same thickness in different sizes. The smaller one has a diameter of 30 cm and costs 30 zeds. The larger one has a diameter of 40 cm and costs 40 zeds.

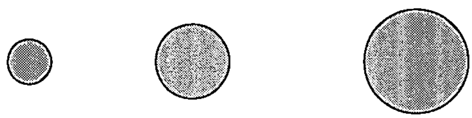
- Which pizza is better value for money? Show your reasoning.

Figure 2. The Pizza *question*

The Pizza question addresses the two big ideas change and growth and/or space and shape, depending on the way the problem is solved by the student. The next question, about coins, is thought to address change and growth only, and is an example of an *occupational situation.*

Coins

You are asked to design a new set of coins. All coins will be circular and coloured silver, but of different diameters.
Researchers have found that an ideal coin system meets the following requirements:



1. Diameters of coins should not be smaller than 15 mm and not be larger than 45 mm
2. Given a coin, the diameter of the next coin must be 30 % larger
3. The minting machinery can only produce coins with diameters of a whole number of millimetres (e.g. 17 mm is allowed, 17.3 is not)

- Design a set of coins that satisfy the above requirements. You should start with a 15 mm coin and your set should contain as many coins as possible.

Figure 3. The Coins *question*

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Chocolate for dessert

The presentation ends with a discussion of the science unit on chocolate (see Appendix). This unit has several questions bearing on the understanding of a healthy diet and knowledge of the different kinds of food that are needed. The unit is presented in one of its first versions. That version included two questions (1 and 2) assessing knowledge and understanding of the role of molecules in smelling, and the heat effect of melting. Question 1 was deleted because doubt was raised about a 'nice smell' being a characteristic of chocolate. Some students even find chocolate a rather odourless substance; a 'question that science can answer', and that was answered empirically at the presentation.

The chocolate unit illustrates more interesting issues in the process of PISA item development, such as the discussion of communication items, like question 7 in this unit.

And question 5 for instance, which was seen as one that represents a core issue in assessment of science literacy: the ability to use one's science skills to distinguish between facts and fiction. After the field test, however, it became clear that the question, relevant as it might be, was far beyond the ability of the target population.

But it was for other reasons that the unit started its life as an illustrative set of items rather than becoming part of the main study. One of the measures that was taken to avoid any offensive, culturally biased or otherwise inappropriate material in the main study was a cultural review by a panel of experts. An international study as PISA may be severely invalidated when after the administration items are criticized for such reasons. Therefore, when some panel members felt that the Daily Mail article might invite weight-conscious young girls to go on a chocolate diet, the only decision that could be taken was to withdraw the unit from the stock. The fact that many questions were inviting students to engage in reasoning proving the contrary did not help. After all, students who are scientifically illiterate may read, but not reason.

Concluding remarks

PISA is making an effort to assess the competency of students to solve real life problems, using math and science concepts. In co-operation with an international team of renowned math and science specialist, the consortium that is implementing the project, of which CITO is one of the partners, has specified the dimensions of these competencies in a framework. Of course, the proof of the pudding is the items that show what is really expected from students. The paper makes clear that only from these a full picture emerges of what we understand by mathematical and scientific literacy, and the extent that we expect students to address this competency in functioning as responsible citizens. The iterative process in which the frameworks are being refined on the basis of further item development, students' responses and experts' comments will be continued in next cycles (2000–2003 and 2003–2006) of the PISA project.

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Appendix: The chocolate unit

NB: This is an old version and is used here for discussion purposes only. Some items have been included in the PISA illustrative items, published by OECD

Question 1

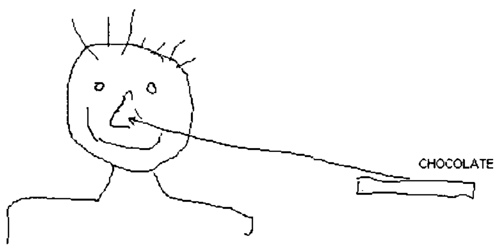
Read the text and answer the questions.

Chocolate

Chocolate has a number of characteristics which make that people enjoy it very much. It is both sweet and fatty, and mankind probably has an inborn preference for these ingredients. Chocolate gives a very pleasant cool feeling in the mouth, because it melts just below body temperature. That cool feeling is caused by melting of the chocolate in the mouth. Moreover chocolate smells very nice as well. No wonder it is a favourite treat.

Source: Psychologie, April, 1992

In the text above it is stated that one of the characteristics of chocolate is its nice smell. A child illustrated how the nice smell reaches your nose from the chocolate.



Which of the following words fits to the arrow in the drawing?

A. Radiation
B. Molecules
C. Light waves
D. Electrical impulses

Question intent

Process: Demonstrating knowledge and understanding
Theme: Chemical/Physical changes
Area: Life and health

Scoring

1: Answer B.Molecules
0: Other responses

Question 2

The text above says that chocolate produces a cool feeling in the mouth. It claims that the cool feeling is caused by melting of the chocolate in the mouth just below body temperature. How could this cool feeling be explained?

A. As the chocolate melts the temperature of the chocolate will decrease.
B. To melt chocolate heat is needed and that heat is taken from the mouth.
C. As the chocolate melts heat is released and therefore the mouth temperature will decrease.
D. Melting chocolate makes your mouth water and the saliva produced causes a temperature decrease in the mouth.

Question intent

Process: Demonstrating knowledge and understanding
Theme: Chemical/Physical changes
Area: Life and health

Scoring

1: Answer B. To melt chocolate heat is needed and that heat is taken from the mouth
0: Other responses

Question 3

Read the text and answer the questions which follow.

The girl who stays slim by eating only chocolate

Daily Mail Reporter

A student has confounded diet experts by eating 90 bars of chocolate a week to stay slim. Jessica Coveney, 22, claims eating the sweet snacks and cutting out all other food is the only way to maintain her size 10 figure.

As nutritionists yesterday warned of the potentially harmful effects of her chocolate-only diet, Miss Coveney insisted she had never felt healthier. She allows herself one proper meal every five days, despite attempts by her live-in boyfriend Ben Greer – who works as a chef – to re-educate her palate. Miss Coveney, who is studying in Bristol, said yesterday: 'I've got no intention of changing my diet. It's paradise. My doctor says I'm in perfect health, so why bother?'

She told how she started eating chocolate as a comfort after going on a crash diet at the age of 16, when she weighed more than 60 kg.

Amazingly, she dropped to 50 kg and, as her craving intensified, took a part-time job in a sweet shop – where she was paid in chocolate. She said: 'I promised to ration myself to two bars a day, but soon I was on my fourth by 11am.'

Winnie Chan, of the British Nutrition Foundation, said: 'I am surprised someone can live with a diet like this. Fats give her the energy to live but she is not getting a balanced diet. There are some minerals and nutrients in chocolate, but she is not getting nearly enough vitamins. She could encounter serious health problems in later life.'

Mr Greer's efforts to interest his girlfriend in a balanced diet appear doomed – he now eats eight bars a day himself.

Source: *Daily Mail*, March 30, 1998

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A book with nutritional values gives the following data about chocolate. Assume that all these data are applicable to the type of chocolate Jessica Coveney is eating all the time.

Nutritional content of 100 g chocolate

Proteins	Fats	Carbohy-drates	Minerals		Vitamins			Total energy
			Calcium	Iron	A	B	C	
5 g	32 g	51 g	50 mg	4 mg	-	0.20 mg	-	2142 kJ

According to the table 100 grams of chocolate contain 32 grams of fat and give 2142 kJ of energy. Line 35 of the article says: 'Fats give her the energy to live...'.

When eating 100 grams of chocolate, does all her energy (2142 kJ) come from the 32 grams of fat? Explain your answer using data from the table.

....

....

....

Question intent

Process: Identifying evidence/data
Theme: Energy transformations
Area: Life and health

Scoring

2: Answer 'no' and explains that some energy comes from carbohydrates or proteins or carbohydrates + proteins
1: Answer 'no' and explains that some energy comes from carbohydrates or proteins or carbohydrates + proteins and also from vitamins or minerals
0: Answer 'yes' or
answer 'no',
- without any explanation,
- with the explanation that (only) minerals will contribute to the energy as well,
- with the explanation that other components of chocolate (without mentioning them) will contribute as well.

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Question 4

The table below shows the amounts of nutrients and kilojoules which are recommended per day for a normally active woman.

r o w	Age	Weight	Pro-teins	Fats	Carbo-hy-drates	Minerals		Vitamins			Total energy
						Cal-cium	Iron	A	B	C	
1	16-19 years	50 kg	60 g	85 g	320 g	0.9 g	15 mg	0.45 mg	2.5 mg	50 mg	9180 kJ
2	16-19 years	60 kg	60 g	90 g	350 g	1.0 g	15 mg	0.45 mg	2.5 mg	75 mg	9660 kJ
3	20-35 years	50 kg	60 g	80 g	300 g	0.7 g	12 mg	0.45 mg	2.3 mg	40 mg	8990 kJ
4	20-35 years	60 kg	60 g	85 g	330 g	0.8 g	12 mg	0.45 mg	2.4 mg	50 mg	9240 kJ

The table above contains four rows with data (rows 1, 2, 3 and 4). Which of these rows applied to Jessica Coveney when the article was published?

A. Row 1.
B. Row 2.
C. Row 3.
D. Row 4.

Question intent

Reflecting upon the content of a text
Connecting information from two sources.

Scoring

1: Row 3
0: Other

Question 5

Lines 1–3 of the article say that Jessica has a diet of 90 bars of chocolate a week. Assume that the bars of chocolate she eats have a weight of 100 grams each. From the data in the tables 1 and 2 you can calculate that it is hard to believe that Jessica stays slim with her diet.

Show this with the help of a calculation.

....

....

Question intent

Process: Identifying evidence/data
Theme: Energy transformations
Area: Life and health

Scoring

3: Answer $\frac{90}{7} * 32 = 411\text{g}$ fats per day, followed by the conclusion that the outcome is far more than the recommended amount

A correct computation can also be one of the following ones:

- $\frac{90}{7} * 51 = 656$ g carbohydrates
- $\frac{90}{7} * (32+51) = 1067$ g fats + carbohydrates
- $\frac{90}{7} * 2142 = 27540$ kJ

The calculation has three aspects:
- 90 multiply by 32 (g) or 51 (g) or (32 + 51 g) or 2142 (kJ)
- divide by 7;
- conclusion that the outcome is far more than the recommended amount

Scoring

2: Answer with only two of the three aspects
1: Answer with only one of the three aspects
0: Answer with none of the three aspects

Question 6

Line 39 says that Jessica '...is not getting nearly enough vitamins'. One of those vitamins missing in chocolate is vitamin C. Perhaps she could compensate for her shortage of vitamin C by including a food that contains a high percentage of vitamin C in her 'proper meal every five days' (lines 12 and 13).

Here is a list of types of food.
1 Fish
2 Fruit
3 Rice
4 Vegetables

Which two types of food from this list would you recommend to Jessica in order to give her a chance to compensate for her vitamin C shortage?
A. 1 and 2
B. 1 and 3

C. 1 and 4
D. 2 and 3
E. 2 and 4
F. 3 and 4

Question intent

Process: Demonstrating knowledge and understanding
Theme: Physiological change
Area: Life and health

Scoring

1: Answer F. 2 and 4
0: Other responses

Question 7

Jessica read the article in the Daily Mail about herself. She got annoyed about the statements of Winnie Chan of the British Nutrition foundation (lines 33–41). Jessica decides to write a letter to Mrs. Chan in which she explains that she meets her vitamin need through carefully worked-out meals every five days.

Mrs. Chan writes back. She starts her reply as follows:

> *Dear Miss Coveney,*
>
> *Thank you for the letter you sent me. I am pleased to have the opportunity to discuss your eating habits. However, my opinion about your future health hasn't changed. Despite your carefully worked-out meals every five days you could face serious problems in future. Everyone can get a health problem in future but, generally speaking, people with your eating habits have a higher chance of getting one. Such a possible health problem is* ....

Finish this letter by naming one serious health problem that Jessica may encounter in later life due to her current chocolate diet and its cause. Try to use no more than about 30 words.

....

....

....

Question intent

Process: Communicating
Theme: Physiological change
Area: Life and health

Scoring

3: Mentions one of the following health problems with a cause, in clear language and full sentences in not more than 40 words:
   - heart/vascular diseases, because of the intake of too much fat
   - cancer, because the intake of vitamins/fruits/vegetable is too irregular (at the end of the period of five days there is lack of vitamins)
   - digestion problems, because of the absence of sufficient fibres in the food

2: Mentions one of the health problems mentioned above, in clear language and full sentences in not more than 40 words, but without a correct cause

1: Mentions one of the health problems mentioned above, without a correct cause and doesn't use clear language or full sentences or uses more than 40 words

0: Doesn't give a correct health problem and a cause for it (language, full sentences and number of words don't matter)

Making a place for newspapers in secondary science education

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Increasingly reports in the press and broadcast media either relate to science issues or claim credibility based on 'scientific evidence'. This information influences opinions about many aspects of life in our society. Accessing science reported in the press as an integral part of science lessons can heighten pupils' awareness of the subject in the world around them. It can also encourage them to consider the issues that may influence the presentation of science in the media, so promoting critical evaluation. We did a survey of secondary schools to explore the current use of the media in science and illustrate the diversity of classroom practice in Northern Ireland. The survey indicates the widespread use of newspapers within the science classroom. Data reveals wide variations in the level and type of activity. There are, however, few examples of newspapers used to develop evaluation skills. The study identifies a number of obstacles that may hinder further developments in the use of newspapers in school science. Among these are the low levels of confidence amongst teachers faced with the more challenging aspects of using media reported science, and the absence of references to these skills in examination syllabuses and schemes of assessment. We argue that the development of skills associated with evaluation and interpretation poses a challenge that requires the extension of existing expertise and a vision which extends beyond existing links between schools subjects to forge new alliances.

Introduction: using print media in the science classroom

A trainee teacher in a secondary school in Dungannon, forty miles from Belfast, is working with a class of thirteen-year-old children. For the last few weeks, they have been learning about 'energy'. Her intentions for this lesson, however, are different. She aims to raise her students' awareness of how science-related newspaper articles come to be written.

The trainee teacher introduces the session by reading a newspaper article *Wind Power Raises a Gale of Protest* with the class. She questions the students:

> Why do you think this article was included in the newspaper?
> Why does it make a good story?
> Who was involved in getting the article into the paper?

O. de Jong, E.R. Savelsbergh and A. Alblas (eds.) Teaching for Scientific Literacy, 55-70
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During the discussion, the young people propose a number of people who may have contributed to the news story—the newspaper editor, journalists, scientists, engineers, environmentalists and local residents. The teacher then distributes the script for a short play based, very loosely, on how the article may have been composed. There is a cast of five – Bob, Sarah, Jenny, Joe and Mabel – but no direct indication of the characters' roles. The young people act out the play. An element of humour in the script adds to their enjoyment. They are then challenged to identify the editor, the journalist, the scientist and the readers to discuss the various influences on each. A homework assignment extends the activity by casting each student in the role of reporter pursuing a science-related story. They leave the class talking excitedly about the possibilities. While most prepare short written articles, several produce entertaining and imaginative audiotapes of 'interviews'. One presents a video news report complete with outside broadcast! Evaluating the lesson, the trainee teacher concludes:

> I was very pleased with the pupil response. [The students] seemed to appreciate that everyone had different agendas. They also learned a lot about wind energy. They began to understand that these issues are not black and white but many shades of grey.

An experienced teacher in another school, ten miles to the North of Belfast, is working with a group of 15 year-olds who are studying rural science. She has ordered, on a weekly basis, a farming newspaper for the class. Month by month, the students prepare displays using material from the publication and these *action calendars* are read with interest by other children. It is the case that the articles in the paper relate closely to the course under study. The teacher, however, takes the matter further. In class, the young people discuss how the stories are written and how the newspaper is put together. Links are developed with personnel from the press office. Evaluating the project, the teacher concludes:

> The pupils responded well, extremely well. It was different. The pupils were aware 'This is a real newspaper in front of us'. It created an atmosphere.

These two teachers are addressing an instructional aim which is increasingly being considered important by those from every continent who are striving to design science courses which meet the needs of young people in the twenty-first century. In the United Kingdom, for example, writers of the influential report *Beyond 2000: Science Education* (Millar & Osborne, 1998) suggest that the curriculum should help young people 'be able to understand, and respond critically to, media reports of issues with a science component'. There is a strong case for this proposal. More and more, information presented in the print and broadcast media relates to science issues or claims credibility based on 'scientific evidence'. This influences the opinions we form and the decisions we make in respect of many aspects of life in our society. An appropriate response would seem to be an education in science that provides students with the skills to carefully examine and judge the evidence reported in this way.

To date, relatively few studies have been done on the extent to which and the manner in which teachers prepare their students to *read* media science. Researchers at Queen's University in Belfast, however, have recently conducted two investigations into this issue. The first was a small-scale study of a group of trainee teachers (the Use the News group!) who had attended a workshop dealing with science in the media. Subsequently, they reported on the classroom-based activities which they developed and undertook with their students. The second was a large-scale survey, covering 20% of secondary schools in Northern Ireland, of the use of newspapers in the science classroom. These studies have been reported at length elsewhere (Jarman & McClune, 2000; McClune & Jarman, 2000). In this paper, the survey will be described in sufficient detail to contextualize the conclusions which have been drawn as to how, if this is our intention, teachers could be helped to promote the critical appreciation of media science, and particularly newspaper science, among their students.

A diversity of practice

A survey of secondary schools in Northern Ireland indicates the widespread use of print media within the science classroom. Of the teachers interviewed, 92% reported that they made use of newspapers in the context of science education. Of these, 78% did so as part of their teaching, the remaining 14% used them exclusively for display. At first sight, these figures suggest a high level of interest, among teachers, in the use of newspaper in the secondary science classroom. However, a key finding of this study was the degree of diversity in respect of pattern, purpose and manner of use of this resource.

Patterns of use

In seeking to understand the wide range of patterns and levels of use of newspapers among science teachers, some form of classification was clearly useful. The data set was analysed in order to identify a meaningful basis for assigning teachers to categories. The resulting categories are presented in Table 1.

Category of use as a teaching resource	Number of Teachers	Percentage of Teachers
Proactive systematic	11	22.0
Reactive systematic	6	12.0
Incidental	22	44.0
Non-user as teaching resource (though may use for display)	11	22.0

*Table 1. Categories of teacher-users, based on the survey (*N *= 50).*

In this survey, it was found that science teachers could be assigned, relatively straightforwardly, to one of three categories. The first category comprised those who used newspapers as a teaching resource in a systematic fashion, year on year. Thus, for example, specific material relating to a particular topic might be incorporated into teaching notes, or otherwise archived, and then employed every time that topic was taught. This category was further subdivided into proactive systematic users and reactive systematic users. The former reported that they actively sought out newspaper articles to use in their teaching; the later merely ‘came across’ articles, but subsequently assimilated them into their programme. Proactive systematic users, though all deliberate in their intention to avail of print media, nonetheless represented a range of practice from those instigating substantial newspaper-related projects to those incorporating reference to one article in their teaching of one topic.

Reactive systematic users, on the other hand, offered responses typified by the following.

> There was an article on Power Stations in Northern Ireland. This is directly on the course. I turned the text and graphic into an overhead [transparency]. Now I put it up and talk about it. If I happen to spot something I can use I will. I don't go looking for it though. If I was not a newspaper reader I would not come across this at all.

Overall, only one third of science teachers in the survey were considered to use newspapers systematically as a teaching resource.

The second category of teacher-users comprised those who used newspapers in an incidental fashion. Thus, for example, they 'came across' and turned to account an article related to a topic they had taught, were teaching or were about to teach. However, no subsequent attempt was made to incorporate the material or the media approach systematically into their science programme.

> I used one about UV sunbeds once—'Death Rays'. I happened to be doing the EM spectrum with Form 3. It was the title of the article that attracted me. I used it within that lesson, just as an example.

As can be seen from Table 1, more teachers fell into this category than any other, with almost 44% of teachers being considered to be incidental, essentially opportunistic, users of newspapers.

Finally, there were eleven teachers who did not use newspapers directly as a teaching resource, though seven did use them in display. References were made to classroom noticeboards and exhibits in corridors or other public places within the school. Some were large scale, involving students' work, while others were more modest examples of a picture or graphic which had caught the teachers' attention. Some displays had relevance to a particular group of students and others were offered for general interest.

These categories proved useful in the analysis of the data gathered in the survey and they are commended for consideration by others interested in teachers' use of print media in the science classroom. It should be noted, however, that they were established post-hoc and teachers designations were inferred from detailed fieldnotes made during interviews. In future studies there would be value in including questions specifically related to issues of proactivity and systematization.

Purpose of use

The survey of secondary schools in Northern Ireland also revealed that science teachers saw the use of newspapers as a route to achieving a number of different aims. In a key question in the study, those involved were asked to indicate their intentions in using print media in each instance of practice. An overview of common answers is presented in Table 2. It is not surprising that, given the wide variety of ways of using newspapers, teachers would express their aims in widely different terms. Also they rarely identified only one aim which would adequately describe their intentions. Nevertheless, it was possible to distil from the range of responses, three broad categories in which to group the intentions of a large proportion of teachers.

Declared intention	Percentage of users expressing this intention	Derived aim
To illustrate links with everyday life	76.1	To demonstrate the relevance of science
To relate science to local issues	10.9	
To promote an interest in science	32.6	To develop an interest in school science
To 'reinforce' school science	13.0	
To exploit photographs and graphics for display	28.3	To display contemporary science
To present up to date information	23.9	

*Table 2. The most common aims for using newspapers in the science classroom, based on those teachers who reported any form of newspapers usage (*N = *46).*

The great majority of teachers in Northern Ireland who use newspapers do so with the aim of demonstrating that science is applicable and relevant to the everyday lives of their students. It was their view that articles and reports which connected with young peoples' experience of, for example, the solar eclipse or the use of mobile phones, (two issues making the news at the time of the survey) increased their perceptions of the relevance of the subject they were studying. Furthermore, the regional and community press were seen as sources of examples which allowed teachers to set science topics in local contexts. This was particularly so in respect of environmental issues and concerns. In all, it was argued that this approach increases both the interest and the impact of their teaching.

> [I use newspapers] to link science with everyday life. They're forever saying 'I don't need to learn this' and it shows them the relevance of science, the link between science in the classroom and science in the world outside.

> I use newspapers for their local impact. Farmers they know are fined for washing out their slurry tanks into the rivers. It gets pupils to think about their environment. If we're talking money, they'll sit up and notice.

Many teachers see science printed in the media as an opportunity to enrich and in some way reinforce the work done in science class. Most simply relate that it adds a dimension of interest to school science. Some, however, seem to suggest that science presented in the press has an authority and authenticity which derives from it being seen as worthy to report in the real world. Teachers surmise that as a consequence of reading about science in the press, their students' interest in and regard for school science may be enhanced. In addition, they may in some way accept and internalize scientific ideas or issues.

> [I use newspapers] to reinforce the things I teach. There it is in black and white, scripted on the page.

> [I use newspapers] to reinforce the science I am teaching. Children tend to believe what they see in newspapers.

Science in newspapers is presented so as to catch the reader's attention and get the key message across as effectively as possible. In setting out to explain sometimes complex ideas, the journalist will often turn to pictures or graphics to support or replace the written word. Some teachers have identified these graphics and up to date images as a valuable resource to exploit. Newspapers were also reported to up-date in another sense. They were acknowledged to be a source of information for teachers themselves, keeping them abreast of developments at the cutting edge of science and also, interestingly, providing them with anecdotes to add colour and, at times, spice, to their teaching.

... the message in the gaps

It is contended that one of the most important findings of the Northern Ireland survey relates, not to those aims to which the science teachers referred, but to those aims to which, typically, they did not refer. Large numbers of teachers adopted aims for the use of newspapers in their classrooms which relate to the relevance of science, the enriching of science and the display of current issues and ideas in science. In contrast, very few embraced opportunities to use newspapers to develop skills associated with the critical reading of media science or with lifelong learning in science (Table 3).

Declared intention	Percentage of users expressing this intention	Derived aim
To promote critical evaluation	4.3	To promote the critical reading of media science
To encourage students to be well informed	4.3	To promote lifelong learning (?)

*Table 3. Minority aims for using newspapers in the science classroom (*N *= 46).*

It was the case that, among the 50 interviewed for the survey, only two alluded to the use of newspapers to develop their students' ability to critically evaluate science reports in the press. In each case, critical evaluation was equated, unproblematically, with 'identifying the biases' and 'identifying the mistakes'. Significantly, when teachers were asked specifically how important they considered this media-related aim to be in the context of science education, more than half thought it to be 'important' or 'very important'. When asked how competent they felt to develop, among their students, the skill of critical evaluation in the context of media science, about 40% considered themselves 'not at all competent' and a further 40% considered themselves broadly competent but with reservations. By the same token, only two alluded, and that obliquely, to the importance of telling young people about informal sources of science learning which can be accessed throughout life.

> You have to make sure [the students] can identify bias and incorrect information.

> [I use newspapers] just to make them better social animals, able to communicate, to talk, to have a conversation, to argue a case with people, to debate, to discuss. I'm not saying I'm successful, but that's my aim.

Thus, in Northern Ireland at least, it cannot be assumed that, when teachers use newspapers in the science classroom, their purpose is necessarily to promote the critical awareness of science in the media or to develop an interest in informal sources of science learning. This may well be very important issue. In the small-scale study of trainee teachers who were actively attempting to incorporate *newspaper science* into their lessons, it was found that only some explicitly addressed media-related aims in their lessons. Significantly, perhaps, it was only in these classes that students reported media-related learning outcomes. At best, however, this must be regarded as a tentative finding, awaiting testing on a larger scale.

Manner of use

In the course of the two research studies, evidence has been gathered of a wide range of approaches to the use of print media in the science classroom. They had been used with children of all ages and abilities, though there was a tendency to target older, more able students. Both the quality press and the popular press were used as a source of articles and ideas. Teachers, however, typically quite distrustful of newspaper science at the best of times, were particularly suspicious of tabloid science. Often, such material was reported to be used only because it had a low reading level.

Newspapers were found to be used at all stages of a lesson and as a focus for follow-up homework activities. In two cases encountered, they were used as the basis of revision sessions. The teachers in the two studies designed a wide range of activities around the newspaper articles. These included whole class discussion, small group discussion, directed activities related to texts (DARTS), creative writing, poster presentations, pupil presentations, project work, role plays, drama and educational visits. Occasionally, the activity formed the core of the lesson, most often it was one element amongst many.

In the great majority of cases, the newspaper article or activity was used primarily to support students as they accessed and interacted with the core science concepts associated with the lesson. Any development of skills relating to the evaluation of *media science* was essentially coincidental. There were however, as presaged in preceding discussions, a few instances where the teachers' aim in including a newspaper activity in the lesson was to support the development of scientific concepts alongside the development of a degree of media awareness. The twin cameos presented in the introduction represent the most elaborate examples encountered in the two Northern Ireland studies. There were others, however, and one further will be outlined to prepare the way for a discussion of students' response to such work

The class was composed of fifteen-year olds preparing for their General Certificate of Secondary Education (GCSE). The newspaper task was introduced by the trainee teacher toward the end of a lesson on digestion and it formed the basis of the concluding activity and also a homework activity. The classroom based comprehension exercise related to the text of an article *Eating up your greens could save your life*. The focus here was mainly on science knowledge and understanding. For homework, however, the students were challenged to find a similar article and compare the two against a number of criteria. Significantly, these related primarily to the presentation of the science rather than to the science itself:

> Do you need a good knowledge of science to understand this article?
> Is the journalist expressing her opinion or is she just presenting 'facts'? Which do you think she should be doing? Why?
> Does the article challenge your opinion concerning your diet? If so, in what way does it do this?
> Find another health-related newspaper article and compare the two articles.
> Include in your report comments on presentation, style, science content, interest and relevance.

Interestingly, the trainee teacher reported that, initially, the young people did not respond at all well to this idea. 'The class is very focused on the examination syllabus and they felt that they did not have time for this irrelevant homework!' Once they had completed the homework, however, a much more favourable view emerged. This is clearly evident in the students' evaluation of the lesson, for example:

> It drew to my attention how much is written about science. I never paid much attention to the articles about it in the papers but now I will probably at least scan through the papers.

This pleasing reaction to newspaper-related science activities was also reported by experienced teachers in the large-scale survey. The picture of practice which emerges then is of a number of interesting, at times imaginative, activities prompting a positive response from students.

The account above, however, raises at least two issues which lead into a discussion of the obstacles involved in the use of newspapers to promote among young people the aptitude and ability to read, and read critically, media science. Firstly, the influences of a statutory curriculum and its associated assessment arrangements are seen. Secondly, two students, though indicating that they enjoyed the homework, still remarked that it was 'too much like an English essay'! This tendency for young people to compartmentalize their subject knowledge is an important issue in a consideration of media literacy across the curriculum.

Obstacles to progress

Science reports in newspapers and articles based on 'scientific evidence' have the potential to be a useful resource in the promotion of certain aspects of what is often understood as *scientific literacy*. In particular, they could be used to develop skills of critical evaluation in relation to media science. Through the studies reported in this paper, however, a number of obstacles have been identified which may hinder further developments in the use of newspapers in school science beyond current practice, at least in Northern Ireland. For convenience, these obstacles can be divided into two categories, those associated with the education system as a whole (of which the science education system is a part) and those associated with the individual teacher in his or her classroom. It is recognized, of course, that these concerns are interrelated.

In the first category, for example, the following were identified as among significant barriers to progress: the absence of an external trigger from curriculum and assessment, the paucity of relevant dialogue within the science teaching community, and, paradoxically, perhaps, the widespread use of newspapers in science classrooms. The links between assessment and curriculum have been long recognised, as have the discrepancies between the written or intended curriculum and that delivered and, moreover, that experienced by the individual. Crucially, in this as in other aspects of (science) education, teachers and students prioritize those parts of the curriculum which are assessed. Indeed, in the large-scale survey, examples were found of teachers who reported in the past making use of newspaper science but no longer made time for such activities since the examination question requiring 'reading around the subject' had been discontinued. Furthermore, assessment is not solely the concern of teachers. As indicated above, students themselves can express disapproval of time devoted to media-related activities. There is evidence to suggest, then, that, without an assessment imperative, the development of critical reading skills in science will continue to have low priority.

Some matters within science education generate a high level of ongoing discussion and debate, for example, the place of practical work and the role of ICT. Irrespective of their view, the vast majority of science teachers are familiar with the issues which these, and other topics raise. They can identify a well-rehearsed list of strengths and weaknesses, advantages and disadvantages, arguments for and arguments against. Such lists tend to be consistent across a group of experienced teachers, such as those in the large-scale survey. Interestingly, however, while, taken together, participating teachers produced a lengthy list of possible advantages of using newspapers and aims for this type of activity, individuals were able to offer only one or two suggestions, and that after some thought. Furthermore, there was a relatively limited degree of overlap in their responses. We take this to be indication of the absence of significant or regular discourse on this subject within the community of practitioners. Moreover, the teachers themselves reported that *newspaper science* was not a common topic of discussion, whether formally or informally, in their schools.

The survey revealed a surprisingly high percentage of science teachers reporting to use newspapers to support their teaching. It may seem a paradox to suggest that this widespread use could be a barrier to the development of this resource as a means to promoting a critical awareness of media science. The majority of teacher-users, however, are opportunists, making mention of an article and then moving on. Issues relating to scientific literacy are addressed in a superficial way or not at all. Such teachers, when faced with a challenge to 'help young people ... respond critically to media reports ... with a science component' may simply say 'I'm doing that

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already'. In much the same way that a vaccination introduces the body to a 'weak' form of an infection, thus enabling it to resist the 'strong', so it may be that some in the science teaching community may be desensitized to the real potential of newspaper science because of their previous practice. This is, of course, speculative, but it may be that the modification of teaching behaviour is more difficult than the acquisition of completely new teaching behaviours.

Alongside such systemic barriers to progress are a number associated more specifically with the individual teacher in the classroom. There was evidence from the survey that some held a rather restricted view of the nature of science, particularly of the nature of *emergent science* or *science-in-the making*. There was evidence, too, that some held a rather restricted view of the nature of criticality, equating it simply with *identifying biases* and *identifying mistakes*. By the same token, some were seen to struggle, and with good reason, with the complexities of the science – media – reader nexus. Furthermore, many teachers did not perceive themselves to have either the resources to prepare and develop media-related themes or access to the strategies which they thought would be needed to introduce these issues in the classroom.

Curriculum changes in Northern Ireland over the past decade and, in particular, the emphasis on *investigative science* has raised the level of awareness amongst science teachers of the *nature of science*. Consequently, we might expect the majority to share the view of science as being about enquiry and evidence. The survey responses, however, seem to suggest the prevalence of a different concept of the nature of science. It may be that they reveal a *working concept* or *behaviour influencing concept*, which parallels a *theoretical concept*. This working concept appears little concerned with science in the making or with science as a changing, evolving body of knowledge. It seeks instead definitive statements, correct answers, and clear-cut solutions. When asked to list the disadvantages of using newspaper science in the classroom, many teachers took the view that the material presented was misleading, inaccurate or, in some way 'wrong'. Undoubtedly, some media science is inaccurately or inappropriately reported and some is certainly sensationalized. This would seem, however, to be an argument *for* studying newspaper science in the classroom rather than against. Furthermore, this view does appear unduly dismissive of the work of the cadre of respected science journalists who conscientiously tackle their demanding task of transacting complex and contended ideas with the public. It may be that, in expressing this view, teachers are, as often as not, simply highlighting the difficulty of handling the unfolding story of science as presented in the press. Is this not compatible with science in the classroom?

Interestingly, many survey teachers suggested 'introducing students to the nature of science' alongside 'introducing science in everyday life' as a high priority from a list of possible aims for using newspapers in science education. Based on their reported use of newspapers in the classroom it would seem reasonable to question what if any distinction teachers make between these two. Indeed, some stated that the nature of science is that it is applied in daily life and they left the discussion there. Very few described the nature of science as dealing with the nature of

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evidence and the uncertainty and incompleteness of much that is 'known'. Thus most teachers were content to apprise their students of the presence of science in many situations and of related issues of interest in society.

Analysis of the evidence from the two Northern Ireland studies suggest the notion of *critical evaluation* itself is problematic. A comparison of the two groups involved, trainee teachers and experienced teachers is noteworthy. Amongst the experienced teachers, a high proportion (92%) reported using newspapers at some time in their science classroom. We found no evidence that this level of use had been prompted or promoted by any external influence. From the wide variation in approaches it certainly appeared that the use of newspapers was not being orchestrated. These teachers had independently, and for a variety of reasons, come to see print media as a resource to support their teaching. When describing their aims and intentions, and the benefits derived form this approach, few made any reference to the development, among their students, of skills of critical evaluation. When prompted, however, they did identify critical evaluation as a useful aim for this type of activity. In contrast, the group of trainee teachers had, in preparation for their teaching experience, been exposed to a workshop exploring rationales for the use of newspapers in the science classroom which included the need to develop students' ability to read media science critically. On those occasions that the trainee teachers availed of news articles, the great majority included media-related aims in their statements of objectives for the session. It was the case, however, that some, while listing such intentions, nonetheless made no subsequent attempt to achieve them in the lesson. This adds weight to our supposition that conceptualizing 'skills of critical evaluation' and operationalizing 'developing skills of critical evaluation' are problematic for many science teachers. In addition, some felt insecure in tackling the techniques of open-ended discussion in the classroom.

The introduction of new elements into a curriculum will always incur a cost in time and effort, either or both in terms of developing new skills and designing new resources. By their very nature, with the possible exception of 'classic' articles newspaper-related resources need updating regularly. Their topicality, after all, is one of their strengths. Furthermore, there are relatively few published guidelines or materials to support teachers in such work. Significantly, some in the survey said they would be happy to use print media if appropriate, pre-packaged *of the shelf* units were available to them. Be that as it may, it is perhaps not surprising that, in anticipation of having to prepare such material themselves, experienced teachers expressed concern that this would be an extra burden. In the absence of an *assessment payback* this is felt the more keenly. Hence we have returned full circle to the system-wide issues of curriculum and examination.

The process of identifying, albeit in the limited context of one country, some of the obstacles in the path toward science teachers helping students respond critically to science in the media allows some tentative suggestions to be made as to how these might be addressed. It must be stressed, however, that what we offer is not so much a strategy for development but a first attempt to describe the challenges and identify key tasks.

Challenges for the future.

If, and it is conceded that this remains open to debate, we see a key aim of the science curriculum to be preparing young people to 'be able to ... respond critically to ... media reports ... with a science component', then we are faced with new challenges. In effect, we are attempting to achieve aims not traditionally associated with science teaching. To meet these challenges we need to extend knowledge and develop skill but we may also need to look beyond conventional links between subject disciplines to forge new and potentially productive alliances.

As shown in Table 4 it may be helpful to consider the issues in three strategic areas, curriculum development, professional development and network development. These broad themes provide a structure for discussion and within each there are tasks to be undertaken if progress is to be made.

Theme 1. Curriculum development	Theme 2. Professional development	Theme 3. Network development.
a) To articulate aims	a) To encourage a broader understanding of the nature of science	a) To create new alliances with teachers of other subjects
b) To highlight opportunities	b) To promote the role of science education with regard to 'scientific literacy'	b) To create new alliances with professional journalism at individual and organisational levels
c) To generate materials	c) To develop teachers' (personal) skills in critical evaluation	c) To create new alliances with national and international media education projects
d) To establish links to the statutory curriculum and assessment	d) To extend teachers' (professional) skills in promoting critical evaluation	d) To create new alliances with the new academic disciplines associated with media studies and with science in the public domain
	e) To model good practice	

Table 4 Strategic development themes.

Theme 1: Curriculum development

Articulating aims

It is not sufficient simply to exhort teachers to use newspapers. We need to engage the science teaching community in debate with a view, possibly, to extending the aims currently addressed through their use. Evidence suggests that the primary intention of the majority of teachers who employ print media in the classroom is to demonstrate the relevance of science. There is a case, then, for discussing the value of other less commonly adopted aims, among which, surely, is that of enabling students to read not only with understanding but also with critical awareness. We do our students a disservice if we encourage them to see the media as a source of science information, even encourage them to see it as a route to lifelong learning, but stop short of giving them the tools to access it effectively or in a meaningful way.

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Highlighting opportunities

In demonstrating the extent to which teachers in Northern Ireland interact with newspaper science we have been careful to point out that we came across some interesting and imaginative classroom practice. Often, however, we felt teachers were barely scratching the surface in exploring the potential of this resource. There would be value in seeking to extend the appreciation of the possibilities that print media provide. In the first instance, this might be done by highlighting and illustrating the range of material in newspapers which relates to science and is relevant to the science classroom. This would include articles and reports, certainly, but also, for example, advertisements, cartoons, graphics, headlines, letters, photographs, stock market prices, weather forecasts and even obituaries. It could include both the quality and popular press. This sort of process may (though it is accepted it may not) help to overcome the discomfort which some teachers feel about newspaper science and encourage them to see newspapers as an opportunity not a threat.

Generating materials

The types of materials that may be helpful fall into three categories. Firstly, those which promote as painlessly as possible *media literacy* among science teachers themselves. How do science articles come to be written? What is the journalist's intention? What is the nature of the relationships between the media, the science and the reader? Secondly, a guide to activities. Sample activities, though developed within specific contexts, could serve as exemplars illustrating, in a general sense, how to turn a newspaper article into a classroom activity. Both of these resources could be enhanced by an archive collection of *classic* articles. These could illustrate not only science reported but also aspects of the reporting and the nature of journalism in this field.

Establishing links to the statutory curriculum and assessment

It would be very possible to make advances in each of the first three elements of this theme and still fail to have any significant impact on the science experience of the majority of pupils. Without integration into the statutory curriculum and in particular the scheme of assessment innovations in this as in other areas may ultimately be marginalized. Examples of innovative practice will remain the preserve of a few enthusiasts. A note of caution however is appropriate. While it is widely recognized that inclusion in statutory assessment is one way to establish new themes within the curriculum, undue haste without adequate preparation is a recipe for resentment and retrenchment. Experience would suggest that few meaningful and widespread changes occur without the impetus of curriculum and assessment. Equally teacher support for and confidence in new developments is needed if the aims are not to be distorted and the development reduced to the lowest common denominator.

It is possible that, in Northern Ireland, the increasing emphasis on literacy across the curriculum and the development of programmes to promote 'key skills' will create a climate in which this particular initiative will blossom

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Theme 2: Professional development

Encourage a broader understanding of the nature of science

Science education in Northern Ireland at secondary and at tertiary level has a strong emphasis on subject content. Few teachers have followed a course which explores the philosophy, history or *nature* of science. Of course, this may be different elsewhere, since the emphases within science education differ from country to country. Nonetheless, it remains for us an issue. The nature of the media is such that science reported in the press is often science *in the making*. Evidence from our study would suggest that some teachers have difficulty in reconciling this emergent science with the well established body of knowledge which is the basis of much of school science.

Promote the role of science education with regard to scientific literacy

At this point it would seem difficult to ignore the links with curriculum development and in particular assessment. However, as teachers we do not always value what we assess, or indeed assess in any formal way what we value. It would be short sighted to place all of the development eggs in the assessment basket. Our evidence would suggest that some teachers do promote *scientific literacy* in this way and set store by the opportunity to develop such capability. Many teachers, while not actively pursuing this agenda indicated that, in theory at least, they see newspaper science as a vehicle to promote scientific literacy. It would be enlightening, in our own province, to explore the extent to which teachers have a shared meaning of the concept of *promoting scientific literacy*. Almost certainly this would reveal a great diversity of conception and commitment. Within ICASE and its member associations, much has been done, but possibly also remains to be done, in prompting discussion and debate around these issues.

Develop teachers' (personal) skills in critical evaluation (learning how to do)

Teachers have often observed in their students that knowledge is compartmentalized and that skills learnt in one context do not necessarily transfer easily to another. It may be that the same effect operates amongst us all. A number of teachers indicated that they were not sure how confident or competent they were themselves to critically evaluate media science. We would have fellow feelings! The issues involved are complex and the aptitudes and abilities required are not those we were encouraged to develop within the context of our own training in science, nor to transfer from other contexts where they may have been considered.

Extend teachers' (professional) skills in promoting critical evaluation (learning how to teach)

Having considered their own skills in this area, it would be important that teachers are supported as they consider how to develop these same skills among their students. Learning *how to do* would seen to be an essential foundation for learning *how to teach*. However, teachers being able to engage in critical evaluation is not in itself sufficient to ensure that they will be effective in developing these skills in others.

Model good practice

There is certainly a link between curriculum development and the need for curriculum materials which exemplify the range of activities and strategies (though the latter does not guarantee the former). However, teachers can also gain from the opportunity to see *good practice*, and to engage in activities which cause them to reflect on such practice. This may be possible within a school, where expertise exists in other curriculum areas (sees below) or between schools, through exchange between science teachers. There could also be a role for in-service courses, development. In addition, these issues have implications for initial teacher education.

Theme 3: Network development - creating new alliances.

Alliances with teachers of other subjects

Science teachers are not alone in discovering newspaper material relevant to the classroom. For example, History and Geography teachers typically avail of such resources. In Northern Ireland, it is a required element of secondary English and Media Studies courses. In such subjects, developing skills of evaluation and analysis are more prominent core intentions than is currently the case in science. This teacher expertise within the school could be tapped, and, just as important, links could be developed to promote consistency of approach and commonality of purpose. This would go some way to ensuring that students had a coherent experience and were encouraged to use skills developed in one context in another context.

Alliances with professional journalism

Such alliances already exist. For example, in the UK at least one national daily newspaper has for a number of years provided schools with selected archive materials in CD-ROM format, free of charge. The materials have been annually updated and contain articles and comprehension activities catalogued in several subject areas including science. There would be value in exploiting and extending such co-operative ventures. At a local level there may be opportunities for schools to make contact with local news organisations in order that they may understand more about the nature of their work. At a personal level, opportunities may exist to develop links with those at the cutting edge, the journalists and the reporters. We have in the past witnessed initiatives to bring engineers into schools; we have had artists, poets and most recently scientists in residence. Is it time to explore the potential of the *journalist in residence*, based in the science department?

Alliances with national and international media education projects

Collectively, newspaper organisations have shown a commitment to involvement in education for example, through the Newspapers In Education (NIE) initiative. There may be opportunities to influence the future direction and emphasis of developments in some aspects of their programme, particularly in relation to science.

Alliances with the academic discipline of media education/media studies

Media studies or media education as an academic discipline encompasses a diverse range of interests. By the same token, academic centres of excellence focusing on science in the public domain are being established or are expanding. Within these frameworks, it maybe that there are sources expertise which could be used to advantage.

Conclusion

If the teachers in our survey are in any way representative of those practising farther afield, then it seems likely that a significant number of students will, during their time in secondary school, be exposed in some degree to science reported in the newspaper. The majority of these teachers see the value of newspapers in supplementing what they perceive as the core business of teaching science. They hold the view that this resource can be used to illustrate applicable and relevant science. Many teachers see the opportunity to enrich the science taught in the classroom or to use print media as sources of contemporary science. Essentially, they see newspaper science as a garnish on the main course.

By contrast a small minority of teachers approach newspapers with the aim of developing in students the additional skills to allow them to critically examine the science they meet outside the context of the textbook and even the classroom. For these teachers the use of newspapers constitutes an additional course on the menu.

It is important to retain a realistic perspective. It would not be our view, nor did we find any suggestion amongst teachers that newspapers should be seen as an altogether alternative menu, the science teaching equivalent of the vegetarian option.

If we seek to make the most of the opportunities presented as a result of the interest shown by the media in reporting on science and science related topics it would seem pertinent to address key issues in the areas of both curriculum and professional development. Furthermore it may be timely to be proactive in establishing networks of new alliances to nurture possible developments.

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Effectiveness of teacher-developed scientific and technological literacy materials

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The teaching of scientific and technological literacy for all (STL) involves increasing the relevance of teaching through relating it to local issues or concerns and incorporating values education. These are seen as areas that go beyond the conceptual learning needed for concept map formation. This paper explores the potential of teacher developed supplementary teaching materials to increase the STL component of teaching. STL supplementary teaching 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) and criteria were developed for its evaluation when used in the classroom. Twenty five teachers took part in a project to increase their effectiveness by first participating in a workshop where they were introduced to the STL philosophy and teaching approach and guided to create supplementary teaching materials. The teachers then used such materials in the classroom and their effectiveness was determined. 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 a dominance on facts and concepts; *sequenced activity based*, with emphasis on process skills; *social issue based*, including problem-solving and decision-making strategies.

Introduction

Promoting STL among students has become a major target of science teaching over the last decade. Different countries have been approaching this process from their own viewpoint, but it has been obvious that teaching facts, or even guiding students to acquire isolated scientific concepts, was not enough. The focus of school programmes has been to move beyond acquisition of knowledge and focus more on the development of learning skills, values and ideas. The target of science teaching has been to help students gain the total range of educational objectives put forward for schooling at a certain age level. Bybee (1993) divided these educational objectives and by modifying his ideas slightly four major areas can be put forward—

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empirical knowledge, scientific method, personal development of students including career awareness and social development, or achieving the aspiration of society.

Achieving these objectives is not an easy task for teachers. Research has shown, that there are big gaps between students wishes and traditional teaching, heavily influenced by teachers' attitudes (Hofstein & Malmok, 2000; Rannikmäe 1998; Yager &Weld, 2000), lack of teaching skills to assess wider goals of science education and the need for in-service guidance for better understanding about the socially oriented goals for teaching science (Holbrook, 1999). In post Soviet countries, there appears also to be a lack of interdisciplinary knowledge among science teachers (Rannikmäe, 1998).

Teachers are afraid of change. They try to avoid change especially change where their expertise may be undermined. Therefore, they must be guided through the various teaching stages (Aikenhead,1997). Teachers in research projects had concerns about doing something different in the classroom (Bell & Gilbert 1994). These concerns include fear of losing control in the classroom, covering the curriculum, meeting assessment requirements, etc. At the same time, we know that teachers are excellent learners who are interested in enhancing their teaching methods. But after attending in-service courses they still feel unable to use the new teaching activities, curriculum materials or content knowledge to improve the learning of their students (Bell, 1998).

Teacher change is linked with teacher beliefs. Previous studies have showed that perceptions and beliefs of teachers are strongly connected with their practice and behaviour. Teachers and their beliefs play a major role in science education reform, since teacher beliefs lead to actions, and these actions ultimately impact on students (Lumpe & Haney et al., 1998). These beliefs and perceptions are part of teachers' professional ownership of, and greater control over, their own work. The importance of teacher ownership of their work has been valued since the Nuffield curriculum projects of the 1960 and 1970 (Jenkins, 2000). Jenkins also noted that teachers have not been using the maximum freedom of choice to choose teaching materials and methods and kept ignoring new ideas and resources. Science teachers ownership of their own work imposes limits on the power of external agencies to effect change.

Teachers assimilate new content better and use varied teaching methods when they are actively participating in the development of teaching or evaluation methods (Sabar & Shafriri, 1982), or when they cooperate in the framework of a teacher team in planning their work (Oakland, 1995). So far there is little literature, which describes models, and case studies that can help in building an educationally effective framework for the professional development of teachers. Current research has considered outcomes documented in the Iowa Project (Yager, 2000), the Learning Science Project (Teacher Development) (Bell, 1998) and the Science: An Ever Developing Entity Project (Mamlok, 1998).

Based on the above issues, the goal for this study was to determine criteria for the evaluation of the effectiveness of STL teaching among students and to find factors which most strongly influence teachers skills to promote STL among students. For

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teaching STL (Holbrook, 1996), it is obvious that teachers should be equipped with new types of teaching materials (Holbrook & Rannikmäe, 1997) that will motivate students' learning and take school science away from purely subject oriented textbook based teaching. However, simply using new types of teaching materials does not lead to the desired outcomes. Rather these materials require an adapted teaching strategy. It appears that there is also a need for special in-service programmes to help teachers understand and acknowledge the importance of a socially-oriented, student-centred approach and the need for assessing all components of science education. Without the special in-service programmes, teachers only adopt the materials, but keep their traditional teaching approach and continue to assess only subject knowledge (Rannikmäe, 1998).

Research design

Teachers participating in this study were encouraged to develop their own teaching material meeting the STL criteria (Appendix 1) and to try it out in the classroom. The layout used in earlier STL materials (Holbrook & Rannikmäe, 1997) was modified, replacing the detailed description of a suggested teaching strategy with a consequence map, where the emphasis was on social issues or concerns arising from the scenario (see e.g. Appendix 4) and also on describing different ways to approach this problem-solving and/or decision-making situation. The consequence map differed from simple *what if* consequence maps (Lock & Ratcliffe, 1998) in its complexity and included the following components:

- relevant problem for the students;
- different (min. 3) teaching approaches which led to introducing science content helpful to the finding of a solution, or making a decision;
- science content as a core of teaching (could be presented as a concept map);
- solutions (min. 2) which lead to the final decision-making (Appendix 4).

The hierarchy within the consequence map was expressed in terms of the information/skills needed (taken) from the previous steps.

The following hypotheses were put forward:

1) The skill of the teacher to develop STL teaching depends on ownership of the STL teaching approach by the teacher. Ownership of teaching STL is developed in the process of creating STL materials and trying them out at school.
2) The process of developing consequence maps illustrates teacher change towards STL teaching—teachers will become more creative and discover more links between the science taught and the social environment.
3) Students will gain in problem solving and decision making skills.

Research method

Twenty five chemistry teachers, highly motivated to work with the principal investigator, were invited to participate in the study undertaken in 1999–2000. All teachers had been involved in earlier in-service courses by the principal investigator and had at least 10 years of experience in teaching high school chemistry.

During the six month intervention period, teachers attended three writing workshops (a total of 24 hours face to face contact), where STL supplementary teaching materials were created and modified and the draft versions of students pre- and post-tests created. All teachers were asked to use also already existing STL materials (Holbrook & Rannikmäe, 1997) and develop these, by themselves, into teaching material suitable for grade ten students. At the same time, the teachers were trained to recognize the need for wider goals for science teaching, to use student-centred teaching approaches, develop problem-solving and decision-making skills and assess students on the skills gained (Appendix 3).

Qualitative data were gathered to describe the process of teacher's change. The data collection included the use of semi-structured pre- and post- intervention interviews with teachers, observations and written records from all stages of the process of the development of scripts, and marking schemes (strategy) used by the teacher to assess students in the pre- and post-tests.

Quantitative data were collected from 693 students. Tests were first assessed by the teachers and later, separately, by the principal investigator against STL criteria (Holbrook, 1998). All teachers were asked to collect students opinions after they had been using the material created by the teachers. From 25 teachers 21 attended all workshops. Therefore, the total number in Table 2 is different for different workshops.

Development of research instruments and validation of data collected

The pre-intervention half structured interview was planned to determine teacher's perceptions and beliefs in three areas:

- Goals for teaching chemistry in grade 10.
- Understanding about the development problem-solving and decision-making skills among the students.
- The meaning of student-centred teaching.

The post-intervention interview concentrated on outcomes and values of the intervention study i.e.:

- Students achievements.
- Teachers gains and constraints during the intervention.
- Concerns which may influence the continuance of STL teaching.

The interview data were validated by triangulation against the workshop records.

Students pre- and post-tests were created during the workshops as group work by participants. The structure of the tests was designed against STL criteria and was expected to assess, besides science knowledge, problem solving, decision-making and communication skills (Appendix 2). Four questions were sequenced in the test, in a hierarchical order: factual recall and understanding, problem-solving, decision-

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making, or organization and presentation of ideas. The marking scheme summarized elements belonging to the same domain across the whole test. Outcomes were validated after the research by teachers participating in study.

The actual number of students taken part in the pre- and post-test was not equal. As no data was available on the number of occasions where each student was physically present in the class (and hence the amount of actual instruction received), no attempt was made to undertake data reduction matching students taking both pre- and post-test.

Research findings

Teachers readiness to teach STL

STL teaching demands the stating of wider educational goals for the lesson, developing higher order thinking skills among the students and, definitely teaching in a student centred way (Holbrook & Rannikmae, 1997). From the teachers pre-intervention interview, it appeared that teachers were separating subject knowledge from skills. Skills were linked with students involvement in the learning process, knowledge was given by the teachers' talk or the textbook. (i.e. 'to teach general properties of metals', or 'skill to write ionic equations using the table of solubility'). Teachers' answers were not organized—most of their answers included fragments from the curriculum content and there was no balance between the subject oriented goals and more general goals. ('to teach logical thinking', or 'to understand the world around us').

Table 1. Pre-intervention interview, stated goals of teaching.

	Number of teachers mentioning this goal type	Number of goals in this category accumulated over all interviews	Goals worded in	
			teacher centred way	student centred way
Subject oriented	25	87	84	3
General skill oriented	18	25	18	7
Social focus	10	13	5	8
Total	-	125	107	18

Table 1 illustrates the focus of goals. The division is based on the teachers answers and does not cover all possible domains. Social goals were linked with environmental issues; only very few teachers mentioned goals linked to careers, or daily life needs. All the ten teachers who recognized social goals, also emphasized the need to teach general skills in chemistry lessons ('to develop a responsibility to protect the environment', or 'to understand possibilities for linking future life with chemistry').

The manner in which teachers worded the goals illustrated their actual approach to teaching. The fact that less than 20% of goals were presented in a student-centred

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way was partly based on their understanding of student-centred activities. Problem solving and decision making were not seen as components of students-centred teaching. Student-centred teaching was expressed in terms of solving numerical tasks, doing individual work with the textbook, conducting an experiment. Communication between students was never highlighted. Problem-solving often appeared as a *lower level* thinking activity where there was little link with everyday life, if at all. Other indicators were:

- wrong understanding about problem-solving (6 teachers)
- subject oriented problems presented in question format *Why* (20 teachers)
- problems coming from everyday life (4 teachers)

As Einstein put it, 'the formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill' (Penick, 1996). The findings indicate the need for suitable in-service for teachers. *Why* type of problems demand only one certain answer and do not develop the creativity of the learner. Only four teachers indicated problems stemming from everyday life. Teachers need be taught to look beyond the textbook and recognize wider problems.

Teachers change during the workshops is presented in Table 2.

Table 2. Change in emphasis during workshops.

	Workshops			
	I		II	III
	1st day	2nd day		
Subject content	20	10	4	5
Activities involving use of scientific method	3	6	12	7
Social issue based	2	7	6	12
Total	25	23	22	24

After becoming familiar with the STL philosophy and the existing materials, the teachers started developing their own STL materials. Table 2 shows that the crucial time for changing the emphasis when developing the materials was second day of the first workshop, when ten teachers moved away from a purely subject oriented approach. The most difficult part was finding an issue or concern coming from the society and formulating it as a scenario—the starting point for STL teaching. Teachers gave mainly examples that illustrated scientific theories and their application (20 teachers from 25) and only two teachers saw a real issue which could be solved through school science. In the process of the development of the scripts, the following observations were noted :

1) The teachers skill to formulate the first draft of the scenario depended on their previous perceptions about problem-solving situations—teachers who

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acknowledged socially derived problems in their interviews were able to find applications within the curriculum material (Table 2, emphases on B, C).

2) Teachers who stated, besides subject oriented goals, general and social goals (7 teachers) for their everyday teaching, or presented large number of subject oriented goals (3 teachers) in a variety of ways, were easily guided to reformulate the scenario (table 2, second day of the first workshop)
3) The process of developing the consequence map (Appendix 4) encouraged teachers to overemphasize activities based on process skills and the scientific method (Table 2, the second workshop B).
4) The emphasis in the scenario finally chosen is linked with the quality of the consequence map created by the teacher. Well designed, socially derived scenarios indicating several strategies for seeing and solving the problem—the social-issue based scenario authors (9 from 12) found more than two different strategies for using the materials in the classroom.
5) It was possible to use the following criteria for the evaluation of consequence maps created by the teachers: number of different teaching approaches emerging from the concern (problem, issue), complexity (interdisciplinarity) of the subject content part, nature of the expected solution (including both negative and positive statements, values) These formed the baseline for categorizing the teachers with respect to change during the intervention.
6) Poor consequence maps (teaching strategy leading to a simple concept map without decision-making in a social context) describes the teachers (Table 2 day III A) whose priority for teaching was and stayed to teach subject content and find, due to the intervention, more examples to show the application of science outside the school.
7) The need for guidance decreased from workshop to workshop. Teachers picked up each others ideas and could interact orally, for example, in the consequence map formation. In so doing, teachers slowly moved in the direction of be able to create exemplary STL supplementary materials.

Teachers' ownership as a criterion to assess STL

Assessment of student's knowledge and skills by the teacher is part of the teachers' professional ownership. Through noting the assessment strategies and associated marking, it is easy to find the emphasis in teaching.

In the current study, no guidelines for assessment against curriculum topics were given. Teachers were introduced to assessing techniques for STL in using supplementary teaching materials. It was predicted that teachers would only change their assessment strategies within the curriculum domains based on their professional ownership of teaching STL. Therefore, both tests (pre- and post-) covered curriculum material and there was no need for teaching units outside the textbook.

Table 3. Weighting given to different components of the test.*

	Teacher emphasis	
	Pre-test	Post-test
Equal weight to components 1, 2, 3, 4	18	6
More weight to component 2,3	7	6
Emphasis included for component 4 (within the essay)	-	6
Value judgement scored (component 5)	-	7

*) 1. Science conceptual; 2. Problem-solving skill; 3. Decision-making; 4. Communication skill; 5. Skill to recognize values.

Table 3 illustrates the change of teacher emphasis in assessment. The pre-intervention marking schemes gave equal weighting to all four components in the pre-test (18 teachers), or gave more weighting to problem-solving and decision-making questions It was difficult to judge whether problem-solving (decision-making) were the focus in themselves in those cases, or the style of question directed the teacher to this differentiation.

Weightings in Table 3 are presented in a hierarchy, starting from equal weightings to all components and ending up with giving some weighting to value judgements. It is obvious that value judgement is based on previous problem-solving and decision-making and definitely includes the correct scientific context. This hierarchy is close to the science education objectives described by Bybee (1993).

Based on the marking schemes for the post-test, 13 teachers reached the level of assessing for STL among their students (table 3 last two row) These teachers could be described by the relations:

- between the emphases put on the communication skill question (essay) and a well structured consequence map (5 teachers from 6 who emphasized communication skill in marking)
- between stated social goals and giving a weighting to values in assessment (5 teachers from 7 who emphasized value component in marking)
- between emphases on STL material scenario and considering values or a communication component in the assessment (10 teachers from 13 who reached the STL assessing level)

Students achievement

Science learning is always linked with conceptual development. New approaches to the teaching process should lead to gains in areas of focus, but conceptual development should not suffer. The Iowa SS&C project (Yager & Weld, 2000) showed that students achieved significantly better than in typical textbook dominated courses in each of the assessed domains: concept, process, application, creativity, attitude and world view. The current research outcomes (Table 4) show the biggest improvement in problem-solving and decision-making domains. The slightly lower mean values in conceptual development were not significant and could well be explained by the different curriculum materials (metals, non-metals) assessed in the pre- and post-tests.

Table 4. Students' pre- and post test scores.

	Pre test (N = 682)					Post test (N = 623)				
	Mean	% students reaching score				Mean	% students reaching score			
		0	1	2	3		0	1	2	3
Problem solving (max. = 2)	0.80	20	58	12		1.16	12	52	26	
Decision making (max. = 3)	0.55	76	20	4	0	1.21	51	15	29	5
Skill to recognize values (max. = 1)	0.1	90	10			0.42	58	42		

	Pre test (N = 682)		Post test (N = 623)	
	Mean	Std. dev.	Mean	Std. dev.
Conceptual development (max. = 9)	5.75	1.45	5.31	1.40
Communication skill (max. = 11)	5.4	2.3	7.22	2.12

In scoring student achievements in each of the domains, it was considered that:

- Science concepts, factual recall, understanding and application is included in all test items (all 4 questions gave scores).
- Communication skill is part of every open-ended answer (questions 2–4 gave scores).
- Problem-solving and decision-making were part of two questions (2 and 3, or 3 and 4).
- Skill to recognize values appeared mainly in writing the essay.

Through STL teaching, an additional 24% students succeeded in achieving a decision-making score; close to maximum scores were achieved by 25% more students than before the intervention.

Students change was similar across all the schools and classes, indicating there was very little (not significant) influence by the teacher.

Students opinion about STL material

Student achievement in STL-related domains is influenced by learning motivation. Students' open-ended answers (opinions) about the new type of lessons/materials were highly positive, but still influenced by the final examination demands. The following types of comments were brought up by students (some students mentioned more than one comment).

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Interested in the new activities (35,4%):

> [A]t the beginning we did not take seriously what the teacher suggested we do, it was not what we were used to doing ...new activities that we never use in chemistry lesson – we were drawing pictures. It was interesting, but we should learn the textbook too...

Communication and collaboration (55%):

> I liked the groupwork, but there was a lack of additional material. My knowledge was not so good. It is good when strong students belong to the group; they can help the others. I am afraid I did not learn much knowledge for the exam, but I could discuss about interesting problems and analyse the graph showing the cleanliness of the school swimming pool water...

Problem-solving and decision-making in social context (72%):

> [I]t was easy to solve these tasks; they were taken from everyday life. I recognized problems that I never thought were linked with school chemistry...

Teachers opinions

During the intervention most of the teachers developed a more advanced perception regarding their role as facilitators of learning. The teachers increase their confidence to teach science (chemistry) in a student-centred manner. They appreciated the students' motivational feedback, collected through the essay type answers after lessons where the material, developed by the teacher, was used.

Teachers did not recognize their growth in curriculum-related knowledge and skills, as their marking scheme (even though it had changed) still gave a high emphasis to the role of subject knowledge. The fact that students' essays were more developed than in the pre-test was not recorded by teachers. Teachers were not familiar with strategies for assessing essays. Essays were marked against subject knowledge. On the other hand, teachers had a deep interest in the marking scheme used by the principal investigator and showed their interest in wishing to analyse their students responses again. All teachers agreed with the increased students' achievement in the problem-solving and decision-making areas and, through that, recognized their change:

> I did not think that I was teaching so differently. I just did my usual work and used STL materials and ideas. Maybe I really have changed. Maybe I was using approaches without acknowledging that I was using more problem-solving examples in my teaching...But I agree that when I look again at the test, and if I had marked the test against these criteria—many students did better. But a lot of that is not in the final examination...

Besides the 'hidden' change, teachers acknowledged their achievements in non-subject areas. Table 5 compares teacher's achievement against the type of STL material (the edited version) they had created.

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Table 5. Gains of the intervention, as judged by the teachers.

	Frequency	Answers by teacher orientation		
		Subject- oriented	General skills	Social goals
Pedagogical knowledge	20	2	8	10
Interdisciplinary scientific knowledge	15	5	7	3
Research experience	10		3	7.
Enjoyment of collaborative work	18	1	6	11
Leadership skills	7		2	5

Most teachers saw the greatest contribution of the intervention in the domains of teamwork, wider pedagogical knowledge and interdisciplinary knowledge. As all teachers involved in the study were teaching chemistry only, the need for wider interdisciplinary knowledge in solving daily life related situations become crucial. Many teachers promised to collect additional information during the summer to make the teaching material they had developed more justified. The process of developing teaching materials rose the teachers interest in publishing them. Here again the value of team work was highlighted and the need for looking through and discussing together all developed materials. The idea of the teacher as a researcher was acknowledged .

Discussion and conclusions

During the intervention, all 25 teachers changed. Students taught by teachers showed positive results and attitudes in STL related areas. This paper concentrated on teacher change and therefore paid little attention to describing students' achievements. Teacher ownership of STL teaching was defined as professional skill to teach students using STL criteria. Based on this, attention was paid to the way supplementary teaching materials were used.

As a major finding from the research, three categories of teachers were found related to STL ownership:

1) Subject learning activity based teachers (5 teachers).
2) Sequenced activity based teachers (8 teachers).
3) Social issue based teachers (12 teachers).

These categories describe teachers attitude towards STL teaching and were developed for the following components:

- pre-intervention perception about goals for teaching chemistry;

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- understanding about socially related problem-solving situations;
- skill to develop a consequence map;
- acknowledgement of the need to assess against STL criteria;
- opinions about values education in the intervention.

The above given factors were given a differing importance for each group .

Subject learning activity based teachers put continued emphases on facts and concepts, encouraged by the examination system. They placed dominance in assessing subject knowledge, even in socially related test items. They did not express the value of collaboration during the pre-intervention interview for the intervention. Supplementary teaching materials developed by these teachers carried a strong science content, including applications as add-ons.

Sequenced activity based teachers. This group was very unstable. Although 8 teachers finally belonged to this group, this stage was passed by a number of other teachers during the workshops. These 8 teachers approached problem-solving situations overwhelmingly using scientific method. There was a strong component of practical work in their teaching materials and in the consequence maps.

Social issue based teachers put emphases on problem-solving and decision-making, and sometimes value judgements were included in the teaching materials. This group of teachers developed well structured consequence maps and showed competency in assessing students against STL criteria. Social communication was seen as the biggest value during the intervention.

Lumpe and Haney (1998) also distinguished three types of attitudes towards STS curriculum programmes: those who realized that STS curriculum provides applications of science to real life for students; those who do not like the inclusion of social studies with science, and those who were concerned about the time it takes to implement STS in the classroom. These groups resemble the categories found in this study—the major difference being in the hierarchy (in current study, it is based on developing higher order thinking skills, whereas in the STS study, it was content of study).

Teachers enjoyment of the collaborative work was found to be the major professional outcome leading to science teachers programme (Mamlok & Hofstein, 2000). In their study, the participants were elected based on their experience; this was for a training programme for leaders. The current study involved ordinary chemistry teachers who had volunteered to be part of the intervention.

Conclusions

1) To effect teacher change, it is essential to use techniques similar to the writing workshop, which give teachers ownership of developed materials and teaching methods.
2) Teacher ownership is important in directing teachers to follow developments and for motivation to work as a team.

3) Consequence maps are effective tools in developing STL ownership among teachers.
4) Students gains in problem-solving and decision-making areas encourage teachers to acknowledge the need for change.

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Appendix 1 Criteria for STL Teaching Materials

1) Student participatory i.e. the student is involved either individually or in groups for a considerable (> 60%) of the teaching time;
2) Originates from a concern or issue in society, but examines a range of scientific principles in an interdisciplinary manner.
3) Explicitly states a range of education objectives to be achieved; these include relevant scientific method skills and scientific concepts.
4) Makes the student tasks explicit for the learner.
5) Includes a suggested teaching strategy to guide the teacher.
6) Involves students in utilising higher order thinking skills.
7) Promotes communication skills and cooperative learning.
8) Specifies the link between the educational objectives to be achieved and the student tasks to be performed.
9) Provides suggested assessment strategies related to the educational objectives.
10) Includes additional notes to assist the teacher.

Appendix 2 Pre- and post test

Pre-Test on Metals

1) Explain what is meant by the term metals. State 5 metals and give, in each case, an example of use, based on the properties.
2) To fix an iron plate at the wall you can choose between nails made from the following metals: Cu, Zn, Al. Which nails will you choose for permanent (lasting) attachment of the plate ? Explain your answer.
3) During the building of a house, you need to make a decision about which type of frames to choose for the windows. The house is built from panels, but later it will be plastered. The frames could be made, in addition to the normal material, from aluminium, or iron. What would be your choice and why ?
4) Copper and its alloys are in wide use. They have advantages and disadvantages. Write an essay (100 words) in which you explain your opinion about the use of copper and it alloys in practice.

Post-Test on Non-Metals

1) What is meant by the term allotrope ? Give examples of allotropes of non-metals (3-4) and explain use, based on the properties.
2) Why will corrosion take place when a metal acid container no longer contains acid and is left without washing. Explain and give reasons for your reply and, if necessary, write a chemical equation.
3) In the North of Estonia it is not suggested to walk on high limestone banks. You will meet the warning sign "Fall". Decide and explain why these places are dangerous.
4) Write an essay about acid-rain (100 words).

Appendix 3 The Structure of the intervention study

Form of intervention	Goals	Activities	Homework
Introductory seminar	Introduce plan of the intervention Collect pre-intervention base-line data from teachers To give ownership to assessment of students achievement	Half-structured interview with teachers about the goals of teaching chemistry in grade 10 and examples of problem-solving & decision-making oriented Collective creation of pre-test on metals	Carry out test with students Think about suitable curriculum topic where to create teaching material
Writing workshop (two days)	Introduce STL philosophy Introduce ways to promote STL among students Introduce existing STL materials Develop first draft of STL material	Try out examples of STL materials Develop consequence maps with the group on existing example materials Creation of scenario, consequence maps and scientific content of STL materials (groupwork) Present and discuss ideas	Try out STL idea and materials in the classroom Modify own STL material against discussion outcomes in the workshop Develop students activities for own STL material
Writing workshop (one day)	Modify STL materials, give ownership to the idea Discuss and clarify constraints which appeared during teaching	Introduction of teacher developed STL materials, dissemination within the group Development of assessment strategies	Continuous usage of STL materials Outcomes of metal test and presentation of assessment strategy Finalize STL materials
Seminar (half day)	Finalize STL material and give ownership of teaching Develop post intervention test for students	Groupwork to analyse each others materials Creation of post intervention test	Finalize STL materials Try out STL materials and collect students feedback
Continuing communication with research leader	To help and guide the use of STL ideas in the classroom	Use STL scripts and ideas in teaching	Student feedback on teacher-created materials Carry out final test
Final seminar	Post intervention findings Planning follow up activities	Half-structured interview with teachers and their and students' achievements Collect assessment outcomes and strategies against final test Evaluate usefulness of script	Analyse students achievement Modify script and plan for next year

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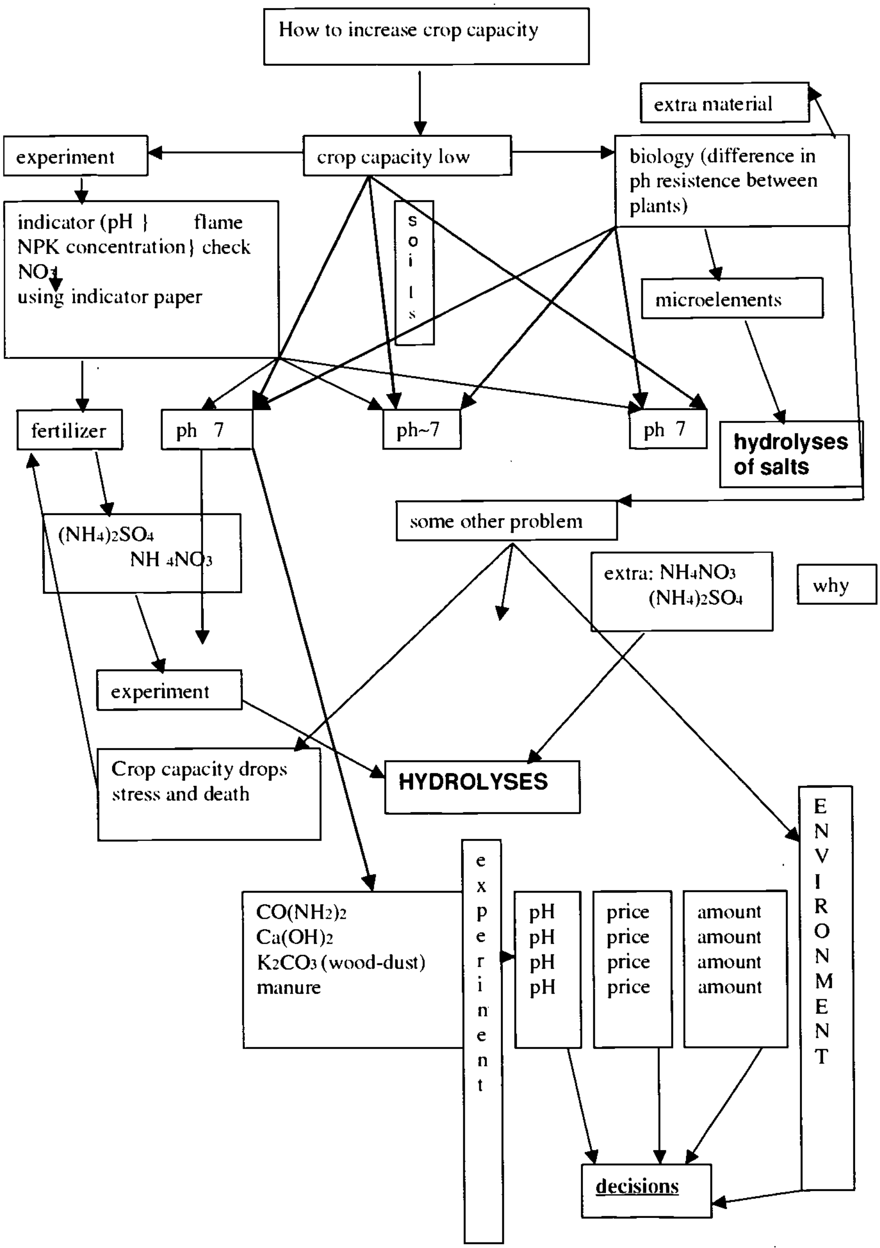
Appendix 4 Example of consequence map (created by teachers)

Scenario: Every year a farmer is getting less and less grain. He is using the same land and even the same fertilizers.



A problem-posing approach to teaching for scientific literacy: The case of decision-making about packaging waste

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One of the many aspects of scientific literacy is the skill of decision-making. This implies that science knowledge should help students in their decision-making about science/technology-related social issues; for instance about packaging waste. This paper presents the development and evaluation of a teaching unit on 'decision-making about packaging waste'. Motives, aims and methods underlying the study are briefly discussed. The resulting, empirically based, topic-specific *didactical structure* – with a focus on developing the students' *decision-making competency* – is discussed more extensively.

Introduction

About a decade ago the *Centre for Science and Mathematics Education* at Utrecht University decided to start a small-scale, in-depth research study with the aim of addressing the topic: just what might *decision-making* mean, how to teach/learn it, and what to expect of it in a target population of grade 8, middle-ability students? A full report of the research is presented in Kortland (2001).

This introductory section will briefly outline the *motives* for undertaking this study, its *aim* and its method of *developmental research*.

Motives

The motives for undertaking this study can be found in three movements in Dutch secondary education over the past decades: the emergence of *science, technology and society education* and *environmental education*, a growing perceived importance of and emphasis on students' *skills*, and an attempt at applying *constructivist ideas* about teaching and learning to classroom practice. Or, in other words: a shift of emphasis with respect to *contents*, *skills* and *teaching/learning process*—a shift of emphasis towards science contents in an everyday life context, towards skills to use these contents productively, and towards a teaching/learning process to reach these aims effectively.

O. de Jong, E.R. Savelsbergh and A. Alblas (eds.) Teaching for Scientific Literacy, 87-98
2001 *CDβ-Press, Utrecht, The Netherlands.*

The first two movements mentioned above have led to the introduction of an attainment target about *decision-making* on science/technology-related social issues (including *environmental issues*) in the physical science programme at the junior secondary level: the students 'are able to present an argued point of view in decision-making situations'. However, the (scarce) didactical research on students' decision-making in science education points at a not unproblematic tuning of conceptual science knowledge to everyday life decision-making situations in which it has to be used productively (Fleming, 1987; Eijkelhof, 1990; Ratcliffe, 1997). Furthermore, a clear operationalization of the decision-making attainment target seems to be lacking. Both issues provided a first broad motive for undertaking the study at hand.

The third movement mentioned above reflects the adoption of *educational constructivism* (Ogborn, 1997) in which learning is viewed as a process in which the learner is actively involved in the integration of new experiences and information into what he or she already knows. The constructivist teaching/learning strategies of the 1980s that deliberately employ cognitive conflict (Duit & Treagust, 1998), however, do seem to be problematic as far as the status and interpretation of the students' existing knowledge as a starter for their learning process is concerned (Klaassen & Lijnse, 1996). This has led to the idea of a *problem-posing approach* to the teaching/learning of a topic (Klaassen, 1995). The issue of how to operationalize this for the interrelated teaching/learning of knowledge and skill provided a second broad motive for undertaking the study.

Aim

The *aim* of the study was to develop and validate a *didactical structure* (Lijnse, 1995) for the teaching/learning of the topic chosen: *decision-making* about the *waste issue*, limited to *packaging waste*. Such a didactical structure encompasses the didactical starting-points and a related global description and justification of the teaching/learning process. These didactical starting-points could be summarized as an approach in which the teaching/learning process reflects a careful balance between *guidance from above* (by the teacher and teaching materials) and *freedom from below* (for the students), starting from a proper interpretation of the students' existing issue knowledge and decision-making skill as being coherent and sensible (Klaassen & Lijnse, 1996), and using these productively to have them arrive at the very ideas one wants to teach through a *problem-posing teaching/learning process* which is largely driven by starting from and further developing the students' own, content-related motives (Klaassen, 1995).

Developmental research

Designing such a didactical structure is a topic-specific activity, asking for an empirical process of closely interconnected research and development: *developmental research* (Lijnse, 1995)—a cyclical process of reflection on contents and teaching/learning process, small-scale curriculum development and teacher preparation, and classroom research of the interaction of teaching and learning

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processes. This eventually leads to an empirically based description and justification of the teaching/learning process for the topic under consideration: a didactical structure. A critical element in such a process is the use of a *scenario* for designing the sequence of specific teaching/learning activities, for preparing the teacher on the classroom trial, for focusing the classroom observations during the trial, and for guiding the post-trial reflection on the question whether or not the designed didactical structure could be considered *good enough* for the practical purpose of effective classroom teaching. Such a scenario can be seen as an extensive, explicit description and justification of the intended and expected teaching/learning process.

The pre-trial development of a scenario allows a comparison to be made between the intended and expected teaching/learning process as described in the scenario and the actual teaching learning process as observed in classroom practice. As long as classroom practice shows no major deviations from the scenario, the teaching/learning unit and its underlying didactical structure could be considered good enough. Observed major deviations from the scenario, however, represent serious points for reflection: where exactly did the observed teaching/learning process go astray, and why did this happen?

The above points at the necessity of an in-depth, small-scale and qualitative observation and analysis of classroom practice. This was done during two complete cycles of developmental research, featuring two successive experimental groups of grade 8, middle-ability students at the same school and taught by the same teacher. This was considered to be enough to provide sufficient empirical support for the hypothetical didactical structure. Only if the designed didactical structure in the end appears to be good enough under these limited and controlled circumstances, it would become useful to extend the research into a large-scale, quantitative and comparative direction.

The design: a hypothetical didactical structure

This section will describe the design of the hypothetical didactical structure and its elaboration into a teaching/learning unit (as a combination of a scenario and student materials), focusing on the key features of students' existing and developing *knowledge and skill* and the problem-posing character of the *teaching/learning process*.

Knowledge and skill

The construction of the didactical structure started with identifying an appropriate conceptual network of the waste issue and an adequate decision-making procedure, followed by interpreting the students' existing issue knowledge and decision-making skill in these respects. For reasons of limited teaching time and the characteristics of the target population, the waste issue was limited to discarded packages in household garbage while the energy aspects of packaging and waste processing were not taken into account. The structure of the thus limited waste issue, emerging from an analysis of a number of Dutch national research and policy documents on waste

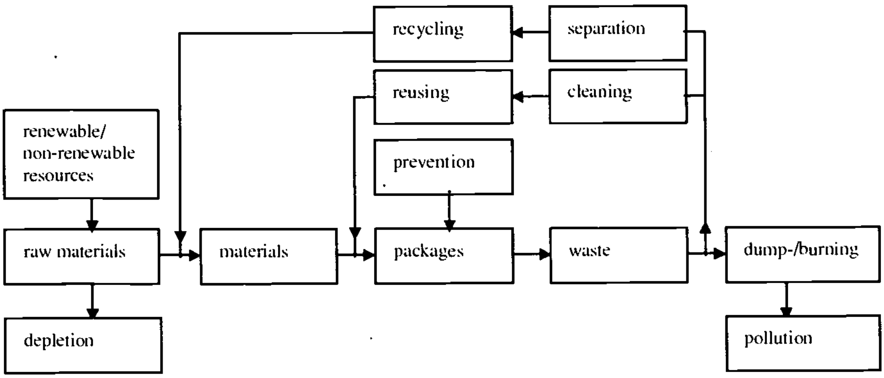

Figure 1. A model of the waste issue, limited to household packaging waste.

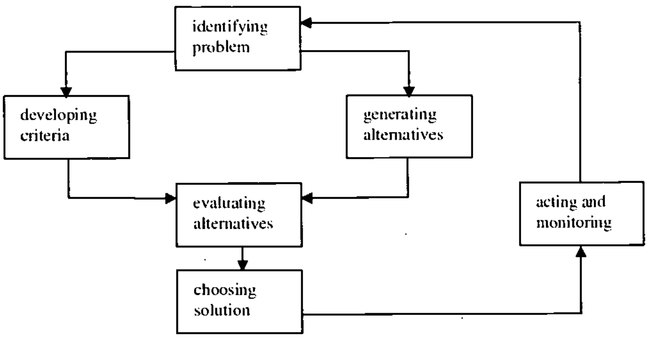

Figure 2. A model of a decision-making procedure.

management, is reproduced in Figure 1. This model reflects the variety of life cycles of packages connected to depletion of raw materials and pollution through dumping and burning of waste as environmental problems.

An adequate decision-making procedure, emerging from an analysis of the decision-making literature, was thought to be the one reproduced in Figure 2: a stepwise sequence of identifying the problem, developing criteria, generating alternatives, evaluating the generated alternatives on the developed criteria, and finally choosing and implementing the best solution (e.g., Carroll & Johnson, 1990; Gouran & Hirokawa, 1996). Such a procedure is also used in education—that is, in those few cases in which decision-making is explicitly addressed in an educational setting (Baron & Brown, 1991). In connection to the waste issue, the relevant criteria can be drawn from the waste issue's structure: the extent to which packaging alternatives contribute to *depletion* of resources and to *pollution* of soil, water and air—as these are the environmental problems that trigger the need for decision-making from an environmental point of view. This allows the identification of an *adequate body of*

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issue knowledge: knowledge about the general structure of the waste issue is necessary for identifying the relevant environmental criteria for evaluating packaging alternatives, and knowledge about the criteria-related properties of packages and packaging materials is necessary in order to actually evaluate packaging alternatives on the identified criteria.

What is further needed in order to design a didactical structure, is an idea about how the students' pre-knowledge and decision-making skill relate to what is thought to be adequate. Contrary to an earlier interpretation from the point of view of students having *misconceptions* (Kortland, 1996; 1997), now the position is taken that they as a result of their everyday life experiences and preceding formal education already know about the general structure of the waste issue—apart from some specific issue-related terminology. This means that students are expected to have a clear enough idea about the production of packaging materials including the possible depletion of non-renewable resources, about waste processing through dumping and burning including the possible pollution of soil, water and air, and about prevention and reusing/recycling as possibilities to counter depletion and pollution. Furthermore, the position is taken that the students in their own everyday life decision-making are familiar with either implicitly or explicitly comparing alternatives on one or more criteria and thus do already have the skill of going through the decision-making procedure—apart from the use of some specific procedure-related terminology. However, what still has to be learned is the conceptual input into the decision-making procedure: knowledge about the relevant environmental criteria (depletion and pollution) and specific issue knowledge in terms of the criteria-related properties of packages and packaging materials (renewability, recyclability, reusability and harmfulness when dumped or burned). Moreover, what is desired somewhere in the teaching/learning process is making the decision-making procedure explicit as a potentially useful tool for structuring their decision-making and presenting their resulting argued point of view on other, new and complex issues. These points reflect the *educational aims* for the teaching/learning unit to be developed.

Teaching/learning process

After having established *what* should be addressed in the teaching/learning process, the next question is *how* this should be done. In designing the desired problem-posing teaching/learning process for the topic of decision-making about the waste issue, the following sequence of five interrelated teaching/learning activities or phases gradually emerged as a sensible and useful way of structuring: *motivation*, *question*, *investigation*, *application* and *reflection*. The resulting global outline of the teaching/learning process is represented in Figure 3.

The teaching/learning process starts off in the *motivation phase* by connecting to the students' assumed motive of wishing to contribute to *a better environment*, in order to induce a sense of purpose for at least beginning to study the topic and to provide them with a first sense of direction concerning their prospective learning process. By identifying environmental decision-making situations related to their use of materials, water and energy in their everyday life and by identifying the similarities

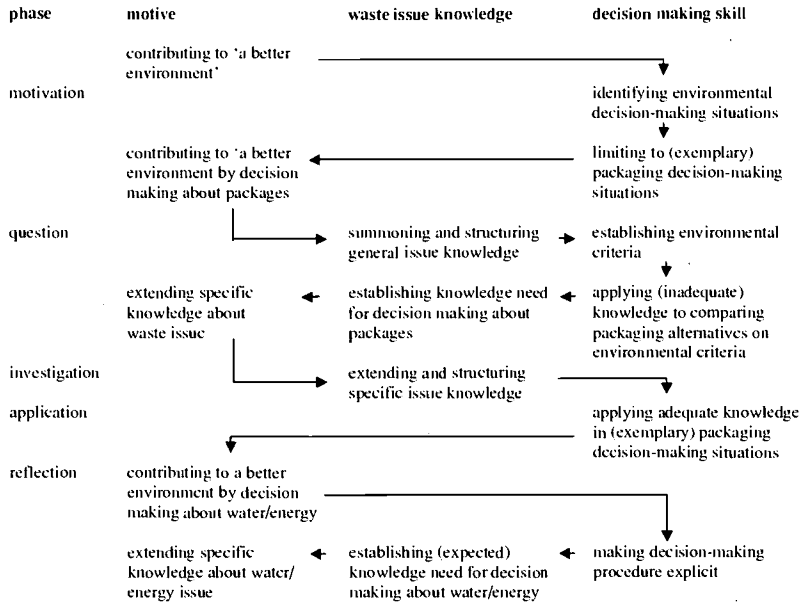

Figure 3. A (hypothetical) didactical structure for the teaching/learning of decision making about the waste issue, indicating the interaction between the students' existing and developing motive, issue knowledge *and* decision-making skill.

between these situations the students come to realise that decision-making about packages might also bear relevance to decision-making about the other environmental issues as identified by them. The teaching/learning process continues in the *question phase* with making the students become aware of a *need for extending their issue knowledge*. This phase starts with summoning and structuring the students' pre-knowledge by having them construct a concept network of the waste issue, guided by a puzzle format of the task. The puzzle's solution reflects the model of the waste issue of Figure 1, although not in such a schematic form. Next, this structured body of general issue knowledge is used productively by asking the students to identify the two environmental criteria (depletion and pollution) relevant for decision-making about packages. After having established the environmental criteria in this way, the students are presented with a decision-making situation about packages and are asked to compare the packaging alternatives on these environmental criteria. Based on the assumed lack of specific pre-knowledge about the criteria-related properties of packages and packaging materials, it is expected that this task of comparing will summon quite a number of instances of disagreement between students or of simply not knowing. These instances can then be turned into questions for further investigation about the criteria-related properties of packages and packaging materials, that further drive the students' learning process in the *investigation*, *application* and *reflection phases*. This (roughly) reflects the problem-posing character of the teaching/learning process: the students' global motive of contributing to a better environment is narrowed down to the specific motive of extending their waste issue knowledge. This specific motive, expressed by their own questions for further investigation, is developed in the context of the decision-making situations identified at the start—the same situations as those in which the answers to their questions will have to be applied at some later stage.

The teaching/learning process logically continues with having the students extend their specific issue knowledge in the *investigation phase* by studying reference materials, performing experiments and conducting interviews. In the *application phase* this is, again logically, followed by having the students use their extended specific issue knowledge *for the purpose it has been extended for*: decision-making about packages—first in the situation already encountered, and after that in self-identified situations. The students' reports on their decision-making can then be used productively to learn about *presenting an argued point of view* as required by the attainment targets. Finally, the teaching/learning process is concluded in the *reflection phase* by making the decision-making procedure and the required knowledge input into this procedure explicit, again guided by a puzzle format of the task. The puzzle's solution reflects the model of the decision-making procedure of Figure 2, although not in such a schematic form. This is then followed by a reflection on the tentative usefulness of this metacognitive decision-making tool for dealing with other environmental issues as surmised at the start of the teaching/learning process.

The above characterization of the didactical structure shows that the way in which the educational aims in the areas of issue knowledge and decision-making are expected to be reached are closely intertwined from the start until the end of the teaching/learning process. This close connection of what in general terms might be called knowledge acquisition and skills development could be summarised as follows: a start with an emphasis on knowledge acquisition in the context of decision-making, gradually shifting towards an emphasis on skills development in the area of decision-making with the help of the acquired knowledge.

The test: validating the didactical structure

The still hypothetical didactical structure and its elaboration in terms of a scenario and student materials could be considered as the first product of extending our didactical knowledge about a problem-posing approach to teaching decision-making about the waste issue. A product, however, that still has to be put to the test in order to acquire the required empirical support. As mentioned earlier, the question of whether or not the design is good enough is answered by comparing the intended and expected teaching/learning process as described to reasonable detail in the scenario with the observed classroom practice. The results with respect to the two earlier-addressed key features of the hypothetical teaching/learning process will be summarized below, followed by a reflection on the students' *decision-making competency*.

Knowledge and skill

The assumption about the students' general pre-knowledge about the waste issue has proven to be largely correct. As expected, the students had no difficulty to construct and elucidate the waste issue's concept network. It also appeared that students experience no difficulty in using a criteria format for decision-making and in making the decision-making procedure explicit.

Teaching/learning process

During the classroom trial of the teaching/learning unit the motivation and question phases went roughly as planned in the scenario—apart from some instances of not yet sufficiently adequate teaching practice. It appeared that in the question phase the students had no difficulty to establish the intended environmental criteria (depletion and pollution) for decision-making about packages, but did experience difficulties in comparing packaging alternatives on these criteria. As a result, the expected questions for further investigation about the criteria-related properties of packages and packaging materials did emerge in the context of decision-making.

From then on things started going off-track. In their investigation the students did find the intended answers to their questions—at least, so it seemed. When asked to apply their thus extended specific issue knowledge to decision-making in the unit's application phase, a serious mismatch between the information in the reference materials and the students' perception of pollution through dumping and burning of packaging materials became apparent. The result was an unexpected classroom controversy over the reliability of the reference materials as far as these qualify the dumping and burning of packaging materials as not causing (much) pollution. As a consequence, the discussions about the results of the students' decision-making were quite confusing. An explicitation of a complete and correct comparison of the packaging alternatives on each of the two environmental criteria – that is, a *content standard* for an argued point of view – was lost in the confusion. The same went for developing a *presentation standard* based on the argued points of view put forward by the students about their self-identified decision-making situations: a clear presentation of the alternatives and criteria, a systematic presentation of the comparison of these alternatives on these criteria, and an explicit presentation of the necessary weighting of comparisons and the resulting final decision. The presented argued points of view did, as expected, not yet comply with such a standard. The problem was, however, that the feedback given by the teacher and the students in the ensuing whole-class discussions did focus on 'getting the qualifications of the alternatives on the criteria right' and did not address the different parts of the presentation standard—thus making an ensuing explicitation of such a standard in general terms impossible. In summary, there was a clear *stagnation* in the teaching/learning process. A stagnation that, in retrospect, could be traced back to a lack of clarity in the scenario, both with respect to the purpose of the tasks concerned and with respect to a procedural specification for these tasks. However, by retrospectively analysing the students' factual utterances in terms of the necessary feedback on the content and/or presentation of their argued points of view,

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it was concluded that it would have been possible to develop and make explicit both the content and the presentation standards—provided the *knowledge problem* was already solved in a satisfactory way. The identified stagnation in the teaching/learning process and lack of clarity in the scenario, of course, had some repercussions in the unit's reflection phase. Nevertheless, the students were able to make the decision-making procedure and its required knowledge input explicit to quite some extent, and seemed to recognize the possibility of transfer to other environmental decision-making.

From the data gathered through a post-trial content test it might be concluded that the still disappointing learning effects concerning the presentation of an argued point of view are in line with the observed stagnation in the application phase of the teaching/learning process.

Decision-making competency

From the above it must have become clear that the students' decision-making competency aimed for consists of the following three related elements: knowledge of a satisfactory *decision-making procedure*, of the required *knowledge input* into this procedure (environmental criteria and criteria-related properties of packages and packaging materials), and *standards* for the *content* and the *presentation* of an argued point of view. The hypothetical didactical structure seems to have been adequate for reaching the first two aims, and (yet) to have failed with respect to the third aim.

Reflection

The pre-trial development of a scenario did allow a comparison between the intended and expected teaching/learning process as described in the scenario and the actual teaching learning process as observed in classroom practice. As far as classroom practice did show no major deviations from the scenario, the teaching/learning unit and its underlying didactical structure could be considered *good enough* for practical purposes—that is, teaching practice. However, from the identified stagnation in classroom practice and the scenario's lack of clarity the conclusion was drawn that the second part of the problem-posing teaching/learning process is not yet good enough, and that some specified fine-tuning and revision of the scenario and its underlying didactical structure would be necessary. The empirical data, however, were considered strong enough to speculate with quite some confidence that in this way it would be possible to arrive at a *good enough* design and a more articulate expression of the final *didactical structure*. The purpose of this section is to outline this final didactical structure, to make some cautionary comments on its demands on the teacher with respect to *teaching style*, and to speculate about its *didactical generalizability*.

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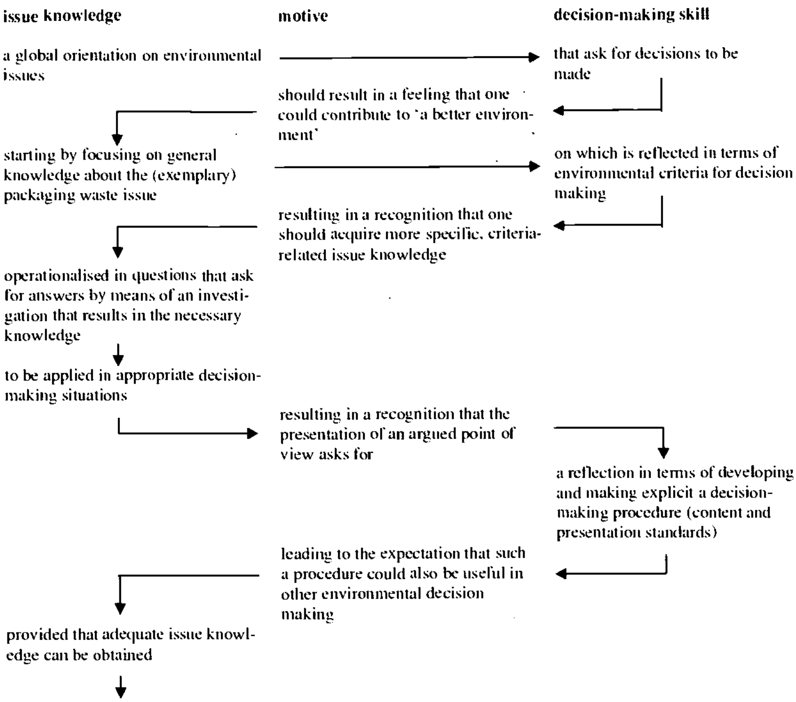

Figure 4. Didactical structure for a problem-posing approach to teaching/learning about decision making on the waste issue.

Didactical structure

The developmental research did yield indications for a necessary fine-tuning and revision of the scenario and its underlying didactical structure. A major point in this revision concerns the *reflection phase* of the teaching/learning process which should – in hindsight – focus on creating a need for reflection on the students' decision-making skill (that is, their *presentation* of an argued point of view), resulting in another content-related motive that would further drive the students' learning process towards developing a metacognitive tool for an improved performance of this skill (that is, a *presentation standard* for an argued point of view). An incorporation of these ideas results in a final didactical structure, the core of which is the interrelated development of environmental issue knowledge and the skill to use this knowledge in related decision-making situations. More specifically, a problem-posing approach requires that students are provided with and (further) develop content-related motives to make their learning process make sense to them. This motives-driven interrelated development of knowledge and skill is summarized in Figure 4. The three-column scheme shows how the teaching/learning process switches between issue knowledge and decision-making skill, and that these switches seem to come rather naturally forward because of the content-related motives that are developed. A comparison between the didactical structures of

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Figures 3 and 4 show an improved expression of the coherence of the teaching/learning process and the inclusion of the above-mentioned development of a content-related motive with respect to the presentation of an argued point of view.

This didactical structure reflects the main content-related steps to be taken in teaching about the topic of decision-making on the waste issue as an example of an environmental issue, as well as the interrelatedness of two teaching processes focused on learning to present an argued point of view. The development of a content and a presentation standard shows how the skill of being able to present an argued point of view crucially depends on having available sufficient knowledge to compose the argumentation to be presented, while, at the same time, this knowledge is acquired in view of this argumentation.

Teaching style

On the basis of the empirical data collected so far it can be hypothesized with quite some confidence that this modified didactical structure and an accordingly improved scenario will make the teaching/learning process progress as intended in a follow-up larger scale testing, involving a variety of teachers and students and adopting a more quantitative and comparative research design to further establish the validity of the didactical structure and to assess its learning effects. However, one further issue has to be addressed. The topic-specific didactical structure for decision-making about the waste issue has been elaborated with a strong emphasis on classroom interactions between the teacher and the students and between the students among themselves as a result of the character of the student materials. These materials exclusively consist of tasks made up of a brief introduction followed by open-ended questions, without any connecting explanatory storyline in between the tasks—thus asking students to construct this storyline *by themselves*. The students are expected to interact in order to summon and structure their shared pre-knowledge, to arrive at their questions for further investigation, to establish content and presentation standards for an argued point of view, etc. The teacher is expected to interact with the students to guide these whole-class discussions, to interpret and question what the students are putting forward, and to make the global and local teaching/learning process explicit on the basis of what the students have been putting forward in connection to the scenario's 'prescriptions'. What can be learned from the study at hand is that teaching in this way heavily calls on the teacher's ability to recognize and implement the required change of teaching style from *transmitting knowledge* to *coaching and facilitating* the students' learning process—maybe too heavily. This raises the question whether or not the amount of time spent on whole-class interactions should be reduced in favour of the students' working and learning independently—a question to be addressed and reasonably solved in an elaboration of the modified didactical structure.

Didactical generalizability

In the teaching/learning unit based on our didactical structure, the focus on decision-making is operationalized as 'being able to present an argued point of view about the waste issue'. The procedural heuristic rules that are to emerge from reflection on actual presentations of an argued point of view, are thus still contextualized. A first extrapolation can take place when these procedural rules are extended to 'presenting an argued point of view about other environmental issues'. This represents a curriculum focus, in which this skill is developed gradually, as already hinted at in Figure 4. A further step regarding this skill could then be made by changing the focus from 'presenting an argued point of view' towards 'decision-making as a topic in itself'. By a reflection on the contextualized procedures, a decontextualized set of heuristic rules may be formulated that may function as a tool for decision-making in rather complex situations. Or, in other words: as a metacognitive tool that helps the students to regulate and control the cognitive steps to be taken in such a process.

This brief sketch of a stepwise and content-embedded approach towards the teaching of the *general skill* of decision-making may possibly be extrapolated to the teaching of other complex intellectual skills as well—such as the skill of problem solving.

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Contextualizing Biodiversity

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Recently, the concept of *biodiversity* has drawn attention because of its importance in debates on nature management and conservation policy. It would be desirable that students learn to participate in such debates. Therefore, a teaching unit on biodiversity was developed. The paper describes how *context* and *contextualizing* play an important role in a teaching and learning strategy for biodiversity. The meaning of these concepts is discussed along with the process of developmental research, which led to the aforementioned teaching and learning strategy. The paper advocates a Vygotskian approach to the concept of *context*.

Introduction

The aim of the project described in this paper was to design a teaching and learning strategy, and accompanying curriculum materials for learning to use the concept of biodiversity adequately and critically in discussions about nature management. This issue involves biological, ethical, esthetical and emotional reasoning, with the research emphasis in this project being on biological aspects.[1] The project was assigned by the Dutch government, and carried out in co-operation with teachers and students in upper secondary school biology classes of various levels. There were four rounds of development, with a classroom trial in each round. In the second round of development it became clear that students probably could learn to *conceptualize* and *contextualize* their own concept of biodiversity. Using these notions, rooted in Vygotskian psychology, a useful teaching and learning strategy was found.

The word 'context' is in the title of this symposium for good reason. It is widely considered to be a core-notion for science education research. A word does not have much of a meaning, without knowing at least the sentence it is part of.

> *For a large class of cases – though not for all – in which we employ the word 'meaning' it can be defined thus: the meaning of a word is its use in*

[1] In education for scientific literacy, other ways of reasoning than scientific reasoning, such as ethical, esthetical and emotional reasoning, deserve equal attention. For instance, because in actual political discussions, like about gas exploitation in the Wadden Sea – the nature management case used in this project, emotional reasoning can be as important as scientific reasoning.

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the language. (Wittgenstein, 1963, p. 20, §43)[2]

Similarly, learning does not make any sense without a well-defined context; learning is 'no use' if it stays unclear for what purpose it is that you learn, that is, what you can do with those new ideas and skills. The importance of context is clearly recognized in approaches such as *conceptual change* and *situated learning*. However, the use of the concept of *context* among educational researchers is not unambiguous. Rather, a variety of meanings of the concept coexist. The many ways in which *context* is used, obscure the clarity of the teaching and learning principles we attempt to describe and explain. Therefore, the concept should be discussed and clarified by educational researchers, and be related carefully to their approach of teaching and learning.

This contribution builds on the Dutch pedagogue Van Oers' activity-approach to context, which is based on Vygotskian learning-psychology (Van Oers, 1998). Students' actions are at the centre of this learning theory, and these actions are interpreted from the cultural activities in which the students are introduced. A developmental research project about biodiversity is used in this paper as an illustration. Two didactical principles are discussed, i.e., conceptualizing and contextualizing. Guided by the design of the learning-activities, students discover useful definitions of *biodiversity* and learn to use these definitions to find new meanings for biodiversity in new situations.

In this paper three research questions are answered.

1. What is a fruitful way for educational researchers to perceive the notions of *context* and *contextualizing*?
2. How do students' learning activities relate to these notions?
3. What educational applications can the activity-approach to context and contextualization have?

Biodiversity

The concept of biodiversity hardly bears any connotations for a layperson. However, biodiversity is a hot item on the agenda of nature-conservation policy-makers and ecological and environmental scientists. In biological research-projects 'biodiversity' can be found as a useful, operational concept, although not univocal. It has many statistical definitions, different denotations, and a variety of connotations. Biodiversity has its own meaning in almost each research-project (Magurran, 1988).

For biologists the *biodiversity* of a specified area on a specific moment in time, refers to the 'livestock and vegetable supply' of that area, statistically expressed as species-richness and/or species-abundance, or sometimes as ecosystem-richness or even genetic variability. Biodiversity is an important parameter of the ecological

[2] In his *Philosophical Investigations* (Wittgenstein, 1963) elaborates on the 'other cases', where his concern is the grammar of words like 'this'. I categorize the concepts of *context* and *biodiversity* as cases for which the quoted definition is valid.

condition of an exactly specified plot (Dobson, 1997; Groombridge, 1992; Huston, 1994; Kareiva, 1996; Reaka-Kudla, Wilson, & Wilson, 1997; Roos, Bekker, & 't Hart, 2000; Schulze & Mooney, 1993; Solbrig, Van Emden, & Van Oordt, 1992; Tilman, Wedlin, & Knops, 1996; Van Nieukerken & Van Loon, 1995).

For politicians it has the strong symbolic overtones of 'green', 'good', 'nature', and at the same time, the undertones of 'species loss', 'natural resource' and 'measurement'. The UNCED in Rio was a start for the Western World to acknowledge their responsibility towards the less rich and powerful part of the world. Among many other issues was the fair distribution of *natural resources*. One of the conventions signed in Rio, was the *Convention on Biological Diversity* (UNCED, 1992). The definition of the concept of biodiversity, which is quoted below, is formulated to be interpretable in many ways. This made it possible for by now as many as 177 governments to sign the convention.

> Biological diversity *means the variability among living organisms from all sources including,* inter alia, *terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.* (UNCED, 1992, Article 2)

Article 13 of the convention deals with *Public Education and Awareness*.

> *The Contracting Parties shall: (a) Promote and encourage understanding of the importance of, and the measures required for, the conservation of biological diversity, as well as its propagation through media, and the inclusion of these topics in educational programs; and (b) Cooperate, as appropriate, with other States and international organizations in developing educational and public awareness programs, with respect to conservation and sustainable use of biological diversity.* (UNCED, 1992, Article 13)

The Dutch ratification of the Convention (July 12, 1994) led to the following question: how should we promote public awareness and understanding of the importance of biological diversity through education? The view expressed in Article 13, is that biodiversity education is a tool for nature conservation. Nevertheless, the question addressed by the Dutch government was: how should we promote public awareness and understanding of biodiversity through education in a *pedagogically sound* way? Normally, the Dutch government asks the environmental educational community to endorse international policy-plans (see also Margadant-van Arcken, this volume). In this case policy-makers made and exception, and recognized the necessity of a pedagogically sound solution.

Developmental research

One of the results of the *Convention on Biological Diversity*, was considerable finances for biodiversity education. At the department of Biological Education, Universiteit Utrecht, a two-year exploratory research project, financed by the Dutch

Method	Purpose	
1. Explorative study		1995
Expert-consultations ($n = 9$)	*General orientation* meanings, values, ethics, philosophy, psychology, policy, environmental education	1996
Literature review	*In-depth study* meanings, values, ethics, psychology, instruction, environmental education	1997
Delphi-study ($n = 32$)	*Stepping stones for contextualizing biodiversity education* learning enhancement criteria, objectives, guidelines, perspectives and themes	
	Scientific theorizing and reporting publishing the stepping stones (Van Weelie & Wals, 1998; Van Weelie & Wals, 1999), various journal articles	1998
2. Developmental research		
Four successive case-studies	*Development of curriculum materials and an educational strategy for biodiversity* an accumulating hermeneutic process, consisting of four rounds of small scale curriculum development	1999
	curriculum materials for upper secondary school, validated and ready for publication (Van Weelie, 2000)	2000
3. Reflective study		
Secondary data-analysis Reflective reconstruction	*Reconstruction of the study, formulating educational strategy, methodological reflections* dissertation	2001

Figure 1. Composition of the study.

Ministry of Agriculture, Nature Management and Fisheries was carried out in co-operation with Wageningen University. Shortly after this project was completed, a three-year developmental research project was financed by the national environmental educational program NME Extra Impuls/NCDO. In the latter project, curriculum-materials were developed for upper secondary school biological education[3], based on ideas developed in the first project. In Figure 1, the two studies are presented.

At the moment of writing, the data collected in the two projects are being analysed again, in a reflective study for the author's dissertation. In this paper, the second project, the developmental research is discussed. Developmental research in Dutch mathematics and science education has been greatly influenced by Freudenthal (Freudenthal, 1991; Gravemeijer, 1999; Gravemeijer, 1994; Lijnse, 1995). Two

[3] For 4 HAVO (sub-A-level, middle ability, upper secondary school, preparing for college, students aged 15-16), 4 VWO (A-level, higher ability, upper secondary school, preparing for university, students aged 15-16) and 6 VWO (A-level, higher ability, upper secondary school, preparing for university, students aged 17-18).

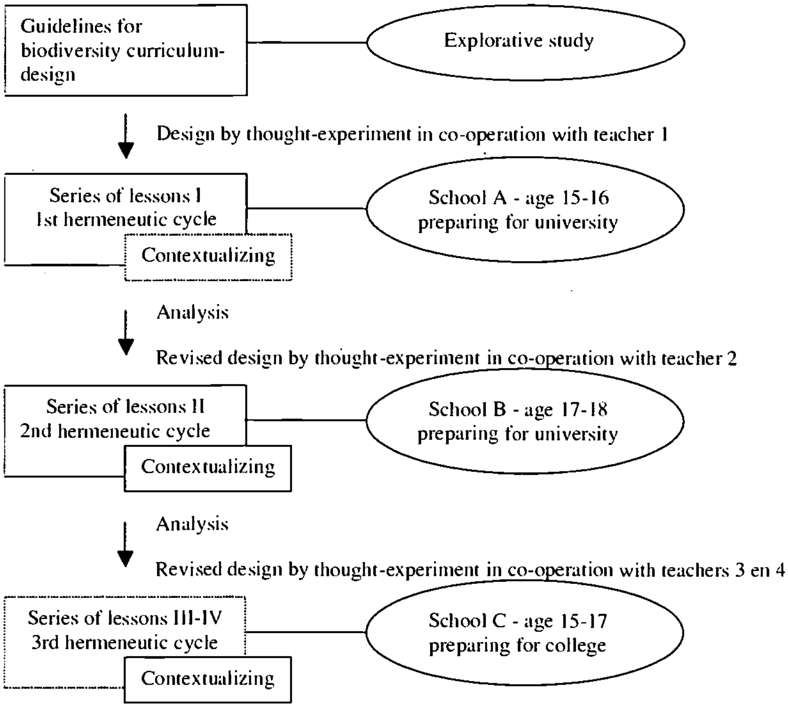

Figure 2. Research design of the developmental research project.

science education researchers (Gravemeijer, 1994, p.116; Vollebregt, 1998, p.35), quote the same fragment from Freudenthal's work, which is worth to repeat once more.

> *In short,* developmental research *means: experiencing the cyclic process of development and research so consciously, and reporting on it so candidly that it justifies itself, and that this experience can be transmitted to others to become like their own experience.* (Freudenthal, 1991, p.161)

According to Freudenthal, the product of a developmental research project is what the researcher has learned. The researcher's aim is to learn that which is relevant for fellow researchers as well as for teachers and students. Also, the product should be made transparent, so it can be shared.

In four rounds of development, a teaching and learning strategy for biodiversity was developed, as well as concrete curriculum-materials. The research design is presented in Figure 2.

The teacher and researcher collaboratively designed a *scenario* for a sequence of learning activities (Janssen, 1999, p. 23, 51-52; Vollebregt, 1998, 34-35). This scenario describes how the students are expected to act and understand, these expectation being based on thought-experiments (Gravemeijer, 1999; Klaassen, 1995, Ch.4). After a classroom trial, the expectations in the scenario are compared to the performed curriculum. The scenario includes goals, descriptions and expectations of activities, and a plan for data-collection. Even more important, the scenario contained a conceptual structure of the core-content, and a structure of questions, which make up the sequence of activities. This scenario was compiled in such a way that both the teacher and the researcher believed (on rational grounds, proficiency, common sense, sensitivity, and *Fingerspitzengefühl*) that the formulated goals would be met if the students would carry out the sequence of activities in a sufficient way.

Scenario writing and rewriting is mainly a tool for the researcher. It increases the reliability of data-collection and evaluation by comparing the actually performed activities with the planned activities, as well as the validity of improvements in the next round. The scenarios written during this developmental research project were used after the last round of development, to refining the learning-materials, and to write teacher's manuals (Van Weelie, 2000).

Each round the project was introduced to the students, the aim and relevance of the project for them was discussed, and the students were asked not only to join in the school-project, but also to join in the research-project as co-researchers. The sequence of learning-activities were carried out following the scenario as close as possible. Alterations were noted and taken into account in later evaluations and explanations. A variety of data was collected: audio-recordings of scenario-writing meetings, of evaluations with teachers, of group work, and of interviews with students, as well as student's written work, student's final written tests and essays, and field-notes of observations.

After each round, the researcher would investigate two questions:
a) How does what happened in the classroom qualitatively match the scenario?
b) What changes should be made to the next round scenario, or eventually what last minor changes to the final curriculum materials?

By analysing the data, and evaluative interviews with students, each round of development was evaluated by the researcher and the teacher. Then the results would be used to write the draft-scenario for the next round, which was read by a new participating teacher from a different school. With this teacher the final scenario for the next round was written. This process was repeated until the strategy to be tested and refined reached an optimum. The process reached a point of saturation in four rounds, i.e. a fifth round would probably not improve the activities and learning materials significantly.

The context-problem

The first trial was held in a high ability class, with 15-16 year old students. The series of lessons is shown in Figure 3. The strategy in this round was to introduce a working-definition in lesson 3, as a tool for conceptual analysis (see Figure 3).

Lesson 1	*Wadden*-case being introduced by a short video and a guest lecturer, an enthusiastic bird-watcher, who's talk and slides were about his personal experiences. Student think about and discuss propositions about interests and values of "biodiversity" (nature) of the *Wadden*. Questions are listed.
Lesson 2	Questions discussed in whole class discussion. Assignments on worksheets to explore biodiversity, text reading and interpretation. Try to define biodiversity. Schedule of the project is discussed.
Lesson 3	How to prepare your research project. How to carry out a literature study. Were to find other sources of information. *Working-definition of biodiversity* presented by means of a worksheet, and explained as a tool to narrow down your research question. Assignments for practicing the use of the tool. Formulating research questions.
Lesson 4	Students' research project
Lesson 5	Students' research project
Lesson 6	Finish report, prepare talk
Lesson 7 + 8	*Wadden* conference

Figure 3. Series of lessons in the first trial (a lesson is 50 minutes).

> ***Biodiversity** represents variability in biological entities in a specific space at a specific moment in time.*

This definition was one of the results of the explorative study, mentioned in Figure 1 (Van Weelie & Wals, 1998; Van Weelie & Wals, 1999). The rationale was to introduce the context first, by the guest-speaker, and the assignments in lesson 2. Then, in the next step, the biodiversity-tool would come in handy, at the moment the students needed such a tool. However, the assignments meant to get the students used to the applications of the tool, did *not* work as planned in lesson 3. This was not caused by wrong conceptualization, but by wrong *contextualization* in the curriculum-design. An acceptable number of students did actually *understand* the notion of biodiversity at the moment of introduction. Examples of utterances to support this result are easily selected from the transcripts. An example:

> Teacher: Is it also called *biodiversity* if there are many of the same kind of animals?
> Freddie: No, that doesn't matter. Whether ten different animals would inhabit a square meter, or one million of the same kind, the biodiversity is higher for the ten animals.
> Teacher: Yes, very good.

As for the isolated concept, the introduction and the assignments were not too difficult. What went wrong is that the activities did not lead to understand the *point* of the concept, i.e. why and how to *use* it in further activities. Indications for this are found in the final essays. The students did not use the concept of biodiversity at all in the research-projects the groups carried out, although the group-work as well as the essays reveal a great deal of enthusiasm. Apparently, the students did not feel the need to use the concept of biodiversity. Therefore, in the next round, efforts were deployed to have the concept of biodiversity invented by the students themselves (guided re-invention).

Solutions

An important step towards solutions for the problem of how to get students to use the *concept* of biodiversity, was the activity-approach to *context* (Van Oers, 1998). In the light of the problems raised by the first round, Van Oers published his article at exactly the right moment. As the research-problem was understood at that time, the students could not see the relevance of the tool that the concept of biodiversity could be for them. In other words, the concept of biodiversity was not meaningful for the students in *their* situation.

In his suggestions for further research (Van Oers, 1998, p. 485) Van Oers asks questions about younger children, like: 'How do they examine new ways of acting within the context of an activity?' and 'How do they expand an activity into new directions, generating new perspectives within the activity?' It was a challenge to develop the small-scale curriculum for biodiversity education further on the basis of those appealing ideas, although the curriculum was meant for students at the age of 15-18. In the following quotes, Van Oers defines the concept of *context* for science education research.

> *In sum, in the activity theoretical perspective a context emerges into existence in the interaction between people, when it becomes clear what kind of activity is to be accomplished. 'It is the activity between [people] and their socially (and linguistically) constituted situation that "structures" what they do or say, not wholly they themselves' (Shotter, 1993, p.8).* (Van Oers, 1998, p.480)

> *What counts as a context depends on how a situation is interpreted in terms of activity to be carried out.* (Van Oers, 1998, p.481)

In short, *context* according to the activity-approach stands for a cultural activity – which can range from soccer to ecological research – within which you are able to perceive and perform your actions and those of others meaningfully. Teaching and learning serve to introduce students into these activities, by facilitating the learning of new possible actions. Mental operations and actions are also seen as purposeful behaviour. So, there is not much difference for this approach between, say, learning to dance, or to play chess, or to respond to a newspaper article in a scientifically literate way. *Contextualization* then, means the action of interpreting a concept within a specific context. Usually, this action will take place quite unconsciously, but in some cases – such as learning the complex new concept of *biodiversity* – it might be beneficial to make the process of contextualizing a conscious (meta-cognitive) learning-activity. To test this promising hypothesis, the notions of context and contextualization were developed along the activity-approach, starting, as already indicated, with the second trial.

In the second trial, held in a high ability class with 17-18 year old students (Figure 2), context was thought of in terms of the students' learning-activities. The original context of political activities concerning nature management served as background for the students' actions, which were designed to be meaningful from *their* point of view at each moment in the series of lessons. The focus of the study was the

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students' interactive (verbal) ecological thinking-activities, needed in a debate concerning gas-exploitation in the natural area of the Wadden Sea. Consequences for the sea bed conditions, noise, disturbance, and so on, were discussed fiercely in the media at that time (and they will be as long the lucrative natural gas field is there, and the area is not permanently protected). In particular, of course, *biodiversity* and scientifically sound reasoning based on this concept, was to be related to the issue of gas-exploitation in the Wadden. The students' activities were not sequenced around the introduction of the concept of biodiversity this time. The concept, as defined earlier above, was split into three parts. In Figure 4, this move is represented.

In this way, a didactical problem-structure emerged (Klaassen, 1995, p. 105-107; Lijnse, 1995), that was expected to guide the students through their learning-activities, with the intended learning process as a result. The strategy now, was to *contextualize* each of the conceptualization-steps revealed by the didactical-structure. This time, the students developed their actions as expected and described in the scenario.

1. An intuitive notion of *variability* as so many different kinds of plants and animals, constructed, i.e. *conceptualized*, by hands-on learning activities.

   → *Biodiversity represents variability...*✂

2. A taxonomical notion of 'variety of species'. The categorization of biological species on earth is not bound to space and time. Therefore, taxonomical learning activities are suitable to construct a more advanced, but not yet ecological notion of 'biodiversity'. Important: students became aware that they were building a notion of biodiversity. Each next activity they were invited to use the concept as defined by themselves, and discovered that expansion was needed for the concept to be useful in the next action.

   → *... of biological species...*✂

3. The *jigsaw-method* (Dees, 1990) was used to let the students add the dimensions of space and time, and develop an ecological concept of biodiversity, formally equal to the working-definition, but phrased in their own words.

   → *... and the numbers of individual organisms per species...*✂
   ...for a specific area, and for a specific time-interval.

Figure 4. Emergence of a didactical problem-structure.

A teaching and learning strategy for contextualizing biodiversity

The third trial, as well as the fourth, was held in a middle ability class age 15-16, in another participating school. The strategy was not changed fundamentally for this less advanced level, but the series of lessons had to be somewhat redesigned, in order to make the guided steps smaller. The rewriting was done in co-operation with two biology teachers, i.e. those who would also take care of the lessons. In this section results from the third round are discussed to illustrate the process that led to further refinement of the educational strategy for learning to conceptualize and contextualize biodiversity.

Lesson 1 – Exploring values of nature
Lesson 2 – Hands-on exploration of a variety of organisms
Lesson 3 – Hands-on exploration of a variety of organisms
Lesson 4 – Taxonomy and the concept of biodiversity
Lesson 5 – Measuring in space and time: bird-diversity, and a *working-definition* for biodiversity
Lesson 6 – Applying biodiversity: gas-exploitation in the *Wadden*
Lesson 7 – Written test

Figure 5. Series of lessons in the third trial (a lesson is 50 minutes).

The school project consisted of a series of seven lessons. An overview is presented in Figure 5. During the lessons students worked alternatively in teams of two, and groups of four. Each group consisted of two teams of two students. The teams would receive assignments that prepared for the group assignments. The learning-activities were designed by following the 'jigsaw-method' (Dees, 1990), i.e. the teams needed each other's preparations in order to solve the group problem. This general strategy had showed its usefulness already in the previous round.

Students defined biodiversity in three steps, partly self-directed, partly guided by other means of support. The first and second notion of Biological Diversity, BD (1) and BD (2) are displayed below.

> *BD(1) Biodiversity, or biological diversity, represents the differences among living things in nature.*
>
> *BD(2) Biodiversity represents in many cases the differences, or variety among organisms or species. For some it means the same as 'nature', for others it denotes the collection of all the variety of species as a natural resource, and the word can be used as an indicator of the quality of nature.*

As a context for BD (1), their own discussion-activities about the value of nature were used. For the second, practical activities in taxonomy were chosen. Specimen of plants, fungi and animals were studied for determining traits[4]. Important for this paper, is not only that the students activities were identified as the fundamental context, but also that the context was *changing*, as the activities were changing in the learning process. A guided shift of contexts, following the same route as the conceptualization of biodiversity, turned out to be the key to a workable pathway from the students original repertoire to authentic biodiversity oriented activities.

By the time they had developed BD (1), the students were aware of a peculiarity of the word 'biodiversity', i.e. its meaning changes. And by observing closely a variety of species during the practical, they had formed an idea and conceptualized a taxonomical concept of biodiversity, i.e. BD(2). However, taxonomical diversity has no dimensions in time and space. BD(2) cannot be used in ecological activities. At this point, the teacher reminded the students of the *initial reason* for exploring the

[4] The practical assignments, as well as the other materials used in this developmental research project, are available at NCDO (Van Weelie, 2000). Research results concerning this matter are to be expected in the authors dissertation, which will be published in 2001.

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concept of biodiversity: to clarify their own discussions about the values of nature. Now, she asked her students whether their description of biodiversity so far, would be helpful to clarify these discussions. The students were challenged to study the concept even better, to find out what elements were still missing to serve this purpose.

The assignments designed for this step, concerned the question how birds are counted in the Netherlands. Especially for this task the jigsaw-method was followed. One half of the teams of two students were given a map of the Netherlands, showing blocks representing 5 square kilometres each. A part of this figure is shown in Figure 6.

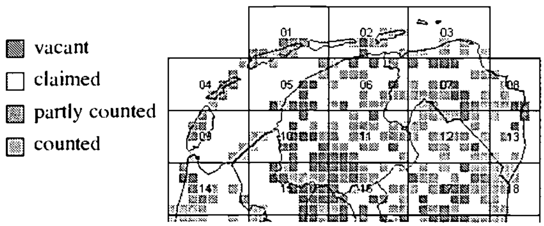

Figure 6. Legend and part of the map used in the Bird-diversity assignment

The map was originally created by SOVON[5] as information for volunteers who could claim still vacant red blocks. The students were asked to apply their current knowledge of biodiversity to discuss whether these volunteers were measuring biodiversity, and to change their definition of biodiversity if necessary. Studying the map, the students discovered how birds are counted to find out about bird-diversity, and how biodiversity is related to the surface of an area. The other half of the teams were given a table, partly displayed in Figure 7, showing the results of bird counting in previous years.

Species name	Increase/decrease per 10 years (%)	Significant trend	'92	'93	'94	'95	'96	'97
Little Grebe	-21.2	-	76	87	92	101	85	76
Great crested Grebe	-6.2	-	102	92	110	99	90	88
Mute Swan	27.4	-	122	132	146	155	114	152
Greylag Goose	437.7	Increase	567	294	740	985	889	1321
Egyptian Goose	51.7	-	118	141	208	245	247	266

Figure 7. Part of the table used in the Bird-diversity assignment.

Also these teams were asked whether this table is about biodiversity, or not. The students were encouraged to change their definition, if this was necessary in their opinion, to make it useful in this situation. Important for the learning process was the *reflective discourse* (Cobb & Boufi, 1997) in groups of two teams: the timetable-experts explained to the other team how changes in 'bird-diversity' can be measured

[5] Dutch Bird Research Institute. Source: http://www.sovon.nl (in Dutch).

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by counting birds every year, whereas the map-experts explained to the others the relation between diversity and the surface of an area.

After these group-discussions the students were able to add the dimensions *time* and *space* to their definition. The teacher just facilitated the activity of classroom reflection. After a while the blackboard showed a number of defining elements to be added to the definition of biodiversity. Elements were discussed, and those elements finally considered to be essential, were selected. This procedure resulted in the following definition, formulated in the students' words—literally translated in English, including the brackets:

> *BD (3) Biodiversity is the number of organisms (the number of organisms of one species, and the number of different species) in a certain place and per unit of time.*

Formally, this definition is equal to the working-definition in the teachers' manual. The students were eager to know if *their* definition was 'right', so the teacher read her working-definition (Figure 4) aloud. One of the students explained why they liked theirs better: 'Because it is our language, we understand that much better than the wordy language of the other one.' A major advantage of the strategy used to come to this point was indeed that the definition was *their* product.

Now that the students had *explicitly conceptualized* the notion of biodiversity for their aim, that is, as a tool for clarification of biodiversity-related scientific reasoning in the Wadden-debate. At this point, they were ready to *contextualize* biodiversity explicitly. Indeed, as the teacher and the researcher expected, the excitement and enthusiasm the students expressed about this particular lesson, carried over to the next lesson.

In the lesson that followed, the students applied the concept of biodiversity in a much more complex situation than bird counting. They investigated the issue of gas-exploitation in *Wadden*, using the *Interwad* website (http://www.interwad.nl). Until now they had been involved in the action of contextualizing only once, in small guided steps, without the activity being transparent to themselves. In this lesson, they were able to take a few steps at once, guided by each other. During the lesson some students asked the teacher for help, but generally they were able to contextualize the concept of biodiversity within the specific case of the gas-exploitation-debate. The best evidence for the validity of this interpretation is generated by the written test that followed this lesson. These results are discussed in the next section.

Written test results

The lessons were followed by a written individual test, to get an impression of the students' individual learning process. One of the questions will be discussed here. The question, which was accompanied by a table providing information about sea-mammals, reads as follows:

According to table 4 not only seals, but also other sea-mammals are found near the Dutch seashores. If you read the information in table 4, could you say which sea-mammals? Do you think these animals count for the biodiversity of the North Sea and the Wadden Sea? Write down and explain your opinion. Your opinion can't be right or wrong, but you have to explain it as clearly as possible. Use the concept of biodiversity.

Three answers – literally translated into English – will be discussed. Ann answers 'yes', the other animals should count for the biodiversity too. She names two species of dolphins, and she names whales as one group altogether. About these animals she says (all brackets are hers):

I think they count as well, because (see definition above: biodiversity = the number of organisms (the number of one species and number of species) in a particular area per unit of time) biodiversity can be any arbitrary group of organisms. One could count per species (seals), but not only they count for biodiversity in the Dutch sees. There are more organisms living there, so they count too.

Before starting to interpret, let us look at two more answers. Rose, for example, also answers "yes" to the question whether the other animals should count for the biodiversity too, or not. She names all dolphins and whales she can find in the table, and she names them by their full species name. Then, this is what she says about these species:

I think these animals count for biodiversity of the Dutch seas too. Because if those would be for example seriously polluted, these animals would not live there. This tells something about the health of the Wadden Sea. If these animals were not there, the Wadden Sea would have a completely different biodiversity.

But not all students think that in order to measure biodiversity, all the species you can find in this area should be counted. Sara is one of the dissidents, and says 'no'. Sara names only dolphins. Her idea about biodiversity is this:

No, because these animals exist in warmer sees most of the time. It does not occur very often, therefore your research would not be correct, because it would say nothing about the environment of these groups.

These creative answers illustrate personal variation in the students' reasoning, especially were values are concerned, and at the same time that their biodiversity-based reasoning is *sound* from a biological and logical point of view. Not all of the information they use in their argumentation is biologically *correct*. For example, certainly not all of the other sea-mammals in the table of the exam 'exist in warmer seas most of the time' (Sara). Actually, some of them occur exclusively in *polar* territory. The table the students used simply did not contain this kind of information. Sara's answer preferable should be interpreted as filling in this lack of information with a fair *hypothesis*. This is sound reasoning for a beginners-level biologist. Furthermore, this 'mistaken assumption' does not affect Sara's line of reasoning. The animals she is talking about really *are* very rare guests in the Dutch territory of the Wadden Sea. This information could be obtained from the table provided in the exam. As she writes down herself quite explicitly ('your research would not be correct'), Sara has a strong point about the usefulness of the measurement of biodiversity. She knows that *by definition* – a definition she invented herself, with help of her classmates, of course, but still – species counting in a certain area is involved. Because she constructed the definition for a purpose, she has learned to use the definition of biodiversity as a tool, instead of an algorithm. Counting all species is not compulsory, according to Sara, since the purpose of biodiversity-measurement is collecting information about the environment. This argument had not been anywhere in the learning materials, nor was it on the website, neither did the teacher mentioned the idea. She thought of it during the exam. In other words, she was able to contextualize biodiversity individually, readily and purposefully. Ann did the same, but she disagrees with Sara about the value of counting particular species. Rose is more informative about the information a particular kind of 'biodiversity' gives you about the health[6] of the Wadden Sea. Another reasonable line of thought.

In the two classes of the third and fourth round of development were thirty middle ability students, age 15–16. Ann, Rose and Sara were not exceptional. A reasonable number of students managed to use the concept of biodiversity in a scientific literate and original way, to express their thoughts about the Wadden-debate. The examples showed here, were chosen from the third round to show dispersion in one class, and put together for their eloquence. They provide evidence for the possibility that students are able to learn to conceptualize and contextualize biodiversity.

Conclusions

The research questions I tried to answer in the previous sections are, as a reminder, the following three questions:

1. What is a fruitful way for educational researchers to perceive the notions of *context* and *contextualizing*?
2. How do students' learning activities relate to these notions?
3. What educational applications can the activity-approach to context and contextualization have?

Answer to question 1: The activity-approach to *context* and *contextualizing* is a fruitful way to perceive these notions. Perceiving context as cultural activity, guides the curriculum developer and educational researcher to design learning-activities that are meaningful for the students. The notion of contextualizing within this approach can have a broader meaning than 'to translate scientific knowledge into the words and daily life experience of students'. It is fruitful as well, to consider 'contextualizing' as a meta-cognitive learning-activity.

Answer to question 2: Context seen as activity is something the student can learn to join in. To design learning activities guided by this idea proved to be useful. The point is to see what the students, in the end, can achieve, and what is pedagogically wise to aim for. This idea differs from the common idea that students, in the end, should know particular scientific knowledge and skills, and will only be able to

[6] In fact, ecologists would use the word *quality* here, and preserve *health* for a slightly different trait of the ecosystem (Roos, Bekker, & 't Hart, 2000, p. 46). In the series of lessons we used *health* for both these aspects, for the pedagogical reasons that this concept is immediately appealing and easy to introduce by examples taken from economy and health care.

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reach this goal if this knowledge and skills are put in the right context. By facilitating students to contextualize key-concepts themselves, they learn explicitly about the purposes of the knowledge and skills they develop.

Answer to question 3: How the activity-approach can be put into practice, is by sequencing learning activities according to a didactical-structure, based on a conceptual and pedagogical analysis of the context into which the students are introduced. The definition of biodiversity, used above, and the strategy that was developed from it by developmental research, are example of results of such analyses.

Discussion

As we concluded, the activity-approach to context is a fruitful approach for developmental research in science education. Yet, the approach has its difficulties. One is discussed here, followed by suggestions for further research. This difficulty is the tension between the social and the individual picture of context. Van Oers is clear about this, although his language is uncommon, and it is difficult to operationalize his concepts for empirical research:

> *[T]he 'activity-as-context approach' essentially views the agent as a socially constituted entity, but at the same time acknowledges personal variety in the concretization of activities. Activities and personal action are reflexively related.* (Van Oers, 1998, p. 481)

For research purposes, I interpret this as follows. In developmental research, two kinds of contexts should be considered. One, the *social context*, is the cultural activity within which the actions that the students learn to appreciate, understand, and perform are meaningful. For biodiversity, such a context was 'decision-making in Wadden Sea issues'. The other, the *personal context* is the outcome of a person choosing from a repertoire of possible actions, those that are meaningful in a given situation. Or, as Van Oers expresses it:

> *A context is constructed by an agent every time he gets actively involved in a setting ...* (Van Oers, 1998, p. 482)

The following discussion is limited to an outset of operationalizing the notions of personal and social context, based on the research experience described in this paper.

In the case of the Wadden Sea, the social context is presented in the newspapers. This cannot be a complete image, however. After all, 'agents are socially constituted' and these agents, that is: you, me, and them, undertake the actions that constitute the cultural activity of 'decision-making in Wadden Sea issues'. This is exactly the context that was analysed to prepare curriculum development for biodiversity (see Figure 1, Explorative Study). Context is not a life-world story you can add to a boring subject as a sugar icing, to make the students swallow down the curriculum. But without making the mistake of this objectivism towards context, on

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account of what is said above, it is useful to link the social version of context to the notion of *goal context*.

The main goal of the project was to cope with the flexible context-dependent concept of biodiversity. Context here obviously does not mean 'decision-making in Wadden Sea issues', because the concept of biodiversity changes meaning from one context to another *within* this broader context. Still, this use of the concept of *context* is consistent with the activity-as-context approach. Any activity can be seen as a set of activities on a smaller scale. In other words, activities as contexts are nested: 'decision-making in Wadden Sea issues' is a subset of *decision-making*, and so on. Indeed, this is why Magurran (1988) discovered so many operational definitions of *ecological diversity*, as mentioned above in the section on biodiversity. A research project is a specific small-scale social activity, a *context* for the, *socially constituted*, researchers involved. This context determines his or her interpretation of *biodiversity*. Any researcher has to cope with this conceptual phenomenon. The students were challenged to cope with this conceptual phenomenon in the project lessons. We might call this learning-process *guided contextualization*: the students were guided to the point where they understood and appreciated the necessity to *contextualize* and *recontextualize* their concepts of biodiversity repeatedly. This way, the study was an empirical contribution to the research program suggested by Van Oers:

> *[T]he really interesting thing here is how a person achieves the application of something learned outside the original context. We might call this process 'desituating' (following Hatano & Inagaki, 1992). It is assumed here that any process of desituating depends on the ability of contextualizing something in a new way (i.e. recontextualizing), of creating an alternative context for a well-known action, object or symbol. In future research we should try to shed more light on transfer by studying this process of recontextualizing.* (Van Oers, 1998, p.483)

The students started in the first lessons to conceptualize their intuitive ideas and to recontextualize them to taxonomy, from taxonomy to bird-counting, and from there to the ecology of the Wadden Sea. This teaching strategy was effective to achieve the learning-goals, but also to clarify the process of contextualization. By shifting from context to context, individual changes in the students' personal contexts could be made visible.

Most students were able to express their new thoughts and thinking processes in the group-work, as well as on the written test. It took me a while to realize that these verbal activities I observed, had two functions. First they revealed the classroom learning process. Second, but indirectly, the individual reflexive construction of new ideas was reflected in the students' utterances. It was only in the third and fourth round that I could see how qualitative changes took place in individual students' personal contexts. This, I believe now, is where learning occurs.

> *[T]he basic process here is the process of context making (which I will call contextualizing), which is an intellectual activity by itself, embedded*

> *in a current sociocultural activity.* (Van Oers, 1998, p.482, original italics)

It is just natural to introduce term *learning context* to refer to this personal context that changes in the process of learning.

Goal context and *learning context*, in my opinion, are fine candidates for further research and useful stepping stones for curriculum development. However, it is not obvious from this set of concepts that a goal context is an interpersonal, social-cultural construct, and that a learning context is not just a personal, but also an *actual* construct, dynamically changing in the process of learning. Both are human constructs of human actions, and both are prerequisite for the construction of meaning. Furthermore, they are reflexively related extremities of a social-cultural-individual continuum. To be able to assist students learning to construct meaning explicitly by contextualizing and conceptualizing key-concepts, the educational researcher must study and learn to work with the phenomenon that learning takes place in the dynamically changing *personal* contexts, and is only meaningful within a reflexively constructed *social* context. Even if the *curriculum* might appear as a rigid, determined 'object', a list of things to learn, *context* is not an object which can be clipped from a newspaper, and added or removed and replaced independent of the curriculum, and, notably, not independent of the student.

Hopefully, this article adds conceptual and empirical considerations to Van Oers' (1998) suggestions for further research, and accordingly makes a case for research into contextualization as a learning-activity. Developmental research into *guided contextualization* as an *educational strategy* should be part of that program.

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Science and the senses: An educational experiment at the Utrecht University Museum

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As an initiative to encourage children's interest in science, the University Museum has developed the *Youth Lab*. The purpose of the project is to develop a museal and educational laboratory that raises curiosity and interest in science of 10 to 14 year old children. The Lab should challenge children to explore the world around them, and give them an opportunity to 'peek over the shoulders of science.' In this paper we discuss the design philosophy of the Lab, the way we implemented our ideas in concrete laboratory assignments, and the first evaluation results.

Objective

It is our objective to develop an educational museum laboratory, using our collections, to bridge the gap between the natural curiosity of children (aged 10 to 14) and the study of science. The so-called *Youth Lab* should invite them to make a discovery trip into the world behind the things that surround us and peer over the shoulders of science. In doing so, they should get aware that studying science is a human pursuit and an important element of human culture.

Pedagogy

Beginning in 1993, a new structure has been implemented for lower secondary education in The Netherlands. This reform is termed the *Basisvorming* (Basic Secondary Education). There are 15 subjects, and for each subject learning objectives are stated in general terms: the so-called *core objectives*. The major change of the new educational system is not so much in the content of the lessons as in the way they are being taught. Here three keywords are crucial: application, skill, and cohesiveness. One aspect of the new approach is that pupils discover how they can solve many new problems themselves. More than it used to be, the issues are related to (the history of) the individual pupil's environment. In our opinion, the Basisvorming, and the associated core objectives offer many opportunities for various kinds of museum education.

The Youth Lab developed an educational setting to support this focus on solving new and challenging problems. Our learning approach starts from problem-based

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activities. The environment should encourage a child to learn-to-learn. Therefore, we could not simply add a museum lesson to a standard exhibition. Also, interactivity in the form of pre-cooked, press-the-button, experiments would not do. In the Youth Lab, visitors themselves have to create and implement experiments or parts of experiments. By working in this manner, we emphatically call on our visitors' own sense of enterprise.

Justification of the thematic approach

Despite the fact that Youth Lab is not an exhibition of our collections, the collection items – the raison d'être of our museum – figure prominently. In the pedagogical concept, their role is to support children's investigations, rather than being the starting point of the story. To make a visit to the Youth Lab an acceptable replacement for one or more classroom lessons, the lab activities must address some of the core objectives of the Basisvorming.

To establish a link between the collections of the museum and teaching, core objectives from nearly all school subjects, have been compared with the widely ranging collections of the University museum. In order to find as many fits as possible, we developed, in co-operation with the curators, a tiered model to represent the museum collection. Each tier or layer represents part of a collection. The core objectives that were felt to be relevant to it were written into it. In this way, we obtained a good idea of which collection(s) covered which core objectives. This resulted in two global themes going beyond the others: *observing* and *forces*.

Based on the starting point as regards content: illustrating science from a human perspective, the theme *observing* was chosen. For the target group, using your own senses is an entertaining and recognisable occupation.

The entire project covers all senses. For implementation, the theme has been subdivided into four phases: 1) seeing; 2) smelling and tasting; 3) hearing; 4) feeling. In the following sections we will mainly discuss the implementation of the first phase: *seeing*.

Pedagogical design

How does one translate the principle of problem-based activities into an instructional design? To be able to act in a problem-solving manner, there first has to be a problem or a question. In the Youth Lab, these are triggered through *marvels*: interactive exhibits which are situated in surroundings that children can identify: a kitchen, a bathroom and a living room.

Marvels are to be found all over the Youth Lab. Turn on the shower taps and you will see light rays in the water spray. Telephones emit odd smells and there is a refrigerator in which you can change the colour of the light (Figure 1). In the refrigerator, if the light is green, the meat and the tomato show black, whereas red light makes the meat look deliciously. This phenomenon triggers questions. What makes things change colour? How does it come about? As we do not expect physics-based answer from the pupils, the first lab-chart asks the children to colour fruit on a colouring picture with realistic colours, and then use coloured light to make the picture look like the fruit in the refrigerator again. In the second chart they are to unravel the composing colours of the ink in a felt-tip. Both lab charts are presented in the Appendix. To answer these questions and to do the experiments described on the lab charts, visitors return to their desk in the lab (Figure 2).

Figure 1. At the refrigerator.

The half open kitchen, bathroom and living room are centred around the laboratory, where each visitor has his own lab table. Once a question has been triggered by a marvel in one of the rooms, the visitor returns to the lab table to search for a solution. Answers can be found by doing the experiments and by looking for information. In each lab table, all the materials that are needed for the experiments can be found in a chest of drawers underneath the table. The visitors do not receive written instructions as to what they should do, but they have to look for the method to do the experiment and for information needed themselves. For example, they need to experiment with the *marvel* of the changing colours in the refrigerator and read the information that can be found near the marvel; in the kitchen this information can be found printed on milk cartons and jar labels, in the living room for instance CD boxes and newspapers would be lying around to present the background information. In addition, there are computers around the lab, which can be used to answer questions about the experiments and to provide backgrounds to the phenomena (short films, internet sites). Finally, visitors can print some worksheets and information for use in the lab or for experimenting at home.

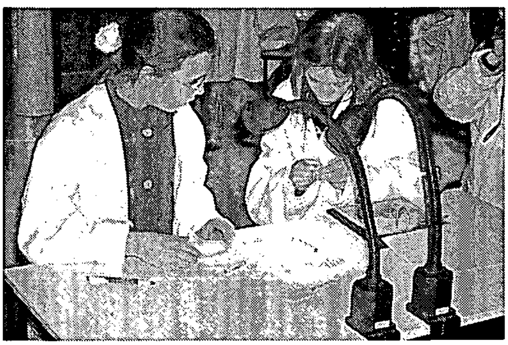

Figure 2. Back at the lab table.

Both the spatial layout of the Youth Lab, and the activities are designed to keep children from running around too much. Of course, it is important that children look around, but we want them to stop at the questions raised. We aim for more than the

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'oh, how beautiful and on-to-the-next' response. The interactive exhibits in the rooms are not the most important part. They are a means of getting the children to return to the lab to experiment. At the same time, we can use these situations to show what role science can play in our daily lives. The collections have been integrated into the background and serve as a reference and source of information. In the past scientists have used these objects for similar experiments. Thus, visitors discover that our ancestors were looking for the same answers, and that we in our daily lives make use of their findings and continue to build on them.

A visit

The Youth Lab has been specially equipped to accommodate group visits. It has a capacity for 32 children. Groups are welcomed and guided by *youth laboratory workers*. These are undergraduates from teacher-training colleges who have been trained by the educational department of the museum. One of the most important instructions they receive is that they should not *answer* questions, rather they are supposed to ask a question in return that gives the visitor some guidance, e.g. have you sought help from the computer helpdesk or have you tried at the marvel?

To distribute the group over the Youth Lab, the youth laboratory workers hand out different strips of paper indicating the places where visitors can *be marvelled*. Since the marvels have been integrated into the background, the indications refer to e.g. the refrigerator or the shower. At the particular spot, an icon points to the relevant experiment. After distributing the slips of paper, it is immediately apparent which groups have learned to tackle things on their own. Pupils taught in a traditional manner (teacher-centred) will sit back looking bewildered and waiting for further instructions. 'Teacher, what do you want me to do?' Once started, it shows that, given the opportunity, these children too are able to work independently.

What have we learnt so far from the Youth Lab?

At this moment, the Youth Lab has been operating for one and half years. From the start, the educational staff has made it a habit to regularly study *undercover* those visiting the Youth Lab. It soon became apparent, that the set up provided too little guidance. The lab charts on the tables did not mention the drawers holding the materials. The visitors were inclined to go through their neighbour's drawers when the particular object could not be found in their own drawers soon enough. The neighbour's drawers were then extensively searched, because, yes, it had to be there.

In the pedagogical design of the Youth Lab, we assumed that during the experiments the visitors would regularly return to the marvels, to check what precisely was happening. In reality, this did not happen. Once safely installed at the lab tables, they stayed at their table. Experimenting went along fine, but the extra information to be had at and from the marvels, remained a secret for many visitors. To improve the situation, we made the first question on the lab charts refer to the relevant marvel. Also, the new lab charts and the computer tips were made to refer to information present in the situations and in the computers.

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With these revisions, in our opinion the Youth Lab can provide an important contribution to teaching the children aged 10 to 14 how to learn. In the past one and a half years, 170 school groups and 35 undergraduate groups have visited the Youth Lab as a part of their studies. The responses have been promising. However, at the time our major problem is with the educational culture at school. In order to establish the Youth Lab, we have entered into co-operative arrangements with the teacher-training colleges in the Utrecht area. These co-operations made clear that prospective teachers have little knowledge of, and virtually no interest in, the field of nature and technology education. This is despite the fact that the subject is covered in their teacher training.

At the moment, students can graduate and become certified to teach Nature and Technology, even though their studies involved only one brief course on the subject. Of course, these teachers will be poorly motivated to come to the Youth Lab. After all, they have hardly an inkling of what it is all about. This factor, combined with a chronic shortage of teachers and with schools willing to come but short of funds or unable to find adequate supervision, explain why it is difficult to ensure full-time occupation of the Youth Lab.

This last problem, we have now started to tackle. We are now conducting a two-year pilot project in association with the other Utrecht museums and the city council, to attract all the groups from 10 Utrecht schools to the Youth Lab and other museum activities. The museums provide activities geared to each individual target group and the city pays for transport and other expenses. Our common objective is that we can provide 90% of the 120 Utrecht schools with these facilities. Of course, we will also continue our efforts to involve schools, students, and teachers. Two teacher-training colleges have now included in their curriculum either an internship at the Youth Lab or the development of educational materials for the Lab. We have also started in-service training courses for teachers of Nature and Technology. We naturally hope that schools and the governmental Department of Education will take steps to break the present tendency of disinterest in Nature and Technology. And as far as we are concerned, an annual museum card giving free entrance will help more here than getting your own email-address.

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Appendix. The refrigerator lab chart

First, paint the fruit on the colouring picture *fruit* (this is a print file), and next, try to make it look the same as it looked in the fridge. Then, go on experimenting to find out what is going on.

Experiment 1

What do you need?	*What do you do?*
• 3 Wax-chalks (red, blue, yellow) • Colouring picture *Fruit* • Colour filters (red, blue, yellow, green)	Do you know what colour this fruit has at the greengrocer's? Can you colour the fruit realistically with the colouring chalks? In the dark room are 3 lamps/light bulbs. Do you succeed in giving your fruit the same colour it had in the fridge by using one of the filters? And with two or three filters?

Experiment 2

What do you need?	*What do you do?*
• Felt-tipped markers • A strip of filtering paper • Black jar • Tooth picks	Put a small amount of water into the jar. Colour a thick dot on the strip of filtering paper. Do this for different colours. Hang the filtering paper in the jar with the dot above the water. Are there hidden colours in the marker colours?

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Ciência Viva: An initiative for scientific and technological culture

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Scientific and technological culture (STC) is now recognized as a decisive issue in the development of modern democratic societies. We all know that a real improvement in Scientific Literacy demands an unprecedented involvement of the scientific and educational communities. This is a practice that has been carried out and tested in a large-scale programme in Portugal over the past five years. This paper addresses the different strategies and solutions involved.

Introduction

Launched in June 1996, Ciência Viva[1] is a Portuguese Agency created by the Ministry of Science and Technology to promote public awareness of Science and Technology. In particular, the Agency promotes and supports science education projects at school, a Science and Technology Week, summer science activities for the general public. Another mainstream activity is the creation of a network of interactive Science Centres throughout the country, in collaboration with universities and local authorities.

Ciência Viva has been guided by two main principles: the primacy of school in the development of STC and the central role played by practical work in this process. Under the light of these principles, three aims were then established:

- To improve the science education of Portuguese school students through the inclusion of skills of observation and experimentation.
- To promote the dissemination of scientific and technological culture throughout Portuguese society.
- To set up networks of scientific, educational and industrial communities which can share resources, knowledge and strategies in order to promote the teaching of science in a more practical mode.

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Since we are looking at a global and slow transformation of mentality, to increase STC, among the population, a wide range of social actors had to be involved. This is why Ciência Viva was established as an open programme, promoting alliances and fostering autonomous actions. With these goals and principles in mind, Ciência Viva has developed the following instruments:

- A programme – Ciência Viva in School – to stimulate and support practical work and teaching for STC in Portuguese primary and secondary schools.
- A national network of Ciência Viva Centres—conceived not only as interactive environments for promoting public awareness of Science and Technology but also as regional scientific, cultural and economic development platforms, taking advantage of the most active participants in these regions.
- National scientific awareness campaigns, fostering the creation of science associations and providing the population with the opportunity to make scientific observations and to establish a direct and personal contact with experts in different fields of knowledge.

Teaching for scientific culture

One of Ciência Viva's main goals is to carry out and support actions in schools to promote the teaching of science through experimental activities. In order to achieve this goal, Ciência Viva launched, in 1996, a first call for action proposals to be developed in elementary and secondary schools. Based on the principle that a real improvement in a basic scientific education demands an unprecedented involvement of the scientific and educational communities, science and technology professionals, in partnership with educators, were invited to take on responsibilities aiming at improving science education in Portugal. All entities who have been developing relevant work in this area were mobilized to join efforts, in an articulated and supported way, to improve the scientific education of a larger number of students, providing them with conditions and motivation needed for critical experiment and observation, witch are fundamental for live learning of science.

This initiative intended to provide support to an interrelated group of actions to be developed in schools involving elementary and secondary teachers and students. The enlargement and reinforcement of this network has contributed to reinforce the relationship amongst the scientific, educational and industrial communities, in view of sharing resources and knowledge, which enhance the experimental teaching of science in schools.

The actions supported by this program could be presented by the following entities:

- teachers and schools or associations of elementary and secondary schools;
- associations or scientific societies;
- research and higher education institutions;
- student associations (secondary and higher education);
- companies that show interest in joining this program in order to present action proposals in partnership with elementary and secondary teachers and students;
- local councils and other entities with relevant work in this field.

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The proposals were examined and selected by a national multidisciplinary team of evaluators. The process, which is new in Europe in terms of the involvement of a diversity of participants, has also been followed and assessed by an international team of experts in science education.

The diversity of participants resulted in a great diversity of scientific areas covered and in different interactions amongst the proposers: Part of the projects was just school based and used their own human resources. The other part concerned actions involving different partners, some of which involve several institutions—schools, associations and scientific societies, companies, higher education institutions, natural parks and local authorities.

The participation of higher education and polytechnic institutions, research centres, associations and scientific societies has provided technical support and scientific and pedagogical education for elementary and secondary teachers and pupils. These actions took place both in schools and in their own laboratories. The selected companies were responsible for the technical support to the projects that used certain resources. In some cases the companies have had the initiative of developing the resources or allow teachers and students to use their premises under their technical supervision.

A selection of project titles will reflect the diversity of scientific areas covered: Life at the seashore, Geology in the countryside; Light, colour and vision; Synthetic minerals; Astronomy club; Physics in Action; Environment quality: measuring and controlling; From the cell to cheese production; Biological agriculture experiments; Interactive aquarium; Radioactive club; Mathematics without frontiers; Building a mininet to detect earthquakes; Molecular mass through via crioscopic; the Sound; Perpectual movement—the universe dance style; Science and technology from 6 to 16 years old; Discover the scientist in you.

The involvement of the scientific community in the development of science education projects in schools has created models of project management, which are new in basic and secondary schools. Partnerships and co-financing led to new forms of organization and interaction between basic and secondary teachers and other experts from different domains of science and technology. More detailed project descriptions are found at http://www.cienciaviva.mct.pt/concurso/bdprojectos/

Over the years this programme has experienced a continuous growth, as can be seen from Table 1.

Table 1. Evolution of Ciência Viva in Portuguese schools.

	Projects	Schools	Teachers	Students
1996/97	216	400	1200	35.000
1997/98	441	1300	3500	220.000
1998/99	799	2150	6000	280.000
1999/2000	871	2500	8000	380.000

The funding of science education projects carried out in schools on a yearly basis is complemented with a programme fostering the twinning between schools and scientific institutions and a programme for the scientific occupation of teenagers in research laboratories during holidays.

The *Twinning Schools—Scientific Institutions* programme aims at fostering the establishment of partnerships between the scientific community and primary and secondary schools, in such a way as to provide to both teenagers and teachers direct contact with the scientific practices in research and development institutions.

The participation of the scientific institutions in school activities and in the promotion of science has also been translated into the coordination and scientific follow-up of projects within the scope of the Ciência projects in schools and in offering training periods to teenagers during school holidays, within the scope of the Scientific Occupation Programme.

Within the scope of this programme the institutions have been developing scientific and technical consultancy activities in schools:

- technical and scientific support on the premises/refurbishment of laboratories, maintenance of scientific equipment, field trips;
- providing protocols and other materials for experimental work;
- access to the sources of information of institutions (libraries);
- joint organisation of activities for scientific promotion;
- specific support in the field of science (on-site or from a distance).

The Scientific Occupation for Teenagers during the Holidays programme, started in 1997, has provided secondary education students with the opportunity to be in close contact with the reality of scientific research work, through their participation in training sessions in public and private laboratories, research centres and entities for the promotion of science.

Within the context of the programme, teenagers participate in projects together with research teams and carry out laboratory activities under the supervision of specialised researchers and experts.

This initiative aims at promoting a new relationship between schools, research units and businesses, on the presupposition of the need to extend and deepen the education and scientific culture of youth.

The following procedures are used in this process:

- Research institutions are invited to present their proposals for research and practical activities to be carried out.
- Each school must organises, internally, the process, by naming one or more teachers, who will act as a mediator between the students and the institution, in a manner that will facilitate the contacts between the candidates and the selection mechanism.
- Each student may apply for more than one traineeship, but will only be allowed to attend one.
- Ciência Viva gives a grant per student, for each day of attendance of the traineeship, to meet expenses of transportation and food.

The development of this programme over the years is illustrated in Table 2.

Table 2. Institutions and scientists involved in the programme Scientific Occupation for Teenagers during the Holidays

	1997	1998	1999
Institutions	11	25	40
Researchers	45	98	161
Students	130	256	435

Ciência Viva for all

Summertime is extensively used by Ciência Viva to organize large scale campaigns aimed at promoting public awareness of science throughout the country. Through the organisation of scientific tours and events, the population is given the opportunity to actively observe and be in direct contact with scientists and experts in different fields. These activities – totally open and free – are focused on the concept of experimentation, seen here as a form of empirical confrontation of theory and practice.

Since 1996, these national campaigns have provided more than half a million people with an opportunity for scientific observation assisted by researchers and experts. Getting people closer to science often means taking science to people. The beach is, in Portugal, the top leisure environment in people's preferences during the summer. That is why the beach was chosen as the starting point for these actions. *Astronomy on the Beach*, in 1996, was the first example of an open and popular awareness campaign in Portugal. Professional and amateurs astronomers made their resources and knowledge available to more than 100.000 people in the Portuguese beaches.

Another important consequence was the growing interest of local councils in integrating these initiatives into their traditional and cultural activities, side by side with sport, theatre or music. Science dissemination started to be seen as a cultural and entertainment activity for the general public.

The human presence in the interaction between science and citizens is ensured by the direct involvement of experts, transforming these awareness campaigns into a decisive booster for the scientific association movement throughout different regions of the country. Astronomy and Geology in the summer became almost a social movement with the engagement of universities, scientific societies, research institutions, science clubs and high school organizations.

The financing of these activities by Ciência Viva has an important effect in the growth of the resources of these groups. The following figures seem to support this impression: between 1997 and 1998, we had a growth of the number of entities (90%), number of events (36%) and public (25%). Nevertheless, the total amount of financing involved had a reduction of 25%. This might be explained by the growth of the resources of these entities (telescopes and other equipment) and, consequently, a reduction of their needs in telescopes and equipment for the public astronomical observations.

The success of this initiative transformed it into a model that would be extended to other fields, such as Geology. The awareness of national georesources as well as the understanding of geological phenomena is particularly adapted to a model of scientific co-observation. Geology in the Summer was launched in 1998 and soon became a very popular initiative. During the months of August and September, different institutions promote activities aimed at creating an awareness of the Geology and geo-resources of the country. Through the organisation of scientific tours, the public is in direct interaction with scientists and experts who accompany the groups on different types of activities: field trips to the countryside, visiting places of interest from the geological point of view; urban Geology visits; visits to mines and quarries; as well as guided tours to museums and interactive exhibitions.

Following the goal of promoting direct contact between the public, science research institutions and their work, Ciência Viva organizes *Open Doors for Science and Technology* activities offering people the opportunity to get to know what kind of scientific knowledge is produced in Portugal, who are the Portuguese scientists, how they work and what they have accomplished. Using a logic of decentralization and autonomy, research centres, universities, schools and museums open their doors to the public with hundreds of initiatives. Only in the year 2000, 175 institutions have organized more than 722 events in 82 towns and villages throughout the country.

Another central activity of Ciência Viva is the development of a national network of Ciência Viva Centres, conceived as interactive centres for promoting awareness of science and technology. Established all over the country, they operate as regional scientific, cultural and economic development platforms, taking advantage of the most active participants in these regions.

Towards teaching for scientific literacy: Reflections after the symposium

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Centre for Science and Mathematics Education

The symposium *Teaching for Scientific Literacy* brought together a variety of European colleagues working on aspects of scientific literacy: curriculum policy, curriculum development, assessment, teacher training, informal education, environmental education and educational research. In this paper, based on my impressions during the symposium I will suggest some points for further discussion, reflect on the role of science educators between the world of science and the public, and propose directions for future work in this field.

Remaining points for discussion

Reading the papers of the contributors I was struck by the variety of ways the topic of scientific literacy was approached and the number of interesting issues raised. I almost felt the need for a reunion in which we could discuss the points which were not sufficiently dealt with during the symposium, several of which I only realised after ruminating the papers. Let me share with you some of these questions, not to criticize the authors but to feed future discussions on this topic.

Marjan Margadant states:

> *From a pedagogical perspective, it is undesirable that the goals of environmental education be determined by external authorities who are not an integral part of the community of learners taking centre stage in the educational process. In other words, the question is not what young people should know or be capable of doing—the embodiment of authoritative thinking and top-down management. (this volume p. 7).*

This is a strong statement which could be read as a plea for leaving it to the pupils what they should learn, also as regards scientific literacy. It is almost a rejection of curricula in general. Is that really what she means with this statement? Does she not value the contribution of educational and content experts in discussing the goals of scientific literacy? Wouldn't that lead to a 'supermarket' curriculum where the basket could be filled with any combination of products, which might fulfil the immediate needs of the customer but not result in a balanced diet? If 'the goal of forming literate people ... should shift to a focus on creating empowered citizens' (this volume p. 10) doesn't that require a carefully planned curriculum?

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Jonathan Osborne in his paper is very critical on current science education. Hardly any positive comments are made. He might do that from the viewpoint that 'teachers must be dissatisfied with the existing curriculum if the arguments for change are to be heard' (this volume p. 23). I also believe that a certain amount of dissatisfaction is required for change. But I do think that professionals need to be proud of the successes of themselves and of their colleagues. Many teachers I know do not appreciate academics which only emphasize the problems of science education. Shouldn't we as science educators also highlight the goodies of science education, not suggest that anything that is currently happening in science education is based on fallacies and make clear how the successes of science education could be used to improve even further?

Hanna Westbroek, Astrid Bulte and Albert Pilot refer to the learning of science novices by participating in a scientific community:

> *Learners within such programmes become involved in (research) problems that are 'meaningful' for the learner Notions of this aspect of the nature of science are of importance for secondary education. Scientific 'facts' are generated by groups of humans and are subject to change. (this volume p. 31)*

I wonder if such a comparison is valid. Working at the frontiers of scientific knowledge is different from learning science in school. Many of the scientific 'facts' in the science curriculum are less subject to change than most recent theories and students in schools are not in the position to reinvent all scientific knowledge which is incorporated in the curriculum. So in view of scientific literacy, what do they mean with 'notions of this aspect'? Does this refer to insight into aspects 'about science' (i.e. the processes by which scientific knowledge is generated) or to the learning of scientific knowledge itself?

Miia Rannikmäe concludes:

> *To effect teacher change, it is essential to use techniques similar to the writing workshop, which give teachers ownership of developed materials and teaching methods. (this volume p. 82)*

I do believe that such feelings of ownership do have a positive effect on teacher training, but would it really be feasible and necessary to train all teachers to develop their own teaching materials? Would that not require an enormous amount of time and lead to inventing the wheel repeatedly? What would be the lessons of her experiences with the workshops for teacher training courses which are more limited in time and have to cope with reasonable boundary conditions?

Carlos Catalão describes the ambitious and innovative Ciência Viva programme in Portugal. He illustrates the successes of the programme with the increase in numbers of participating institutions, schools, students and members of the public. Though impressive, it would be interesting to have more insight into the learning effects of the many activities of Ciência Viva. Would it be possible to report about the cognitive, affective and institutional learning effects?

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Daan van Weelie sets a good example of trying to define key concepts in his research study, such as *context* and *contextualizing*. In Steven Bakker's paper (p. 41) key concepts are *processes*, *skills*, *concepts*, *content*, *areas of application*, and *context*. I find it rather confusing that 'demonstrating understanding of scientific concepts' and 'understanding the nature of science' are labelled as a processes and I do not see a clear distinction between areas of application and contexts. Would it be possible to present a revised scheme of the dimensions of mathematical and scientific literacy in which definitions of key concepts are used which are more in line with current practice?

One of the problems Osborne refers to is that 'in seeking to make the important measurable, only the measurable has become important' (this volume p. 23). It would be interesting to hear his views on Steven Bakker's paper on the PISA-efforts to assess scientific literacy: which important goals of scientific literacy are not measurable and how to avoid that the PISA-assessment instruments push important goals to the background? On the same issue I would like to hear from Billy McClune and Ruth Jarman which contribution they could make to assessment of what students learn from the use of newspapers in science education.

Koos Kortland (this volume p. 87) uses a detailed didactical structure elaborated in a scenario in his study on teaching and learning about the waste issue. How could a teacher handle such a detailed scenario in normal teaching conditions? What would be the minimum of information which such a scenario should contain?

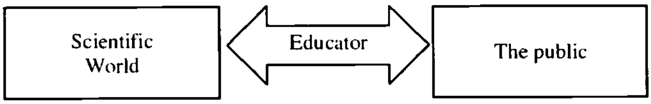
Erik Plomp describes experiences with the youth laboratory of the Utrecht University Museum. His learning experiences (this volume p. 117) refer mainly to difficulties with the open nature of the activities and to logistical problems to get pupils to the Museum. I would like to know how he views the role of his Museum in relation to what pupils learn in school. What could he offer which the schools can't and how should pupils be prepared to make the visit to the youth laboratory more effective?

Of course asking questions is only one, and possibly the easiest way to contribute to the discussions on scientific literacy. In the following two sections I will try to give answers on questions I posed myself after the symposium: What is the role of science educators in scientific literacy? and How to improve collaboration in the field of science literacy education?

The role of science educators in scientific literacy

In my view promoting scientific literacy means trying to make connections between the world of science and the public, which includes young people. Characteristic of the world of science, sometimes described as scientific culture (Solomon, 1997), are a large body of accepted scientific knowledge, a variety of processes by which scientific knowledge is generated and validated, a specific scientific language, motives and codes of conduct of scientists, the economic context of scientific research and the interaction with technology. The public could be characterized by a variety of human beings, in possession of common sense knowledge, mainly interested in living a life in which the basic human needs (food, shelter, safety and security) are fulfilled and in which the children have a promising future, with a language in which words have a variety of meanings which may change over time and living in a world which is increasingly depending on technological products based on scientific knowledge. Of course this characterization of both worlds is very global and could be further differentiated and refined for people living in different parts of the world and with different cultural and socio-economic background, but that is beyond the purpose of this paper.

In the literature on scientific literacy we can find a number of reasons to try and bridge this gap between both worlds, such as related to utility, democratic decision making, cultural awareness and attracting young people to scientific and technological careers (Millar, 1996). Jonathan Osborne (this volume) warns us for some fallacious assumptions in some of these areas. Science educators have as their main aim to improve education of the public in science and are therefore in my view mediates between both worlds (Figure 1).



One basic question then is which role science educators should fulfil in this field of promoting scientific literacy. Let me distinguish some different roles:

1. Information officer: science should be sold to the public by using appropriate marketing techniques in order to attract bright students to a science career and to enhance public support for science.
2. Critical awareness raiser: the public should be made aware of potential negative implications of science and technology and be prepared to support actions to counteract these negative implications.
3. Cultural ambassador: the public should know about the culture of science and should be brought in a position in which they are able to enjoy science, just like many people enjoy literature, music, dance and paintings.
4. Representative of the public: it is in the interest of the public to have knowledge in a variety of fields of science in order to live a comfortable life so specific knowledge which the public needs, is selected and presented.
5. Quality advisor: whatever the purpose of other actors between science and the public the science educator should contribute to an improvement of the quality of science education and communication.

This proposal to distinguish between various roles of science educators is not meant to promote a situation in which each science educator tries to limit its scope to one particular role, but rather to illustrate that a variety of positions is possible serving different interests. This may clarify the motives of those promoting scientific literacy. Roughly seen roles 1 and 3 are mainly serving the world of science, and 2 and 4 that of the public. Role 5 cannot be ascribed to a specific interest group. In reality a combination of roles is likely and one may therefore interpret the roles as emphases in the work as science educator. Personally, I am mainly motivated by roles 5 and 3, but none of the other roles is completely absent in my work as science

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educator. I can accept that other colleagues would put different emphases in their work.

On the other hand I would argue that role 5 is essential in the work of any science educator. Who else could take this responsibility? What could this role encompass in view of scientific literacy:

- To guard that science education is seen as worthwhile by scientists and the public: is it relevant for life and related to developments in science?
- To clarify the motives to educate for scientific literacy: is it to attract more science students or for utility/democratic/cultural reasons?
- To guard that education for scientific literacy is effective: is it suitable for the target group and what are the learning effects?
- To check that new proposals are feasible in current conditions: is it possible to reach the aims within constraints such as time, expertise and resources?
- To translate relevant scientific content into teaching and learning strategies: how to design suitable pupil and teacher activities and an appropriate order of these activities?
- To use experiences with education for scientific literacy elsewhere: which similar educational experiences could be used in order to enhance the quality of the work?

Suggestions for further work

From the symposium presentations and the literature I am familiar with in this field (AAAS, 1989; Solomon & Aikenhead, 1994; Levinson & Thomas, 1997; Sjøberg & Kallerud, 1997; Coughlan, 1999; Cross & Fensham, 2000) it is clear that scientific literacy is high on the agenda of those developing programmes for formal and informal education in many countries. Although traditions in these countries vary, I have the impression that a large number of similarities exist in solving problems in the field of design, evaluation and implementation of scientific literacy education. Symposia like this one offer an opportunity to exchange experiences and to learn from each other. But in my view that is not sufficient for progress in this field as we report on experiences afterwards and do not decide together what the main problems are and how we could tackle them in a collaborative way. Therefore I hope that symposia such as these could stimulate the development of a common (European) programme on the development of scientific literacy. It should start with a comprehensive review of the present state of affairs and an identification of important common problems. Let me roughly sketch some potential areas of common efforts:

- The development of a common language to discuss these issues: what do we mean with terms such as scientific (and technological) literacy, public understanding of science, awareness of science, science culture, science and the citizen?
- The development and use of procedures to select contents which serve scientific literacy (see for instance Law et al, 2000).
- The development and evaluation of teaching strategies.

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- The development and implementation of professional development of teachers in this field.
- The development of means to assess scientific literacy (OECD/PISA, 1999).
- The development of suitable activities which link formal and informal science education.
- The development of common quality standards for teaching scientific literacy.

I would expect that a common programme in this area would prevent a situation in which efforts are duplicated and unrelated. A comprehensive programme might be attractive for potential sponsors for this type of work. This Centre is certainly willing to discuss the possibilities for such a programme with interested partners.

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