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ABSTRACT

This paper discusses the difficulties in transforming the knowledge of science into school knowledge, which is based on the interconnection of scientists/researchers, teachers, and students. Some factors should be taken into consideration during the transformation of scientific knowledge into school knowledge, including the complexity of science tools, limits of human senses, and students' mental capacities. (Contains 21 references.) (YDS)

Difficulties in Transforming the Knowledge of Science into School Knowledge

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INTRODUCTION

During the last decades, more and more people have become increasingly dependent on complex technology. Therefore, it might be expected that there would be a continuously increasing interest in subjects being at the core of science and technology. Instead, the literacy in science is remarkably low (Physics on stage, Project description, 2000).

In Greece, research addressed to the student population revealed that Secondary school students characterize physics as one of the most difficult and least favorable subjects found in secondary school programs of study (Halkia and Karanicas 1999).

We believe that this situation is largely due to the difficulties now facing the transformation of the knowledge of science into school knowledge. The designers of science curricula, and consequently the science textbook writers, often do not take these difficulties into consideration in primary and secondary education. This is primarily the reason why, although a lot of class hours are spent in teaching science, it is usually with poor results in student performance and interest.

The core of these difficulties depends upon three interconnected parameters: the scientists–researchers, the teachers and the students (Kariotoglou 2001). These three parameters have quite different conceptions about the nature of science, as well as a quite different interest in science; sometimes they converge and at other times they diverge from one another.

The scientists–researchers are the "producers" of scientific knowledge, they possess the scientific methodology and they can keep track of the technological products and the scientific principles on which these products are based. The teachers– educators are the "negotiators transformers" of scientific knowledge into school knowledge. They decide which concepts of science should be taught in classrooms today and they possess the educational methodology to teach these concepts properly. The students are targeted as the "consumers receivers" of this scientific knowledge. They have their own interests in special scientific regions; they also have their own way of perceiving the physical world, which is very different from that of the scientists. They cannot easily keep track of the scientific principles and the final technological products and the scientific laws and principles on which these products are based.

Thus, there is a gap between the knowledge of science as it has been constructed over the last five centuries and is continuously produced today in Laboratories, Institutions and Universities and the subject of science as it is taught in science classrooms.

FACTORS HINDERING THE TRANSFORMATION OF SCIENTIFIC KNOWLEDGE INTO SCHOOL KNOWLEDGE

Science is a complex subject to be made accessible to primary and secondary school students. It presupposes the mastery of certain skills and a special way of thinking. Yet it is crucial for the understanding of our world and human civilization. Thus, the way scientific knowledge is transformed into school knowledge demands serious thought, careful design and skillful treatment.

In achieving that transformation, some of the crucial factors to be taken into consideration are:

- *The limits of the human senses as the first and prime medium used to study the world:* Through these senses, the student perceives the world, observes it carefully and constructs – mainly subconsciously – his/her first and most powerful theory of the world's functions (Harlen 1986). But, while human senses are the prime medium used to study the world, science extrapolates this study beyond the capabilities of those senses. Thus, a very small part of the information coming from the entire world surrounding us is actually perceived by the human senses. The major part of the crucial information is perceived through the aid of special instruments and apparatus, which are considered to be the extension of man's physical senses. The scientific theories are based and verified on the entire information spectrum perceived from the world around us and presuppose that the receivers can create specific representations of these theories. The understanding of the microcosm or the macrocosm demands: a) the extension of the world's representations based on common experience, and b) as a result of that, the creation of abstractive models of the world's functions.
- *The complexity of science tools (experimental methodology and mathematics) necessary to understand the physical world and the laws conditioning that world:* These tools are intrinsic parts of students' science understanding. The proper use of these tools presupposes the mastering of mental and practical skills, which is the result of many years of effort. The students' acquaintance with these tools should gradually follow their age potentialities. Thus, students could understand the importance of these tools in formulating final scientific conclusions. Unfortunately, in science classrooms, an effective way of making students properly conversant with these tools has not yet been reached, although from time to time some innovative suggestions have been attempted. In many instances, the application of these suggestions has failed because of teachers' weakness in making use of these suggestions (Nuffield Science Projects 1966).

- *The students' mental capabilities:* Frequently, the mastering of the complex tools of science (e.g. integral calculus), as well as the ability to follow the syllogisms leading to the inspiration of science theories (e.g. Quantum Mechanics), overcome students capabilities. Most students of school age have not yet reached the level of abstract reasoning necessary to understand the mathematical formalism and the rhetoric of science (Piaget 1953). Science curriculums and science textbooks often target higher levels of thinking than those of the addressed student' population (Adey 1994). This creates feelings of inadequacy in students studying science and is one of the crucial factors in causing negative attitudes towards science.
- *The students' preexisting ideas about the world:* Students come to school having already shaped specific conceptions (mainly alternative conceptions) about the way the world functions (Driver 1983). These conceptions usually diverge from those of the accepted scientific model and present very strong resistance to any change, since they have been shaped through personal experience.
- *The everyday language used in education to explain the formalistic language of science:* The language of science is mainly formalistic and is dominated by mathematics. It consists of the communication code between science researchers and science teachers and corresponds to a "mental language". On the other hand, to teach science in primary and secondary education demands the frequent use of everyday language as a means of communication between science teachers and their students, which is a "sentimental language" (Guiraud 1989). In science classrooms, the teachers use the everyday language as a mediator between the code of science and the communication code of students (Sutton 1992). The description of science concepts and the explanation of physical laws in everyday language cause some problems. Often it can strengthen students' alternative conceptions, since everyday language is expressed and is affected by the everyday experiences in the natural world. In addition, everyday language is affected by social experiences too (Solomon 1987). Thus, it carries an ideological "load" which is culturally determined. As a result, it introduces an additional "noise" in teaching the concepts of science (Guiraud 1989).
- *The positivistic view of science:* Science has been established for five centuries. During these centuries, especially in 20th century, it has been succeeded an enormous accumulation of knowledge in several areas. Because of that fact, there is pressure to transmit a significant part of that knowledge in primary and secondary education. The efforts to teach as much science as possible in science classrooms have forced the curriculum designers to present the "knowledge" in a condensed form. This has led to the domination of an undisputed positivism, which has been diffused throughout science textbooks and science teaching. Thus students get the notion that science is not a continuously developing body of knowledge, but a finished one; the reverse of the modern conception of what science really is. On the other hand, students are unprepared to manage the postmodern view of the rela-

tivism in science and are led to confusion. Thus, in science classrooms, the appropriate stimulus must be offered to students so that they realize that science is a continuously developing body of knowledge and is ready to be modified if such an indication results from research (Koulaidis and Ogborn 1994). Only then would they assimilate the fact that science is realistic, it follows processes which obey rational syllogisms and produce reliable knowledge (Longbottom and Butler1999).

- *The notions of science researchers (producers of science knowledge) about school science and their intensions to intervene in education:* Recently, there has been a growing interest by the researchers in several fields of science, working in Institutes and Universities, in educational matters. They often make suggestions about the kind of science content that should be taught in primary and secondary education. Usually they push for more and more content be included in the school science curricula and since they are people with high prestige, their opinion counts. They are experts in science, but they have not studied the didactics of science. So, their suggestions are lacking in didactical effectiveness and their decisions block the attempts of the designers of science curricula.
- *The plethora of information ("knowledge") contained in science curricula:* There is a tendency, especially by the science researchers of the university community, to press the educators to include in science school–curricula most of the recent scientific findings. Thus, it is now being attempted to transfer to secondary education, regions of scientific knowledge, which a decade ago were taught in universities. The argument for this descent of science knowledge, from universities to secondary education, is that in such a way students would be taught more modern and interesting subjects. But an argument like that ignores the fact that the main goal is to teach and not just to inform. Most of this kind of suggested science knowledge demands a highly abstract way of thinking and strenuous efforts to be made. The limited time of school science teaching hours imposes a strict assessment of science concepts to be taught. In such a way, students would assimilate these concepts and acquire the necessary framework of science knowledge, which will enable them later to understand more complex scientific theories, as well as to enjoy the peculiarities of scientific thinking. But, the educators and the curriculum designers have often proved unable to evaluate concepts of science that should be taught in primary and secondary education and they continuously try to include in science curricula as many science concepts as possible. This practice has forced students to memorize the final results, instead of studying the process of the syllogisms that led to those results (Arons1990).
- *The icons, the images, the simulations, the metaphors, the models and every kind of effort to bring the functions of an unseen world closer to our experience:* One of the main aims of science education is to make students able to construct a firm conceptual framework, which would help them to understand the way natural phenomena function. Thus, the educators try to create communication channels with stu-

dents' cognitive schemata; they try to find ways to make the functioning of invisible physical phenomena (microcosm, macrocosm) easily accessible to students' senses and experiences. But sometimes, these representations can create misinterpretations in the student's mind, or displace their interest to elements irrelevant to science concepts (Halkia et al 1998).

- *Teachers' notions and attitudes towards science and the teaching of science:* Many teachers have a limited knowledge of the didactics of science and they automatically repeat practices of the past (Halkia 1999). On the other hand, in science classrooms, teachers are trying to verify their status as scientists–researchers, denying their status as teachers. Their educational practices are confined to the utilization of a strict mathematical formalism interspersed with some empirical efforts of science popularization. Thus, they are trying to balance between practices of codifying science knowledge and techniques of solving exercises on one side, and efforts to help students to construct a firm conceptual framework on the other.
- *A lack of correlation between the teaching of science theories and the "authentic" problems of the physical world encountered in everyday life:* One of the main issues in science education is the achievement of problem solving in science classrooms (Dushl 1999). The problem–solving process is not an easy task; it demands strenuous efforts and mental discipline from students. That is why students are involved in such a process, only when it seems "meaningful" to them. For students, "meaningful" problems are those which are directly correlated with everyday life. These kinds of problems they consider as "authentic" and as worthwhile to be engaged in and to solve (Whitebread 1997). But, since the problems of everyday life are quite complex and are dependent by a number of components, the educators are forced to limit the number of these components in order to make them easily managed by the students in the science classrooms (Gott and Mashiter 1994). Such an approach makes these problems much easier for students, but at the same time it makes them unrealistic, less attractive and meaningless to them.
- *The historical development of the rhetoric and the concepts of science do not necessarily follow the mental development of students:* For some time it has been believed that the way the concepts of science are assimilated by school students is similar to the way these concepts have been constructed. For this reason, most science curriculums and textbooks follow the historic evolution of science concepts. But as recent researches show, the historic course of the construction of science concepts must not be taken for granted when these concepts are going to be exposed in primary and secondary education (Seroglou and Koumaras 2001, Nersessian 1994, Thagart 1992). A reason for that is that the historic evolution of science knowledge did not follow a linear mental course, but in many cases was dictated by necessities of the corresponding historic period, like technological potentialities, social requirements, cultural traditions etc. On the other hand, students do not necessarily possess the same mental skills and the same conceptual representations of

the world as the scientists of the corresponding historical period did. Thus it might be much easier for them if the scientific knowledge was to be presented in a more structured form. Maybe the designers of science curricula should propose a reconstruction of the historical conceptual sequence of science to be taught in schools.

COMMENTS

As has been above exposed, the transformation of the knowledge of science into school knowledge is faced with a series of hindering factors. Maybe these factors are the cause of the students' inability to enjoy the subject of science, to follow the syllogisms which lead to the understanding of the functioning of the natural world, and to gain the necessary science knowledge which in future will distinguish them as scientifically literate citizens. The peculiar thing is that while the negative attitude of students towards science is a common experience in science classrooms, everybody takes it for granted because of a long teaching tradition. On the contrary, we too easily blame students themselves for their negative feelings towards science, attributing these feelings to their indifference, to their social values etc. At the same time, the majority of the educational community seems to have been relaxed in routine– practices of the past, which are in favor of a linear accumulation of "knowledge–information" in the subject of science. It seems to be the right time now to face the difficulties mentioned above and to dare radical solutions in primary and secondary science education. But in applying innovations in science classrooms, the willing participation of the educational as well as the scientific community is needed.

Thus, it is necessary to explore alternative ways of approaching the scientific way of thinking. We believe that the absolute minimum of science education should result in all students leaving school with positive attitudes towards science. In achieving that we should try to offer them a variety of ways of exploring science. These ways would refer to different codes of communication suitable for different student personalities and interests. But in doing this we need the aid of the researchers in science education, as well as much more flexible science curricula.

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