Chapter 2

Rationale and theoretical Background

Introduction

In a global survey of the official curricular requirements for primary schools, Meyer and Kamens (1992) suggested that there is an international convergence in official statements of national curricula. They found that there are great similarities in the subject areas taught and the time given to them, despite the variety in cultural and historical backgrounds of the different countries. In addition, they noticed that there was a tendency for changes in curricula in particular countries to parallel each other and to take the form of conformity to world curricular patterns. It would seem that the various natioanl curricula are, in reality, merging into an international curriculum for the 21st century (Newton and Newton, 1998). Furthermore, at the heart of such an internationally relevant curriculum lies scientific literacy.

In addition, the AAAS report *Science for All Americans* argued that:

> *"the present science textbooks and method of instruction, far from helping, often actually impede progress toward science literacy. They emphasize the learning of answers more than the exploration of questions, memory at the expense of critical thought, bits and pieces of information instead of understandings in context, reciatation over argument, reading in lieu of doing. They fail to encourage students to work together, to share ideas and information freely with each other, or to use moderninstruemnts to extend their intellectual capabilities".*

In recent years, there has been increased stress on metacognitive awareness and epistemological development as important goals for science education (White & Gunstone, 1989). The relationship between student science learning and their understanding of the nature of science has caught the attention of science educators. Moreover, understanding the nature of science has been regarded as one of the basic requirements for scientific literacy and an ultimate goal of science education (AAAS, 1990. NRC, 1996)).

Mathews (1998) reported in the International Handbook of Science Education that in the 1980s and 1990s, knowledge of the nature of science was written into most definitions of science literacy. In 1993, Yvonne Meichtry (1993, p. 429) wrote: „The definitions of scientific literacy reported in the literature over the past three decades all emphasize the importance of an understanding of the nature of science.

6 Definitions of Science Literacy and Understanding of Science

What is the need for Science Literacy? The report *science for All Americans* (AAAS, 1991) claimed that America's future- its ability to create a truly just society, to sustain its economic vitality and to remain secure in a world torn by hostilites- depends more than ever on the character and quality of the education that the nation provides for all its children. Moreover, science education should help students to develop the unserstandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on.

In *Science for all Americans* (AAAS, 1989), the meaning and importnace of the nature of science are extensively described. Indeed, this seminal reform document describes a scientifically literate person as one who:

> *„uses scientific knowledge and scientific ways of thinking for individual and social purposes (AAAS, 1990) and 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" (AAAS, 1991).*

PISA (2000)- the Programme for International Student Assessment -is an international large-scale assessment study. It was initiated by the Organization for Economic Cooperation and Development (OECD) and which provides the OECD member countries with internationally comparable data about their educational systems.

PISA is a long-term project, planned to span three assessment cycles. Each cycle covers the three domains of reading literacy, mathematical literacy and scientific literacy.
The assessment for the first cycle took place in 2000, with aprimary focus on reading literacy. The second cycle focused on mathematical literacy and is assessed in 2003. finally, the third cycle will assess scientific literacy in 2006. The students representative samples are selected from a 15-year-olds populationenrolled in educational institutions. In fact, youth of this age group are nearing the end of compulsory education in almost all OECD countries. Only the German sample consists of 5.073 students from 219 schools; on average, 23 15-year-olds were tested per school (PISA, 2000).

What were the most significant performance results in scientific literacy in 2000 in Germany?

- Only just over 3% of students are proficient at Level V (expert level) of the SL scale. More than one-quarter of 15-year-olds perform at Level I (elementary level) of the scale. They have reached only an elementary level of scientific literacy and are capable only of reproducing simple factual knowledge and using everyday knowldege to draw and evaluate conclusion (PISA, 2000).
- In the sceintific domain, too, Germany is evidently less successful than other countries in providing support for weak students.
- Students in Germany show considerable weakness in scientific understanding and in applying scientific knowldege. These results indicate that German science instruction is still not sufficiently geared to problem solving and practical applications.
- No consistent gender differences emerged for the international scientific literacy test. When analysing test results for the individual subjects separately, however, it becomes apparent that male students in Germany outperform their female counterparts in physics and chemistry.

The focus of OECD/PISA is that students should be *scientifically literate*, which is considered the essential outcome of science education. How does PISA (2000) define scientific literacy?

> *"Scientific literacy includes an understanding of fundamental scientific concepts such as energy conservation, adaptation and decay, familiarity with scientific ways of thinking and working, and the ability to apply this knowledge of scientific concepts and processes, particularly to evaluate aspects of science and technology. It also*

requires the ability to identify questions that can be answered by scientific enquiry and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and changes made to it through human activity".

OECD/PISA Germany (2003) defines Science Literacy or „Naturwissenschaftliche Grundbildung“ as follow (for the German version, Appendix A):

"Scientific literacy is the capacity to use science 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 through human activity".

Furthermore, the OECD/PISA (2003) definition of SL comprises 3 aspects:

- *scientific processes* which, because these are scientific, will involve knowledge of science, although in the assessment this knowledge must not form the major barrier to success;
- *scientific concepts,* the understanding of which will be assessed by application in certain content areas; and
- *situations* within which the assessment tasks are presented (this aspect is often referred to in common usage as the "context" or "setting".

Gräber (2002, p. 144) reported that since the 70th, there has been in Germany a real discussion about scientific literacy (SL), where it was developed among others by Gerda Freise and Peter Buck. Presently, it has been isolated case studies, such as, the Project Schule/Ethik/Technologie (SET) of the Schallies workgroup (Schallies, Wellensiek et al, 1999), which stressed on the development of moral competencies by Grade 8 students. Note that the nature of science understanding of Schallies and Wellensiek (Schallies et al, 2002) are summarized in 4 points:

1. To use – besides factual and instrumental knowledge – purposefully ethics as a means of reflection
2. To recognize problems in the field of new technologies as interdisciplinary problems which could be solved only in an interdisciplinary effort
3. To recognise science as a methodical endeavor to achieve knowledge *and* a social system for acting
4. To identify and take into account the difference between technological approach (a certain technology is taken for granted and applied to the problem) and problem-oriented approach (all alternative technologioes available are taken into consideration) for solving problems.

In the SET Project, the researchers aimed to help secondary students in developing abilities for understanding biotechnology/ genetic engineering. The outlines of the case study were the planning of classroom activities with refernce to cognitive and moral development of students (Schallies and Lembens, 2002).

The most consistent defintion of Understanding of Science to my vision of teaching science for the 10-12 year-olds sample is the following:
For an "appropriate understanding"of science (Wellensiek, 1998; Dietrich, 1998):

- is knowlede of facts, understanding of how to use them, and need ethics for the reflective processes and use it deliberately
- is understanding science as a methodical endeavor to achieve knowledge and a human activity with effects on society, and dependant on instiutions
- is understanding problems of technologies as interdisciplinary, and to solve them in that manner.

7 Definition of Nature of Science

McComas and Olson (1998) started their project with the belief that a single scientific tradition unites humankind. These researchers reviewed eight leading scientific standards documents in the English-speaking countries for their recommendations relative to the nature of science, such as, Curriculum Corporation [Australia], AAAS [Benchmarks], 1993, California Framework, 1990, Council of Ministers of Education [Canada], 1996. These researchers concluded that four major disciplines seem to provide insights regarding the nature of science. These disciplines include the philosophy, history, sociology and psychology of science. Moreover, this study provides an empirical basis of validation of the authors' prior expectations, that philosophy alone is not the sole discipline contributing to a description of how science operates, or in other words, that the nature of science as applied by science educators is not a synonym for the philosophy of science alone. Another interesting conclusion of the study is that the standards documents which include aspects of nature of science vocabulary (i.e., law, theory, etc.) generally fail to define these terms.

Figure 1 represents an approximation of the degree to which each of the four disciplines adds to knowledge of how science operates.

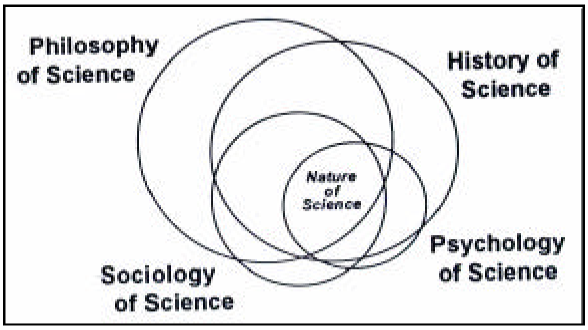

Figure 1. A proposal for the disciplines that add to our undertsanding of the nature of science based on a context review of various science education standards documents. The approximate extent to which each discipline contributes is represented by the relative sizes of the circles. A description of science – the nature of science – is found at the intersection of these various disciplines.

Concerning the history of science category, all documents refer to science as a social tradition. Seven documents state that science has global implications, and five mention the important role that science has played in the development of technology. Also stated in six documents is the effect that social and historical contexts have on the development of scientific ideas. Interestingly, four documents include a statement which refer to the frequent rejection of new ideas by the rest of the scientific community.

In the introduction chapter of *Science for All Americans* or SFAA (AAAS, 1991) about the nature of science stated the following:

"over the course of human history, people have developed many interconnected and validated ideas about the physical, biological, psychological, and social worlds. Those ideas have enabled successive generations to achieve an increasingly comprehensive and reliable understanding of the human species and its environemnt. The means used to develop these ideas are particular ways of observing, thinking, experimenting, and validating. These ways, represent a fundamental aspect of the nature of science and reflect how science tends to differ from other modes of knowing.

It is the union of science, mathematics, and technology that forms the sceintific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the others".

This same report focuses on three principal subjects related to the NOS: the scientific world view, scientific methods of inquiry, and the natture of the scientific enterprise.

The scientific world view aspects are:
1. The world is understandable.
2. Scientific ideas are subject to change.
3. Scientific knowledge is durable.
4. Science cannot provide complete answers to all questions.

The scientific inquiry aspects are:
1. Science demands evidence.
2. Science is a blend of logic and imagination.
3. Science explains and predicts.
4. Scientists try to identify and avoid bias.
5. Science is not authoritarian.

The scientific enterprise aspects are:
1. Science is a complex social activity.
2. Science is organized into content disciplines and is conducted in various intitutions.
3. There are generally accepted ethical principles in the conduct of science.
4. Scientists participate in public affairs both as specialists and as citizens.

The British science education reseachers Ryder, Leach and Driver (1997) define the nature of science, in a paper presented at the symposium "New Perspectives on Conceptual Change in Science and Mathematics Learning" at the American Educational research Association Annual Conference in Chicago, USA, as follow:

"knowledge relating to science to science may be seen as involving two interrelated areas. Knowledge *of* science involves the laws, models, theories, concepts, ideas, experiemntal techniques and procedures of science. such knowledge forms the basis of undergraduate science curricula. However, there is also knowledge which is under the surface of scientific activity and science curricula: knowldege about how scientists decide which questions to investigate, how scientists interpret data they have collected, how scientists decide whether or not to believe findings published in research journals. Such knowldege refers to *the nature of science."*

In the United States, Lederman' nature of science (1992) refers to the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge. Noting that the epistemology of science is the study of the origin, nature, and limits of human knowledge (Britannica, 1991).

The aspects that Adb-El-Khalick, Bell & Lederman (1998) believe they are accessible to K-12 students and relevant to their daily lives are that scientific knowledge is tentative (subject to change), empirically-based (based on and/or derived from observations of the natural world), theory-laden (subjective), partially based on human inference, imagination, and creativity (involves the invention of explanations), and socially and culturally embedded. Two additional important aspects are **the distinction between observation and inference**, and the functions of, and relationship between scientific theories and laws.

In sum, The Nature of Science aspects to introduce in my study are: *Science knowledge as a human activity* and *reflecting on self-learning process*. I've considered these 2 aspects because students of this age group (10-12) started: 1. to learn science or the ready knowledge found in the science books, 2. their beliefs about science started to be shaped and 3. where there no emphasis in initiating students on expressing their opinions on learning neither initiating students to learn to be aware how they learn.