A QUANTITATIVE ANALYSIS OF GREEK PHYSICS TEXTBOOKS WITH RESPECT TO SCIENTIFIC LITERACY

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Abstract
This study examines – through a content analysis method for textbooks – the Greek lower Secondary Education science textbooks, as regards the general objectives of the Greek Curriculum concerning scientific literacy. Textbooks are analyzed with respect to their serving four aspects of scientific literacy: 1) the knowledge of science, 2) the investigative nature of science, 3) the knowledge about science and 4) the interaction among science, technology and society. The quantitative analysis of the textbooks reached the conclusion that the Greek science textbooks mainly focus on “the knowledge of science” aspect, whereas the other three aspects of scientific literacy stated in the general objectives of the Greek curriculum, are practically missing in all textbooks investigated.

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1. Introduction

1.1-Defining Scientific Literacy

The idea of scientific literacy has been used by science educators for more than 50 years, since the early 1950s. It has been a prominent feature of science education since the 1960s. In spite of this, many still seek clarification of this term (Bybee, 1997).

In the mid 60s Pella, O’Heam and Gale reviewed a hundred documents in an attempt to define what constituted a scientifically literate person. As it is stated by Wilkinson (1999), their analysis led them to suggest that the scientifically literate person is the one who is characterized by an understanding of the "... (a) basic concepts of science, (b) nature of science, (c) ethics that control the scientist in his work, (d) interrelationships of science and society, (e) interrelationships of science and the humanities, and, (f) differences between science and technology." (Wilkinson, 1999)

According to the American Association for the Advancement of Science (AAAS) report, Science for All Americans, the scientifically 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”. (AAAS, 1989)

The International Forum on Scientific and Technological Literacy for All, organized by UNESCO in 1993, offered a variety of views of scientific literacy, such as: “The capability to function with understanding and confidence, and at appropriate levels, in ways that bring about empowerment in the made world and in the world of scientific and technological ideas.” (OECD, 2003)

More recently – in 1996 – in the United States the National Science Education Standards defined scientific literacy as, "... the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. It also includes specific types of abilities." (Wilkinson, 1999)

As it is stated by De Boer (2000), the most significant critic of such a broad and wide-ranging interpretation of scientific literacy has been Morris Shamos. Shamos argues that efforts to achieve scientific literacy are futile and a waste of valuable resources. He says it is naive to think that our students can learn to think like scientists. The science-related social issues that might interest students often have very little science associated with them, and when they do it is at a level too complex for students to understand. He says that empowering individuals to make rational, independent judgments on science-related social issues is impractical. Instead, the most important thing is to give people access to responsible, expert advice on such issues. (De Boer, 2000)

Shamos also suggests a clarification of the meaning of scientific literacy in order to aid educators and scientists in redirecting their efforts to make it attainable for all people. For that reason he proposes three levels of literacy, each progressively more sophisticated. These levels are: Cultural Scientific Literacy, Functional Scientific Literacy and “True” Scientific Literacy. The lowest level is the simplest and refers to the kind of factual scientific information which people need to read newspapers, magazines, popular science books and to follow electronic media reports about scientific topics. It involves a rote recall rather than an understanding of the terms. Functional Scientific Literacy adds some genuine understanding to basic facts of science. Not before reaching Shamos’ third level, “True” Scientific Literacy, can individuals be counted upon to really know something about the theories of science and how they have been arrived.
Shamos estimates that only four to five percent of the adult population functions at this level, and most of them are scientists and engineers. (Evans, 1997)

Under Shamos' proposal, scientific literacy would mean: (a) having an awareness of how the science/technology enterprise works, (b) having the public feel comfortable with knowing what science is about, even though it may not know much about science, (c) having the public understand what can be expected from science, and (d) knowing how public opinion can best be heard in respect to the enterprise . . . " (De Boer, 2000)

After a historical review George De Boer (2000) summarizes the goals for teaching science under the following nine statements:

1. Teaching and Learning about Science as a Cultural Force in the Modern World.
2. Preparation for the World of Work.
3. Teaching and Learning about Science That Has Direct Application to Everyday Living.
4. Teaching Students to be Informed Citizens.
5. Learning about Science as a Particular Way of Examining the Natural World.
7. Learning About Science for its Aesthetic Appeal.
8. Preparing Citizens who are Sympathetic to Science.

OECD/PISA science framework defines scientific literacy as follows: “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”. (OECD, 2003)

The debate on an appropriate meaning for scientific literacy is still in progress (Bybee, 1997; De Boer, 2000).

1.2-OECD/PISA definition of Scientific Literacy

The following remarks are stated in the official site of OECD and they intend to explain the meaning enclosed in the definition of scientific literacy according to OECD/PISA:

“Scientific Literacy…

It is important to emphasize not only that both scientific knowledge (in the sense of knowledge about science) and processes by which this knowledge is developed are essential for scientific literacy, but that they are bound together in this understanding of the term. The processes are only scientific when they are used in relation to the subject matter of science. Thus, using scientific processes necessarily involves some understanding of the scientific subject matter. The view of scientific literacy adopted here acknowledges this combination of ways of thinking about, and understanding, the scientific aspects of the world.

…use scientific knowledge to identify questions and to draw evidence-based conclusions…

In the above definition, scientific knowledge is used to mean far more than knowledge of facts, names and terms. It includes understanding of fundamental scientific concepts, the limitations of scientific knowledge and the nature of science as a human activity. The questions to be identified are those that can be answered by scientific enquiry, implying knowledge about science as well as about the scientific aspects of specific topics. Drawing evidence-based conclusions means knowing and applying processes of selecting and evaluating information and data, whilst recognizing that there is often not sufficient information to draw definite conclusions,
thus making it necessary to speculate, cautiously and consciously, about information that is available.

...understanding and help make decisions...

This phrase indicates first, that an understanding of the natural world is valued as a goal in itself as well as being necessary for decision-making and, second, that scientific understanding can contribute to, but rarely determines, decision making. Practical decisions are always set in situations having social, political or economic dimensions, and scientific knowledge is used in the context of human values related to these dimensions. Where there is agreement about the values in a situation, the use of scientific evidence can be non-controversial. Where values differ, the selection and use of scientific evidence in decision making will be more controversial.

...the natural world and the changes made to it through human activity...

The phrase the natural world is used as shorthand for the physical setting, living things and the relationships among them. Decisions about the natural world include those associated with science related to self and family, community and global issues. Changes made through human activity refer to planned and unplanned adaptations of the natural world for human purposes (simple and complex technologies) and their consequences.” (OECD, 2003)

From the above remarks four aspects of scientific literacy, bound together, arise. Those are: 1) the knowledge of science, 2) the investigative nature of science, 3) the knowledge about science and 4) the interaction among science, technology and society.

1.3-Scientific Literacy and Renegotiation of the Curriculum

Influential reports in the USA, the UK and Australia have argued that scientific literacy is the primary justification for giving science a central role in the curriculum (Millar, 2004). It is a slogan used by educators worldwide to guide curriculum development and classroom practice. As a result, a pressing educational agenda for science educators is to renegotiate the culture of school science to meet the 21st century needs of future citizens – an informed public. According to Aikenhead, science educators need to renegotiate conventional school science with its goal of preprofessional training, and replace it with a school science that develops savvy citizens who understand the social context of science and technology (Aikenhead, 2002). For Aikenhead the main axis of scientific literacy is STS (the interaction among science, technology and society), which is one of the four aspects of scientific literacy in our analysis.

The authors of Beyond 2000: Science Education for the Future – Millar & Osborne – state that the science curriculum from age five to sixteen (the years of compulsory schooling in the UK) should be a course to enhance general scientific literacy, with more specialized science education delayed to later years: “the structure of the science curriculum needs to differentiate more explicitly between those elements designed to enhance ‘scientific literacy’, and those designed as the early stages of a specialist training in science, so that the requirement for the latter does not come to distort the former”. (Millar & Osborne, 1998)

1.4-Scientific Literacy and Greek Curriculum

As scientific literacy is an implied aim of science teaching in the 21st century, it ought to form an important part of the aims of any science curriculum (Wilkinson, 1999). Characteristics of scientific literacy are also reflected in the general objectives of the current Greek curriculum. Those resemble to the remarks stated by OECD/PISA for scientific literacy. Issues such as the 1) knowledge of science, 2) the investigative nature of science, 3) the knowledge about science and 4) the interaction among science, technology and society (STS), are addressed in the general
objectives of the current Greek curriculum. This can be seen in the following statements of the Greek curriculum:

“In acquiring knowledge relative to theories, laws and principles concerning the science of physics, so that the student is able to describe and interpret the physical phenomena in a uniform and simple manner.” This statement refers to the first aspect of scientific literacy, “the knowledge of science”.

The aim: “The constant contact of the student with the scientific way of thinking and the scientific methodology (observation, collection – utilization of information from sources, statement of hypotheses, experimental testing of them, analysis and interpretation of data, drawing conclusions, ability to generalize, as well as to create models)” acquire the practical skills necessary to investigate physical phenomena both inside and outside the laboratory and provide evidence of “the investigative nature of science” aspect of scientific literacy.

The aspect of “the knowledge about science” is reflected in the statement: “To the attainment of the ability to recognize the unity and the continuity of scientific knowledge in science, as well as of the ability to recognize the interconnection between them.”

The aims: “In acquiring basic knowledge in order for the student to attain the ability to evaluate the scientific and technological applications, so as to be able to take a critical stand against them as a future citizen.”, “To pronounce on the positive or negative effects of these applications on the individual and social health, on the administration of the natural resource and on the environment, being also able to substantiate his positions with arguments”, “To appraise the contribution of physics in improving the quality of human life. To attain the ability to communicate as a citizen and collaborate with the scientific and social bodies, to collect and exchange information, to present his/her thoughts or his/her conclusions drawn by studies.” indicates “the interaction among science, technology and society” aspect of scientific literacy.

The interesting point is that the aforementioned general objectives are not accordingly reflected in the specific goals of the curriculum which are set during the particular articulation of the units taught in each school class. These specific goals guide also the authors of the textbooks during the writing of the books.

Analytically, the aspect of scientific literacy related to “the knowledge of science” consists the basic axis set by the writers of the curriculum, as it appears itself in a percentage of 70% of the specific goals (e.g. To state the definition of velocity). Only 20% of the specific goals are related to “the investigative nature of science” aspect of scientific literacy (e.g. Solving exercises which include distance, average velocity, time etc). The aspect “the knowledge about science” is not present at all at the specific goals of the curriculum. Finally, the aspect of “the interaction among science, technology and society” of scientific literacy is found in the specific goals at a percentage of 10%, giving however emphasis only in the applications of science (e.g. To state applications and problems of daily life based on expansion).

1.5-Scientific Literacy and Textbooks

Historically, textbooks have played a vital role in the teaching and learning of scientific issues. Chiappetta, Sethna and Fillman (1991) suggested that science textbooks should assist in the development of a scientifically and technologically literate society. They argued that in order to accomplish this task, the content of textbooks should provide curriculum balance which means to stress fairly equal proportions of knowledge, investigation, thinking, and the interaction among science, technology and society. Curriculum balance is a concept that is often recommended for school programs and is reflected in the major movements in USA science education aiming to promote scientific literacy and science, technology and society (STS) (Wilkinson, 1999).
In the present study, the Greek textbooks are analyzed with respect to the degree that they reflect the aspects of scientific literacy, aimed at by the general objectives of the Greek curriculum. It is investigated whether and to what extent the aforementioned four aspects are taken into consideration in the physics textbooks.

2. Research Questions

The purpose of this study is to examine the content of the officially approved physics textbooks of Greek lower secondary education, on the grounds of satisfying the demands for scientific literacy stated in the general objectives of the Greek curriculum. These books were chosen as they are the main learning resource in the formal education of children up to 15-year-old in physics. In particular, this research sought to answer the following questions:
1. Is the content of the physics textbooks in accordance with the request for scientific literacy stated in the general objectives of the Greek curriculum?
2. Is there a balance between the aspects mentioned in the Greek curriculum and those found in the physics textbooks?

3. Methodology

In this study we refer to the method of textbook analysis developed by Chiappetta, Fillman and Sethna (1991 a, 1991 b). The elements of the textbook (units of analysis) that are used in the content analysis include: complete paragraphs, questions, figures, tables with captions, marginal comments, and complete steps in laboratory or hands-on activity. The sample size analyzed is 20% of the total amount of pages of each book, which is considered as a reliable sample size. The developers of the method found that two random 5% samples from the same science textbook contained roughly the same proportion of the aspects of scientific literacy.

The pages to be analyzed were read and each unit of analysis was identified and classified into one of the four categories. The number of the units analyzed, which belong to each category, was expressed as a percentage of the total number of units analyzed in the whole textbook. In this way the percentage of each of the four aspects of scientific literacy were obtained, for each separate physics textbook analyzed.

We distinguish four categories of characteristics of scientific literacy, in accordance with the demands of the general objectives of the Greek curriculum, which share many common characteristics with the categories of Chiappetta, Fillman and Sethna (1991 a, pp.3-5; comp. also Wilkinson 1999). These categories are the following:

1. The knowledge of science

The elements of this category present, discuss, or ask the student to recall information, facts, concepts, principles, laws, theories, etc.

Textbook material in this category:
(a) Presents facts, concepts, principles and laws.
(b) Presents hypotheses, theories, and models.
(c) Asks students to recall knowledge or information.

2. The investigative nature of science
The elements of this category stimulate or motivate thinking and acting by asking the student to "find out." This category reflects the aspect of inquiry and learning in scientific literacy, which involves the student in the methods and processes of science such as observing, measuring, classifying, inferring, recording data, making calculations, experimenting, etc.

Textbook material in this category:
(a) Requires students to answer a question through the use of materials.
(b) Requires students to answer a question through the use of charts, tables, etc.
(c) Requires students to make a calculation.
(d) Requires students to reason out an answer.
(e) Engages students in a thought experiment or activity.

However, if a question simply asks for recall of information or is immediately answered in the text, check Category 1.

3. The knowledge about science

The elements of this category illustrate how the scientific enterprise operates. This type of data also presents the scientific method(s) and the problem-solving capacity and methods of science.

Text in this category:
(a) Describes how a scientist experimented.
(b) Shows the historical development of an idea.
(c) Emphasizes the empirical nature and objectivity of science.
(d) Illustrates the use of assumptions.
(e) Shows how science proceeds by inductive and deductive reasoning.
(f) Gives cause and effect relationships.
(g) Discusses evidence and proof.
(h) Presents the scientific method(s) and problem-solving steps.

4. The interaction among science, technology and society

The elements of this category illustrate the effect or impact of science on the society. This aspect of scientific literacy pertains to the application of science and to the manner with which technology helps or hinders the social progress. Social issues, ethical issues and careers are also involved in this aspect.

Text in this category:
(a) Describes the usefulness of science and technology on society.
(b) Describes the applications of scientific knowledge in everyday life.
(c) Stresses the negative effects of science and technology on society.
(d) Discusses social issues related to science or technology.
(e) Brings out careers and jobs in scientific and technological fields.

The textbooks selected for examination in this study were the physics textbooks officially approved by the ministry of Education for the Greek intermediate school. This selection is based on the assumption that as 15-year-olds begin to make the transition to adult life, they need to know not only scientific concepts, but also how to apply this knowledge and these skills in a variety of situations they will encounter in their lives. This is also the reason why OECD/PISA was developed, i.e. to assess the reading, mathematics and science literacy of 15-year-olds. PISA emphasizes the application of knowledge by presenting students with tasks that involve interpretation of real-world material as much as possible. These tasks reflect the underlying assumption of PISA that by the age of 15, young people should have had a series of learning
experiences, both in and out of school. That would allow them to perform at particular levels in reading, mathematics and science literacy. (OECD, 2003)

4. Findings

In sum, the results show that the main orientation of the Greek physics textbooks is more towards acquainting “the knowledge of science” and less or no attention is given to the other aspects of scientific literacy that are embedded in the general objectives of the Greek curriculum. In particular: 68.5% of the elements fall within the category “the knowledge of science”, 22.6% of the elements fall within the category “the investigative nature of science”, only 1.9% of the elements fall within the category “the knowledge about science” and finally 7% of the elements fall within the category “the interaction among science, technology and society”. These percentages converge with the percentages of appearance of these aspects of scientific literacy in the specific goals of the curriculum. (“The knowledge of science”: 70%, “The investigative nature of science”: 20%, “The knowledge about science”: 0%, “The interaction among science, technology and society”: 10%).

It could be said that the knowledge of science, i.e. presenting current facts, theories, models, concepts, principles and laws, is predominant in the Greek textbooks.

As regards the second category, it should be noted that 41% among this kind of sample data consist practically of lots of abstractive exercises, having a calculative form. 22% of the sample data requires students to answer a question through the use of materials. Those are usually given in special annexes which are not in syllabus. It should be mentioned however that the Greek science textbooks are always handed to the students together with a laboratory guidebook, in which students are given step-by-step instructions on how to conduct the experiments. However, these laboratory guidebooks are very rarely used by science educators.

The 1.9% of the third category practically shows the inadequacy of Greek physics textbooks’ writers in representing the nature of science. All elements were historical anecdotes, which is just one aspect of the nature of science.

The elements of the fourth category, despite the fact that we regarded them as pointing to the interaction among science, technology and society, present, in essence, simplified applications of science in everyday life. Social issues, as well as negative effects stemming from science and technology in society are not addressed to in texts of the aforementioned category.

In the following table (Table 1) the percentages of the subcategories which were distinguished for the analysis of the four aspects of scientific literacy, are shown analytically:
<table>
<thead>
<tr>
<th>Subcategories</th>
<th>Percentage of subcategory in the category</th>
<th>Percentage of subcategory in the total</th>
<th>Total percentage of category</th>
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</thead>
<tbody>
<tr>
<td><strong>Category 1. The knowledge of science</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Presents facts, concepts, principles and laws.</td>
<td>81%</td>
<td>55.5%</td>
<td><strong>68.5%</strong></td>
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<tr>
<td>(b) Presents hypotheses, theories, and models.</td>
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<tr>
<td>(c) Asks students to recall knowledge or information.</td>
<td>19%</td>
<td>13%</td>
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<tr>
<td><strong>Category 2. The investigative nature of science</strong></td>
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<tr>
<td>(a) Requires students to answer a question through the use of materials.</td>
<td>21.7%</td>
<td>4.9%</td>
<td><strong>22.6%</strong></td>
</tr>
<tr>
<td>(b) Requires students to answer a question through the use of charts, tables, etc.</td>
<td>41.2%</td>
<td>9.3%</td>
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<td>(c) Requires students to make a calculation.</td>
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<td>(d) Requires students to reason out an answer.</td>
<td>37.1%</td>
<td>8.4%</td>
<td></td>
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<tr>
<td>(e) Engages students in a thought experiment or activity.</td>
<td>0%</td>
<td>0%</td>
<td></td>
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<tr>
<td><strong>Category 3. The knowledge about science</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(a) Describes how a scientist experimented.</td>
<td>100%</td>
<td>1.9%</td>
<td><strong>1.9%</strong></td>
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<tr>
<td>(b) Shows the historical development of an idea.</td>
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<tr>
<td>(c) Emphasizes the empirical nature and objectivity of science.</td>
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<td>(d) Illustrates the use of assumptions.</td>
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<td>(e) Shows how science proceeds by inductive and deductive reasoning.</td>
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<td>(f) Gives cause and effect relationships.</td>
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<tr>
<td>(g) Discusses evidence and proof.</td>
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<tr>
<td>(h) Presents the scientific method(s) and problem solving steps.</td>
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<tr>
<td><strong>Category 4. The interaction among science, technology and society</strong></td>
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<tr>
<td>(a) Describes the usefulness of science and technology on society.</td>
<td>20%</td>
<td>1.4%</td>
<td><strong>7%</strong></td>
</tr>
<tr>
<td>(b) Describes the applications of scientific knowledge in everyday life.</td>
<td>80%</td>
<td>5.6%</td>
<td></td>
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<tr>
<td>(c) Stresses the negative effects of science and technology on society.</td>
<td>0%</td>
<td>0%</td>
<td></td>
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<tr>
<td>(d) Discusses social issues related to science or technology.</td>
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<td></td>
<td></td>
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<tr>
<td>(e) Brings out careers and jobs in scientific and technological fields.</td>
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Table 1. Percentages of the subcategories of the four aspects of scientific literacy.
5. Conclusions

In conclusion, the above findings show that although the school physics textbooks address the aspects of scientific literacy as they are stated in the general objectives of the Greek curriculum, the emphasis is put on the aspect “the knowledge of science” and – to a certain extent – on the “the investigative nature of science”. More specifically, concerning the second category, we ought to state that the school textbook familiarizes students with only few of the scientific processes and especially in performing calculations. The categories “the knowledge about science” and “the interaction among science, technology and society”, are practically lacking in the total sample, showing that the textbooks generally need to place more emphasis on these aspects. This analysis depicts that the officially approved school science textbooks are still imbued with a positivistic point of view about science.

The writers pay obviously little attention to the general objectives of the curriculum and to the current demands for scientific literacy. The main emphasis is given to the special goals which are set in each unit. The impressive coincidence of the percentages of appearance of the four categories of scientific literacy in the special goals of the curriculum, on the one hand and in the school textbooks on the other, shows off that these goals constitute the main guideline for the writing of the textbooks. The special goals focus on the knowledge of science, are governed by an academic and conservative orientation and are far from following the current trends about scientific literacy.

The results of Greece in the contest of PISA for scientific literacy, confirm in practice the above results. The Greek students have very low scores compared to the students of the other countries in issues concerning the applications of scientific knowledge and the engagement of students in real-world material. In the contest of 2000 Greece ranked 25th in a total of 31 countries with respect to science, while in a total of 40 countries- members of OECD which participated in the contest in 2003 Greece ranked 30th with respect to science and 32nd with respect to problem-solving. For the PISA of 2006, the focus was on scientific literacy. The results will be announced in 2007. In PISA material it is reported that on announcing the results of the PISA contest and the ranking of the countries participated in it, the elaboration, the analysis and the exploitation of the results is going to begin, so that each country can detect the possibilities and the shortcomings of its educational system, as well as of the systems of the other countries, in order to plan and realize specific actions which will develop and improve the performance of its own educational system. This is the reason for each country’s participation in PISA.

From all the above it becomes clear that the Greek educational system must proceed to actions in order to follow up the current tendencies about scientific literacy. In this case with the above analysis, the need to change the structure and character of school textbooks is shown off. During the writing of the school textbooks equal emphasis should be given to all the aspects of scientific literacy, in accordance with the mandate of both the general objectives of the curriculum and the current tendencies of science education.

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