Scientific practices and crosscutting concepts in Greek Lyceum Science textbooks: the case of Physics

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ABSTRACT

This study concerns the analysis of 2 Greek science textbooks for teaching Physics in the 2nd grade of Greek Lyceum (K-11) regarding the scientific practices and the crosscutting concepts included. It was found that (a) certain scientific practices are used very often in the textbooks and other are used rarely or not used at all, (b) certain crosscutting concepts appear often in the textbooks and other appear rarely, and (c) the textbooks investigated do not differ considerably in regards to the frequency of appearance of scientific practices and crosscutting concepts. Relevant implications and limitations are discussed.

KEYWORDS

Science textbook, physics textbook, textbook analysis, scientific practices, crosscutting concepts

RÉSUMÉ

Cette étude concerne l'analyse de 2 manuels scientifiques grecs pour l'enseignement de la physique au 2e degré du lycée grec (K-11) en ce qui concerne les pratiques scientifiques et les concepts transversaux inclus. Il a été constaté que (a) certaines pratiques scientifiques sont très souvent utilisées dans les manuels et que d'autres sont utilisées rarement ou pas du tout, (b) certains concepts transversaux apparaissent souvent dans les manuels et d'autres apparaissent rarement, et (c) les manuels étudiés ne diffèrent pas considérablement en ce qui concerne la fréquence d'apparition de pratiques scientifiques et de concepts transversaux. Les implications et les limitations pertinentes sont également discutées.

MOTS-CLÉS

Manuel scientifique, manuels de physique, analyse de manuels scolaires, pratiques scientifiques, concepts transversaux

THEORETICAL FRAMEWORK

Important changes in our understanding of different scientific issues are common in times we live in. Such changes concern many aspects of our life and thus may influence informed decision-making on both individual and communal levels (Osborne, Simon, & Collins, 2003; Raved & Assaraf, 2011; Summers & Abd-El-Khalick, 2019). For instance, people's ideas about vaccination may prove important in the appearance and course of epidemics (Ampatzidis, Delserieys, Ergazaki, & Jegou, 2019; Raved & Assaraf, 2011) while the ideas people hold on ecosystems' function may play crucial role in the debate about environmental issues such as climate change or sustainability (Ergazaki & Ampatzidis, 2012; Westra, 2008). In the 21st century, it is more critical than ever for citizens to be able to contribute in the discussion about important, controversial issues that arise in human societies (Olson, 2017; Özer et al., 2019).

Considering the fact that it appears vital for science education to concern everybody, it comes as no surprise that the last 3 decades the main objective of science education has evolved to concern the education of future citizens being able to contribute to the discussion of global issues (Assaraf & Orion, 2005; Tripto, Assaraf, & Amit, 2018). As a result, the term 'scientific literacy' appears very often in the discussion about the objectives of school education (Abd-El-Khalick & al., 2017; Millar, 2006). Scientific literacy 'stands for what the general public ought to know about science' (Durant, 1993, p. 129). More specifically, it 'commonly implies an appreciation of the nature, aims, and general limitations of science, coupled with some understanding of the more important scientific ideas' (Jenkins, 1994, p. 5345) or, more simply, scientific literacy refers to a level of understanding of scientific terms and concepts that allow one to read a newspaper (Miller, 1998) or follow news and discussions online.

The term 'scientific literacy' was coined in the late 1950s, and its most probable first appearance in print was by Paul Hurd in a 1958 publication entitled *Science Literacy: Its Meaning for American Schools* (Laugksch, 2000). During the years, several interpretations and definitions of scientific literacy have been proposed. One of the most comprehensive definitions of scientific literacy has been proposed by Showalter (as cited in Laugksch, 2000, p. 76-77) and it includes 7 dimensions:

- The scientifically literate person understands the nature of scientific knowledge.
- The scientifically literate person accurately applies appropriate science concepts, principles, laws, and theories in interacting with his universe.
- The scientifically literate person uses processes of science in solving problems, making decisions, and furthering his own understanding of the universe.
- The scientifically literate person interacts with the various aspects of his universe in a way that is consistent with the values that underlie science.
- The scientifically literate person understands and appreciates the joint enterprises of science and technology and the interrelationship of these with each other and with other aspects of society.
- The scientifically literate person has developed a richer, more satisfying, more exciting view of the universe as a result of his science education and continues to extend this education throughout his life.
- The scientifically literate person has developed numerous manipulative skills associated with science and technology.

As shown above, science literacy concerns, among others, (a) the ability to use processes of science in solving problems and making decisions, and (b) the appreciation of the interrelationship of science and technology with each other and society. Focusing on these 2 dimensions of science literacy, we notice that they are reflected also in the Greek curriculum of science teaching and learning. More specifically: 'science teaching should support students in developing skills concerning the scientific way of thinking and the scientific methodology (observation, data gathering, hypothesis formulation, experimental testing, analysis and interpretation of data, drawing conclusions, the ability to generalize and anticipate emerging patterns)' and, also, 'science teaching should support students in developing the ability to appreciate the unity and continuity of scientific knowledge as well as the ability to recognize the interrelationship of natural sciences' (Greek Government Gazette, 2003, p. 4170). In other words, science teaching aims at helping students (a) to build understanding of science as a set of practices (experimental investigation, modeling, critique etc.) (Longino, 2002; Millar & Driver, 1987) and engaging students in them, and (b) to develop an organizational framework for connecting knowledge from different scientific disciplines into a coherent and meaningful view of the world (National Research Council, 2012).

Considering the above along with the fact that science textbooks determine largely what is taught and learned about science in classroom (Abd-El-Khalick, Waters, & Le, 2008) we decided to explore the Greek science textbooks regarding (a) the science practices, and (b) the concepts that bridge disciplinary boundaries they involve. Our focus here is set on 2 physics textbooks for the 2nd grade of Greek Lyceum (K-11). Thus, the research questions (RQs) we address here are:

- (RQ1) Which science practices are included in physics textbooks for the 2nd grade of Greek Lyceum?
- (RQ2) Which bridging concepts are included in physics textbooks for the 2nd grade of Greek Lyceum?

METHODOLOGICAL FRAMEWORK

Sample textbooks

Greek Upper Secondary Education consists of 2 types of schools: the Vocational Senior High School and the Lyceum. The 2 science textbooks we investigated for this research are both used as main textbooks for the teaching of Physics in the 2nd grade of Lyceum. More specifically, the 2 textbooks we sampled here are *Physics of general education* (referred hereinafter as 'textbook a') (Alexakis et al., 2014) and *Physics of science specialization* (referred hereinafter as 'textbook b') (Ioannou et al., 2014).

'Textbook a' includes 4 chapters: (i) Force between electrical charges, (ii) Direct current electricity (iii) Light, (iv) Atomic phenomena. The 4 chapters of 'textbook a' are consisted of 25 sections and the total number of pages is 206.

'Textbook b' includes 5 chapters: Curvilinear motion: horizontal shot, circular motion, (ii) Momentum conservation, (iii) Kinetic theory of gases, (iv) Thermodynamics, (v) Electric field. The 5 chapters of 'textbook b' are consisted of 48 sections and the total number of pages is 218.

Coding scheme and procedure

Our coding scheme was informed by the framework for science education proposed by the National Research Council (2012). As shown in Table 1, it includes 8 scientific practices and 7 crosscutting concepts. Scientific practices concern the scientific habits of mind and the abilities related with scientific inquiry; on the other hand, crosscutting concepts concern concepts that bridge disciplinary boundaries and have explanatory value throughout much of scientific fields.

TABLE 1

Coding Scheme: Scientific Practices and Crosscutting Concepts

Scientific Practices
1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics, information and computer technology, and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information
Crosscutting Concepts
1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change

For our study, every section of the sampled textbooks was considered an analysis unit. In other words, our treatment of the textbooks would result in the amount of sections every practice and every crosscutting concept appears. This appearance could be partial: for instance in case of scientific practice 5, a section would be considered as including it whether even one out of ‘using mathematics’, ‘using information and computer technology’, and ‘using computational thinking’ appeared in its pages.

Two of the authors coded independently 15 (i.e. about 20%) randomly chosen sections (7 sections of ‘textbook a’ and 8 sections of ‘textbook b’) and the rater agreement was 80%. The cases of disagreement were reviewed and discussed by the two coders and the rest of the analysis was carried out by one of them.

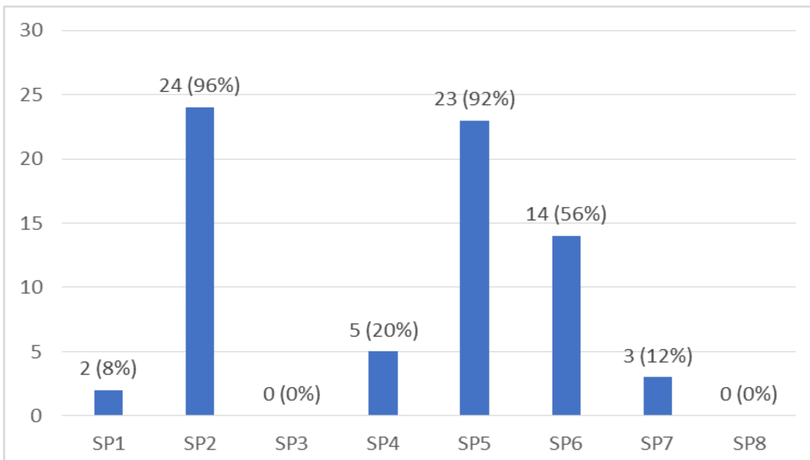
RESULTS

Regarding ‘textbook a’, scientific practice 2 (developing and using models) and scientific practice 5 (using mathematics, information and computer technology, and computational thinking) are the ones appearing in most sections (Figure 1). We should note, though, that scientific practice 5 appears partially in some cases: the use of mathematics is encountered in most sections than the use of information and computer technology or computational thinking.

On the other hand, scientific practice 3 (planning and carrying out investigations) and scientific practice 8 (obtaining, evaluating, and communicating information) are completely missing from 'textbook a' (Figure 1).

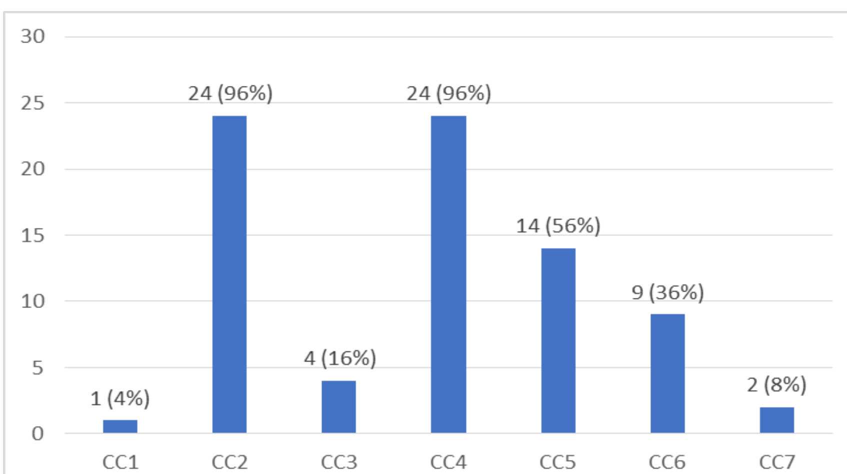
Concerning crosscutting concepts, we notice that all of them appear in 'textbook a' at least in one section (Figure 2). Crosscutting concept 2 (cause and effect: mechanism and explanation) and crosscutting concept 4 (systems and system models) are dominant since they are included in 24/25 (96%) sections of 'textbook a'. On the contrary, crosscutting concept 1 (patterns) and crosscutting concept 7 (stability and change) are rarely used (Figure 2).

FIGURE 1



Frequencies and percentages of sections of 'textbook a' including scientific practices (N=25)

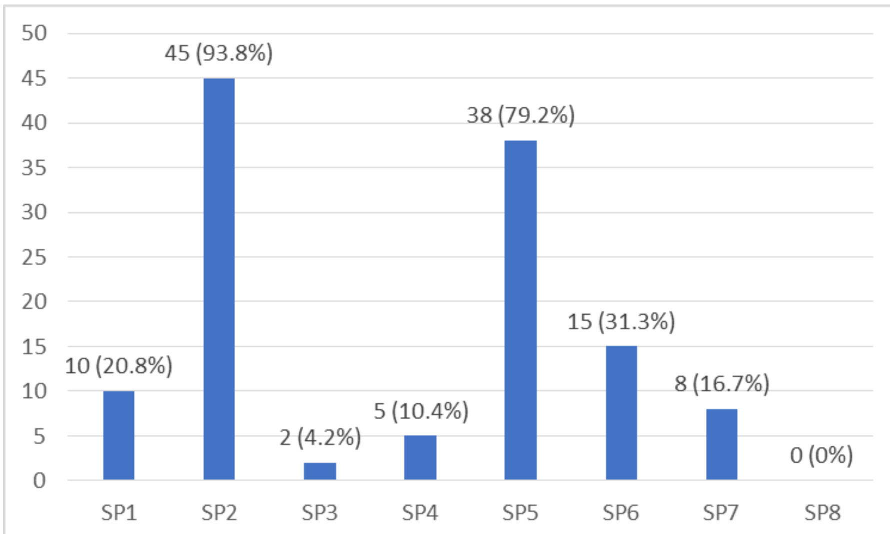
FIGURE 2



Frequencies and percentages of sections of 'textbook a' including crosscutting concepts (N=25)

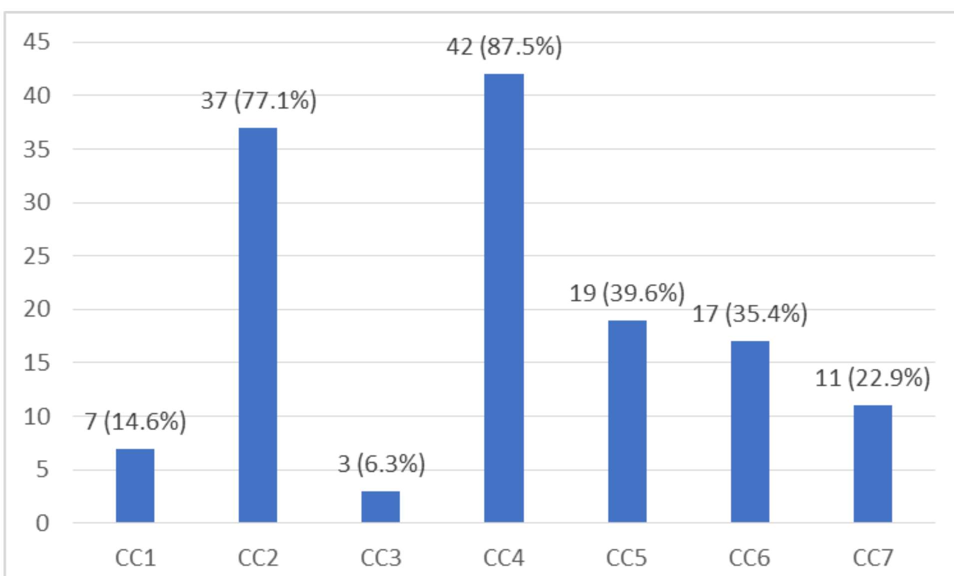
Shifting to 'textbook b', we notice that scientific practice 2 (developing and using models) and scientific practice 5 (using mathematics, information and computer technology, and computational thinking) are dominant (Figure 3). Scientific practice 5 appears in a partial way in 'textbook b' as well: more sections include the use of mathematics rather than the use of information and computer technology or computational thinking. Scientific practice 3 (planning and carrying out investigations) is only used in 2 out of 48 sections and practice 8 (obtaining, evaluating, and communicating information) is completely missing (Figure 3).

FIGURE 3



Frequencies and percentages of sections of 'textbook b' including scientific practices (N=48)

FIGURE 4



Frequencies and percentages of sections of 'textbook b' including crosscutting concepts (N=48)

Concerning crosscutting concepts, we notice that all of them appear in ‘textbook b’ at least in one section as well. Crosscutting concept 2 (cause and effect: mechanism and explanation) and crosscutting concept 4 (systems and system models) are the ones most appearing in ‘textbook b’ while crosscutting concept 1 (patterns) and crosscutting concept 3 (scale, proportion, and quantity) are included in few sections (Figure 4).

DISCUSSION

Developing and using models along with using mathematics seem to be the most popular scientific practices included in the physics textbooks we investigated. On the other hand, there are scientific practices that are rarely used or not used at all in the sampled textbooks (e.g. planning and carrying out investigations or obtaining, evaluating and communicating information). There seems that ‘textbook a’ and ‘textbook b’ do not differ considerably regarding the scientific practices highlighted; some of them are promoted and others are not.

We have to notice here, and this would be a limitation of our study, that ‘textbook a’ and ‘textbook b’ are accompanied by laboratory guides that were not investigated in the framework of our study. Laboratory guides are to be used in science laboratories aiming to support students in their scientific inquiry. However, the tendency among science teachers in Lyceum is to allocate limited, if any, time of their teaching to carrying lab investigations. This happens due to time constraints and the fact that science teachers assume that laboratory time does not contribute much to success in final exams, which is the main orientation of teaching – especially in the last two grades of Lyceum (Siorenta & Jimoyiannis, 2008).

Concerning crosscutting concepts, we note that all the concepts included in our framework of analysis appear in both textbooks. Cause and effect, and system/system models seem to be the most prevalent in the physics textbooks we investigated. On the other hand, there are crosscutting concepts that are referred in few sections of sampled textbooks (e.g. scale, proportion, and quantity or patterns). It seems that ‘textbook a’ and ‘textbook b’ do not differ considerably regarding the crosscutting concepts referred as well. Taking into account that ‘textbook a’ covers a subject of general education while ‘textbook b’ covers a subject of science specialty, we see that aiming different student audiences does not mean difference in crosscutting concepts or scientific practices included. ‘Textbook b’ may treat the scientific content with more details but in regards to scientific practices and crosscutting concepts the two textbooks we investigated appear similar.

We should acknowledge the fact that our analysis is informed by a specific framework which was developed by the National Research Council to guide the textbooks and curriculum of USA. Nevertheless, as shown before, crosscutting concepts and scientific practices are both related with objectives of science teaching as described in papers about scientific literacy and in the official Greek curriculum. Thus, we argue that our study offers a valuable insight in how physics textbooks of Greek Lyceum implement the objectives of scientific literacy in general and the science curriculum more specifically.

We plan to extend our research to more science textbooks of physics and other science disciplines used in Greek school. We think that it would be meaningful to explore whether similar use of scientific practices and crosscutting concepts identified in our study may also be identified in science books of the same or different grades. This way we may be confident in concluding whether Greek science textbooks generally promote certain scientific practices and crosscutting concepts while downgrading some other. Our research so far does not allow one to respond to such a question but it offers preliminary results in this direction.

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