

Science Process Skills in the Greek Primary School Science Textbooks

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ABSTRACT

Science process skills play an essential role in science education. The research assessing these skills in school science textbooks is limited. The aim of the current study was to examine the involvement of science process skills in the content of science school textbooks of the last two primary school grades in Greece. A specific analysis framework was adopted, based on 534 activities included in the two textbooks. It was concluded that the activities included in the two textbooks mainly involved the skills of communicating, observing, and inferring, while the involvement of the remaining science process skills was particularly limited. Therefore, the school textbooks fail to provide students satisfactory opportunities to engage in science process skills and facilitate a better understanding of sciences ideas and concepts. The findings of this study provide information about some strengths and weaknesses of the science textbooks that could be used by teachers in planning for teaching.

KEY WORDS: science process skills; school textbooks; science education

INTRODUCTION

During the last decades, a part of the research held in the field of science education has taken an interest not only in the knowledge that students of both primary and secondary education acquire but also in the science process skills they develop (Kruit et al., 2018a). It has been established that these skills are largely associated with students' scientific literacy, their familiarity with the nature of science, as well as their academic achievements in science (Shahali et al., 2017).

In the past few years, many countries have implemented several reforms to their national school curricula, as far as the latter's goals and content are concerned, for the teaching of science to contribute to the development of science process skills among students of both primary and secondary education levels (Beaumont-Walters and Soyibo, 2001; Dökme and Aydınli, 2009; Kruit et al., 2018b; Shahali et al., 2017). Furthermore, on grounds of the crucial role that school science textbooks hold, being a fundamental part of both the teaching and learning procedures (McDonald, 2016), it has been noted that they should provide students with opportunities to use and develop science process skills (Yang et al., 2019).

Although the importance of students' involvement in science process skills has been well acknowledged (Kruit et al., 2018a; Özgelen, 2012; Tilakaratne and Ekanayake, 2017; Zeidan and Jayosi, 2015), the amount of research focusing on the inclusion of science process skills in the content of school textbooks is rather limited (Yang et al., 2019). Therefore, the need for more research to be conducted in this particular area

arises. The present study examined the activities included in Greek science school textbooks of the last two primary school grades with the aim to investigate to what extent these involve science process skills.

THEORETICAL BACKGROUND

Science Process Skills

The term science process skills (SPS) refers to the main skills employed by scientists when they conduct scientific research, which aims to address a scientific problem and provide explanations on natural world phenomena (Feyzioğlu et al., 2012; Kruit et al., 2018b; Maranan, 2017; Özgelen, 2012). However, the development of SPS is considered essential not only to scientists but also to students for them to achieve a better understanding of science content (Kruit et al., 2018b; Maranan, 2017; Miles, 2010; OECD, 2017).

A proposal classified SPS under two main categories – namely the basic SPS and integrated SPS – whereas the development of the former is to be considered as the necessary building block for the development of the latter (Brotherton and Preece, 1995; Chabalengula et al., 2012; Padilla, 1990). Other researchers, however, incorporate these two categories into a single integrated set of skills (German et al., 1996; Yang et al., 2019). Table 1, presents the SPS along with a brief description.

The development of students' SPS constitutes a substantial objective of science education, since it has been pointed out that students' involvement in them stands as a groundwork for the development of their understanding of science ideas

Table 1: List of Science Process Skills and their description (Yang and Liu, 2016, p. 8)

Skills	Description
Observing	Using the senses to gather information about an object or event
Inferring	Making an educated guess about an object or event based on previously gathered data or information
Measuring	Using standard and nonstandard measures or estimates to describe the dimensions of an object or event
Communicating	Using words or graphic symbols to describe an action, object or event
Classifying	Grouping or ordering objects or events into categories based on properties or criteria
Predicting	Stating the outcome of a future event based on a pattern of evidence
Controlling variables	Identifying variables that can affect an experimental outcome, keeping most constant while manipulating only the independent variable
Defining operationally	Stating how to measure a variable in an experiment
Formulating Hypothesis	Stating the expected outcome of an experiment
Interpreting data	Organizing data and drawing conclusions from it
Asking questions	Raising an appropriate question
Formulating models	Creating a mental or physical model of a process or event

and concepts (Bell et al., 2012; Miles, 2010; NRC, 2012; OECD, 2017).

In fact, acquiring SPS is considered essential not only for students intending to follow a science related profession but also for every other individual citizen (Çakır and Sarıkaya, 2010; Maranan, 2017). Citizens equipped with SPS are able to follow and comprehend scientific progress and engage in decision-making processes concerning science related matters (Miles, 2010).

Research data reveal that the development of SPS contributes to the overall enhancement of students' performance both in science (Aktamış and Ergin, 2008; Feyzioğlu, 2009; Preece and Brotherton, 1997; Prayitno et al., 2017) and other subject areas (Maranan, 2017), and fosters the cultivation of a positive attitude on their behalf toward scientific research and science lessons (Bilgin, 2006; Zeidan and Jayosi, 2015).

School Science Textbooks

In formal education, the learning process in many educational systems revolves around the school textbooks, making them a dominant, fundamental teaching tool (McDonald, 2016). School textbooks shape not only the knowledge which students acquire (Yang et al., 2019) but also influence teachers toward implementing specific teaching strategies (McDonald, 2016; Ogan-Bekiroglu, 2007; Wang and Clarke, 2014). School textbooks serve as a starting point for the activities carried

out in classroom, often providing guidance and navigating the teaching procedure (Lumpe and Beck, 1996).

Research studies have indicated that 90% of the science teachers use the school textbooks not only to carry out their lesson but also to assign tasks (questions, activities) to the students (Chiappetta et al., 2006). In fact, it has been reported that for six out of ten science teachers, school textbooks serve as the exclusive teaching material they use in classroom (Banilower et al., 2018).

The activities included in science school textbooks comprise a significant part of their content. These activities establish the important parts for students to learn and are also often used by teachers to evaluate students' performance (Overman et al., 2013). Therefore, evaluating these activities is of great significance.

LITERATURE REVIEW

Bearing in mind the essential role that SPS hold in science education, the need to examine whether the activities included in school science textbooks provide students opportunities to develop these skills holds a strong argument (Aldahmash et al., 2016; NRC, 2000; Yang et al., 2019).

The existing international literature is rich in studies assessing the content of school science textbooks (Chen and Eilks, 2019; Papageorgiou et al., 2019; Vojř and Rusek, 2019). Among these, studies focusing on the inquiry processes involved in school textbooks' content are included. More specifically, research has been conducted analyzing the activities included in school science textbooks in terms of their efficiency in teaching inquiry processes (German et al., 1996; Tamir and Lunetta, 1978, 1981). Other studies have focused on evaluating the "openness" level of the inquiry-based activities included in school textbooks. To this regard, specific frameworks have been proposed examining whether the problems, steps, materials, and outcomes of the inquiry are provided in advance or are left to be figured out by the students (Bell et al., 2005; Bulunuz et al., 2012; Fay et al., 2007; Germann et al., 1996; Herron, 1971; Lederman, 2009; Schwab, 1962; Wenning, 2007). Some studies focused on the educational functions of the inquiry-based activities included in school textbooks (Millar, 2009). Another part of the research held in this area also turned its interest in evaluating the representation of the essential features of scientific inquiry, as defined from the NRC (1996), as these may appear in school science textbooks. According to the results of these studies, Irish, Turkish, and Saudi Arabian school textbooks failed to include sufficiently the essential features of inquiry (Aldahmash et al., 2016; Dunne et al., 2013; Kahveci, 2010). Similarly, Yang et al. (2019) examined Chinese Biology school textbooks, coming to the conclusion that only some of the activities included in them actually provided students satisfactory opportunities to engage sufficiently in inquiry processes and develop certain science process skills.

It should be noted that the aforementioned studies are focused on secondary school textbooks. There is a lack of research regarding primary school textbooks and the activities included in them toward providing students opportunities to get involved with SPS. More importantly to the present study, there is a lack of research addressing Greek school textbooks despite their prominent role in the Greek educational system. That being said, carrying out research on Greek science school textbooks in relation to the involvement of SPS in their content appears to be necessary, since there is no data concerning this matter.

METHODOLOGY

Aim and Research Questions

The aim of the present study was to determine whether and to what extent the activities included in Greek science school textbooks of the last two primary school grades involve science process skills. More specifically, the following research question is addressed: are SPS involved in the activities included in Greek science school textbooks of the last two primary school grades (for students aged 11 and 12), and if so, to what extent?

Design of the Study

The present study was conducted using content analysis, a well-established and commonly applied method for the evaluation of school textbooks' content (Krippendorff, 2013). This method is consistent with the purpose of the current research, as it allows the analysis of the activities included in the school textbooks examined.

The teaching material to be analyzed was initially identified and, subsequently, the analysis framework to guide the research was selected. Based on this framework the analysis of the activities and the extraction of the results and conclusions followed.

The Teaching Material Analyzed and Units of Analysis

The activities included in the school science textbooks of the last two Greek primary school grades (for students aged 11 and 12) constituted the sample of the study. These particular school grades were chosen because at this point in time students are introduced to a more regular and systematic exposure to science. Every problem, question, and labwork task included in the two textbooks was considered a unit of analysis. More specifically, a total of 534 activities were analyzed, 232 of which were included in the textbook of the 6th grade, whereas 302 in the textbook of the 5th grade.

Analysis Framework

A part of the instrument "Inquiry-based Task Analysis Inventory" (ITAI) was selected as the framework to conduct the current research. This instrument was developed aiming to assess the content of school science textbooks in China (Yang and Liu, 2016; Yang et al., 2019). The instrument focuses on evaluating the involvement of 12 science process skills in the activities included in school textbooks, as presented in Table 2.

Table 2: Scoring Rubrics of the Inquiry-Based Task Analysis Inventory (Yang and Liu, 2016, p.23)

Skills	Scoring Rubrics
Observing	If students are required to or must perform observation, mark YES, otherwise mark NO
Inferring	If students are required to or must infer, mark YES, otherwise mark NO
Measuring	If students are required to or must measure the variables directly related to research questions, mark YES, otherwise mark NO
Communicating	If students are required to or must communicate as part of this task, mark YES, otherwise mark NO
Classifying	If students are required to or must perform classifying that is rigorously defined in the inquiry process (e.g., biological classification), mark YES, otherwise mark NO
Predicting	If students are required to or must predict, mark YES, otherwise mark NO
Controlling variables	If students are required to or must control variables, mark YES, otherwise mark NO
Defining operationally	If the text of this task completely meets the following three criteria, (1) students are required to define operationally, (2) no cookbook procedure examples are provided in the text, (3) well-defined, scientific, and pertinent research questions are provided or students are asked to develop research questions and no ill-defined, unscientific, and non-pertinent question examples are provided, mark YES, otherwise mark NO
Formulating Hypotheses	If students are required to or must formulate hypotheses and this task in fact belongs to inquiries that necessarily test hypotheses (e.g., experimental inquiry), mark YES, otherwise mark NO
Interpreting data	If students are required to or must interpret data, mark YES, otherwise mark NO
Asking questions	If students are required to ask research questions and no ill-defined, unscientific, or non-pertinent questions or examples are provided, mark YES, otherwise mark NO
Formulating models	If students are required to or must formulate models, mark YES, otherwise mark NO

Data Analysis

Each unit of analysis was examined in terms of the involvement of each of the 12 science process skills according to the analysis framework adopted (Table 2). Based on the ITAI, when a science process skill was found to be involved in an activity, it was rated with a "YES" response, while otherwise it was rated with a "NO" response.

To ensure the reliability of the content analysis, two researchers worked independently on the scoring procedure. The units of analysis were coded and evaluated by the two raters as to whether they involve each of the science process skills. Subsequently, the given responses were compared to determine the level of agreement between them. Any disagreements were resolved through discussion between the two researchers.

Table 3: Science process skills in the school science textbooks of the last two primary school grades in Greece: Frequencies and percentages

Science Process Skills	School Science Textbook of the 5 th Grade		School Science Textbook of the 6 th Grade		Total	
	f	%	f	%	f	%
	Observing	221	73.1	175	75.4	396
Inferring	204	67.5	168	72.4	272	50.9
Measuring	25	8.3	6	2.6	31	5.8
Communicating	302	100	232	100	534	100
Classifying	48	15.9	48	20.7	96	18
Predicting	0	0	5	2.2	5	0.9
Controlling variables	2	0.7	0	0	2	0.4
Defining operationally	0	0	0	0	0	0
Formulating hypotheses	40	13.2	8	3.4	48	9
Interpreting data	13	4.3	8	3.4	21	3.9
Asking questions	11	3.6	3	1.3	14	2.6
Formulating models	35	11.6	24	10.3	59	11

On completion of the analysis, the frequencies of the “YES” and “NO” responses for each activity per science process skill were calculated and expressed as a percentage. An example presenting the analysis of an activity in relation to the science process skills it involves can be found in the Appendix.

RESULTS

Table 3 displays the involvement of each of the science process skills in the activities included in the textbooks analyzed, expressed both as a frequency and as a percentage.

As shown in Table 3, the results indicated a frequent involvement of the skills of observing, communicating, and inferring in the content of the school textbooks. In fact, the skill of communicating was involved in all of the activities of both textbooks examined. However, the involvement of the skills of classifying, measuring, formulating hypotheses, and formulating models was rather limited. Furthermore, the skills of predicting, controlling variables, interpreting data, and asking questions were rarely involved. The skill of defining operationally was not involved in any of the activities in the two textbooks.

DISCUSSION AND CONCLUSIONS

The results demonstrated that the involvement of SPS in the school textbooks examined does not follow a balanced distribution, as certain skills were more frequently and to a greater extent involved than others. Therefore, the development of all SPS among students was not equally promoted. In addition, most of the SPS were rarely involved in the activities of the school textbooks.

These results (unbalanced distribution, and limited involvement of some of the SPS) are consistent with the previous research

findings on different countries’ secondary school science textbooks (Aldahmash et al., 2016; Germann et al., 1996; Tamir and Lunetta, 1978, 1981; Tamir and Pillar-Garcia, 1992; Yang et al., 2019).

In conclusion, the science textbooks of the fifth and sixth Greek primary school grades do not provide opportunities for students to develop all of the SPS and become familiar with them. However, current educational approaches have turned their focus on getting students involved in finding solutions in real life problems, by raising questions, and working on them, designing and conducting investigations, collecting, analyzing and interpreting data, drawing conclusions and sharing the findings (Kruit et al., 2018b; Marannan, 2017). Therefore, this marks a shift of the emphasis from the acquisition of science knowledge toward familiarity with the scientific inquiry procedures (Kanari and Millar, 2004; NRC, 2012). The rare inclusion of certain science process skills in the content of Greek school textbooks, or even their complete exclusion, might negatively affect students’ scientific literacy, cognitive development, academic achievements, and development of understanding of the nature of science. Research data reveal that the development of SPS among students facilitates a better understanding of science ideas and concepts (Aktamış and Ergin, 2008; Feyzioğlu, 2009; Preece and Brotherton, 1997; Prayitno et al., 2017) and is apparently associated with fostering students’ positive attitudes toward science lessons and scientific inquiry (Bilgin, 2006; Zeidan and Jayosi, 2015).

Consequently, enriching the content of Greek science school textbooks with activities more extensively involving all of the SPS is considered necessary. An adequate involvement of these skills will allow students to become more familiar with them and improve their degree of understanding of science content.

It should be noted that the analysis carried out in the current research focused exclusively on the school textbooks’ content, without taking into account any teaching implementation methods of such content in the classroom. This fact constitutes a limitation of this study. It is therefore suggested to conduct research evaluating to what extent teaching held in classrooms involves SPS. In addition, to broaden our acquired knowledge on the involvement of SPS in Greek school textbooks, it is necessary to expand the research on secondary education school science textbooks and compare the results of such research with the ones derived from the current study. It would also be interesting to investigate the SPS level among Greek students. Finally, another suggestion would be to develop teaching material aiming to enhance students’ SPS, design an instructional intervention applying this material and conduct research to determine how this instructional intervention contributed to students’ level of SPS development.

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APPENDIX

An Analysis of an Activity: An Example

Activity (School science textbook of the 5th grade)

For this experiment you will need a watch with a second hand.

- Count your pulses for one minute, while you remain seated.
- Repeat the measurement after running in place for a few minutes.

Observations:

Ask one of your classmates to keep time while you count your pulses:

	PULSES PER MINUTE	
	AT REST	AFTER RUNNING
1		
2		
3		
4		
5		
6		

Conclusion:

Write your conclusion using the words: Pulse, heart, exercise, rhythm

Analysis

Science Process Skills	Score
Observing	Yes
Inferring	Yes
Measuring	Yes
Communicating	Yes
Classifying	No
Predicting	No
Controlling Variables	No
Defining operationally	No
Formulating hypotheses	No
Interpreting data	Yes
Asking questions	No
Formulating models	No