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The Scientific Practices on the Science's Textbook in the Fifth Grade of Greek Primary School

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Abstract A plethora of studies related to science teaching and learning in the last two decades, has prompted the design and development of a new framework in order to improve the quality of scientific literacy for all students. The new framework incorporates the coexistence of three dimensions of learning: the scientific practices, the core ideas and the cross-cutting concepts. However, although the importance of the three dimensions of learning is paramount, the research that is focused on the analysis of the teaching material on the three dimensions is very limited. In this research, we focus on the dimension of scientific practices. The aim of this study was the analysis of the science textbook titled "Inquire and discover" (part of the teaching package) in the fifth grade of Greek Primary School on the scientific practices involved in its content. The term scientific practice does not coincide with the term practical skills because the participation in scientific research does not require only skills, but special knowledge and experience for every skill as well. The analysis was carried out by a grid that was structured by the scientific practices as conceptual categories. A part of the scientific practices of the new framework is not evident into the textbook content and important aspects of other scientific practices do not enter into units of analysis. The textbook is not satisfactorily aligned with the new framework of science learning and perhaps these findings negatively affect the scientific literacy of Greek students in Primary School.

Keywords: *new framework, scientific practices, subcategories of practices, textbook analysis, science literacy*

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1. Introduction

This paper is referred to a study which is part of a wider body of studies that focus on the analysis of science textbooks. Specifically, it seeks to analyze the science textbook used in the fifth grade of Greek Primary School concerning the scientific practices incorporated in the textbook content. Through the research of the various dimensions of science textbooks whose quality and generally their contribution and their effectiveness in the teaching practice is being evaluated, many research questions arise relating to sociology, pedagogy and epistemology marking the need for systematic research on the method of content analysis [4]. The results of the textbooks analysis, except for the aforementioned contribution to teaching practices, are conducive to the teachers' careful choice (when possible) for the most appropriate textbook to their students. Textbooks constitute tools to control failures or weaknesses of the authors and are simultaneously an auxiliary tool of the authors to improve or even rewrite them. Finally, the results contribute to the science literacy of students, being conducive to improving the quality of textbooks, the methodological approach, the illustrations, and the lexical elements, the understanding, among others.

1.1. Background

The procedures whereby the scientists produce models, study them and construct theories related to the world in accordance to reference [7] are named scientific practices. Someone can argue that scientific practices are identified with the term "investigative skills", but the Committee of National Research Council (NCR) believes that scientific practices combine research skills with knowledge. For instance, the scientific practice of using mathematics and computational thinking requires knowledge of mathematics [7]. The engagement of students in the process of scientific practices requires appropriate skills and knowledge. At this point it is necessary for the planners of curricula to focus their attention on the enrichment of textbooks with proper scientific practices which must be commensurable with the mental age, the grade and the education level of students. The Committee of reference [7] argues that scientific practices in all grades of primary and secondary education are identical. The element that changes in the long run is the sophistication and complexity of practices. The scientific practices that are used by scientists and by students according to the new framework of science education from pre-school through the last grade of secondary education are:

Asking questions, Developing and using models, Planning and carrying out investigations, Analysing and interpreting data, Using mathematics and computational thinking, Constructing explanations and designing solutions, Engaging in argument from evidence and Obtaining, evaluating, and communicating information. In this paper we will name the scientific practices with initial letters SP.

The literature review has shown that there are not any other analyses focusing on the scientific practices afforded in textbook content. Therefore, the originality of this study may be the starting point for the analysis of all the science school textbooks of Greek education (primary and secondary) using the same analytical framework.

The aim of this study is the science textbook analysis in the fifth grade of Greek Primary School on the scientific practices pertaining to its content. In this perspective the following research questions are radiated outward:

(a) which scientific practices are included in the textbook content and to what extent?

(b) Which individual axes of scientific practices are included in the textbook content and to what extent?

The results of this study are expected to contribute, both in terms of research and in terms of the teaching practice. More specifically, in terms of research it will consolidate the analysis of another aspect of the textbooks content. Also, in terms of the teaching practice the results of this study are expected to contribute: a) To improving or reconsidering the Greek Science curricula by the planners of curricula of the Greek Institute of Education Policy. b) To improving of the teaching practice with the presence of scientific practices. c) To the production of new or supplementary teaching material that will incorporate the scientific practices in its content according to reference [7] and will respond to new or improved curricula. d) To change policy direction the Ministry of Education regarding the professional development of teachers who teach science, targeting to the new standards of teaching about scientific practices. e) To reshaping of curricula of Greek Departments of Primary level Education.

2. Methodology

The methodological approach which was chosen for the analysis was the content analysis. This method is used by the vast majority of researchers in the last twelve years, according to the literature review that was carried out during this present study. The sample was drawn on part teaching package of Science "Research and discover" that is taught in the fifth grade of primary school [1]. The analysis grid was constructed by eight conceptual categories which represent the scientific practices defined by reference [7] and by subcategories of each scientific practice. The features of each subcategory followed exactly the new framework of reference [7] as was constructed by reference [18].

The activity was chosen as a unit analysis.With regard to content, any part of the text with a specific meaning - which was accompanied by analogues images, tables, diagrams, sketches - any section that engages the student in the use of one or more scientific practices were determined as activities. The text parts that were defined as activities were the experiments with or without findings (with pictures, diagrams, tables, sketches or without them), the introduction of each section (with any pictures, charts or tables) and any other text part that provides information to the student or motivates him to take action (with any pictures, charts, or tables). Also as activity was recorded each numbered "homework" with pictures, diagrams, tables or drawings that may accompany it. 313 analysis units were counted with respect to these limitations.

2.1. The Validity and Reliability

The conceptual categories were identified a priori, since they coexisted within the NCR (2012) and this parameter strengthens the validity of the data collection tool. Then the conceptual categories were classified in different subcategories according to reference [18] (see Table 1). The reliability of analysis grid was confirmed since a random part of the sample was analyzed by two researchers. The choice of the random part of the sample read as follows: the researcher who recorded all analysis units (313) matched them, from the first to the last unit analysis, with a serial number. The numbers were recorded in 21 columns of 15 numbers and of these he selected all the numbers (30) of 5th and 13th column which constituted the random part of the sample. The results of his analysis were compared to the results of the other researcher and were found to be satisfactory. The reliability of the analysis results was checked and rechecked by two researchers to avoid memory [20].

Table 1. The grid analysis with conceptual categories and subcategories by NRC (2012)

CATEGORIES	SUBCATEGORIES
Asking questions SP1	1. Asking questions that can be answered through empirical research 2. Evaluation questions 3. Asking questions on the work of others
Developing and using models SP2	1. Constructing and use of models that help questioning 2. Constructing and use of models that help in submission and check of Explanations 3. Constructing and use of models to represent those who have understood 4. Constructing and use models to communicate ideas 5. "Flexible" shift between different types of models 6. Identify the limits of models 7. Evaluation the limits of models 8. Reconsideration of the models
Planning and carrying out investigations SP3	1 .Asking question that can be investigated 2. Expressing a hypothesis based on a model or a theory 3. Recognition of variables 4. Checking how variables can be observed or measured 5. Checking how variables can be controlled 6. Checking of reliability and accuracy of data 7. Observation and collection of data describing a phenomenon 8. Observation and collection of data that check an exist in theory and explanations

	9. Planning for individual study 10. Planning for collaborative research 11. Evaluation of plans for research
Analysing and interpreting data SP4	1. Use tables for the comparison, a summary and data management 2. Use diagrams for comparison, summary and data management 3. Use illustrations for the comparison, summary and data management 4. Use statistical analysis for comparison, summary and data management 5. Recognition of important features and trends in the data. 6. Use of data as evidence. 7. Identify sources of errors.
Using mathematics and computational thinking SP5	1. Visual representation of data 2. Transformation of data between table and chart 3. Statistical analysis of the data 4. Recognition of quantitative relationships 5. Export of quantitative relationships 6. Implementation of quantitative relationships
Constructing explanations SP6	1. Implementation of explanations to the phenomena 2. Formation of explanations for the phenomena based on evidence 3. Connection of evidences with the alleged claims (expression of reasoning) 4. Formulation of claim 5. Use evidence for supporting or refutation an explanation 6. Identification of emptiness or weaknesses in an explanation
Engaging in argument from evidence SP7	1. Engaging in argumentation for identifying of strengths and weaknesses in reasoning on the best experimental design 2. Engaging in argumentation for identification of strengths and weaknesses in reasoning on the best technique analysis of data 3. Engaging in argumentation for identifying of strengths and weaknesses in reasoning for the best interpretation of a data set 4. Engaging in argumentation for identifying strengths and weaknesses in a reflection on how the data support a claim 5. Engaging in argumentation on finding the best explanation for a phenomenon individually 6. Engaging in argumentation for finding the best explanation for a phenomenon collaborative 7. Provision for criticism on others' work 8. Identify weaknesses in an argument 9. Modification of a task in the light of the evidence 10. Identify strengths and weaknesses in reports Science 11. Recognition of the way in which claims are justified by the scientific community
Obtaining, evaluating, and communicating information SP8	1. Oral communication ideas 2. Written communication ideas 3. Communication of ideas through tables and diagrams 4. Communication of ideas through extensive discussions with peers 5. Drawing upon meanings of scientific articles and texts 6. Drawing upon meanings of scientific information presented verbally 7. Evaluation of the reliability of scientific information 8. Integration of information from different sources

3. Results

Table 2. Frequencies and percentage frequencies of scientific practices that enter into textbook content

SCIENTIFIC PRACTICES (SP)		CONTENT ACTIVITIES IN TO INQUIRY AND DISCOVER SCIENCE TEXTBOOK	
		N	N%
SP1	Asking questions	0	0,00
SP2	Developing and using models	9	2,87
SP3	Planning and carrying out investigations	160	51,11
SP4	Analysing and interpreting data	206	65,81
SP5	Using mathematics and computational thinking	12	3,83
SP6	Constructing explanations	158	50,47
SP7	Engaging in argument from evidence	0	0,00

Table 3. Distribution of subcategories of scientific practice "development and using models" that are appeared in the content of the textbook

SP2 DEVELOPING AND USING MODELS: SUBCATEGORIES	N	N %
1.Constructing and using models that help questioning	0	0,00
2. Constructing and using models that help in submission and check of explanations	1	16,66
3. Constructing and using models to represent those who have understood	7	77,77
4. Constructing and using models to communicate ideas	0	0,00
5. "Flexible" shift between different types of models	1	16,66
6. Identify the limits of models	0	0,00
7. Evaluation of the limits of models	0	0,00
8. Reconsideration of the models	0	0,00
total	9	

Table 4. Distribution of subcategories of scientific practice "Planning and carrying out investigation" that are appeared in the content of the textbook

SP3 PLANNING AND CARRYING OUT INVESTIGATION : SUBCATEGORIES	N	N %
1. Asking questions that can be investigated	0	0,00
2. Expression an hypothesis based on a model or a theory	0	0,00
3. Recognition of variables	0	0,00
4. Checking how variables can be observed or measured	0	0,00
5. Checking how variables can be controlled	3	1,87
6. Checking of reliability and accuracy of data	0	0,00
7. Observation and collection of data described a phenomenon	151	94,37
8. Observation and collection of data that check an existing theory and explanations	4	2,50
9. Design plans for individual study	2	1,25
10. Design plans for collaborative research	0	0,00
11. Evaluation of plans for research	0	0,00
total	160	

Table 5. Distribution of subcategories of scientific practice "analyzing and interpreting data" that are appeared in the content of the textbook

SP4 ANALYSING AND INTERPRETING DATA : SUBCATEGORIES	N	N %
1. Use tables for the comparison, summary and data management	12	5,82
2. Using diagrams for comparison, summary and data management	1	0,48
3. Use illustrations for the comparison, a summary and data management	26	12,62
4. Using statistical analysis for comparison, summary and data management	0	0,00
5. Recognition of important features and trends in the data.	164	79,61
6. Use data as evidence.	1	0,48
7. Identify sources of errors.	2	0,97
total	206	

Table 6. Distribution of subcategories of scientific practice "using mathematics and computational thinking" that are appeared in the content of the textbook

SP5 USING MATHEMATICS AND COMPUTATIONAL THINKING : SUBCATEGORIES	N	N %
1. Visual representation of data	1	8,33
2. Transformation of data between table and chart	0	0,00
3. Statistical analysis of the data	0	0,00
4. Recognition of quantitative relationships	2	16,66
5. Export of quantitative relationships	6	50,00
6. Implementation of quantitative relationships	3	25,00
total	12	

Table 7. Distribution of subcategories of scientific practice "constructing explanations" that are appeared in the content of the textbook

SP6 CONSTRUCTING EXPLANATIONS: SUBCATEGORIES	**N**	**N %**
1. Implementation of explanations to the phenomena	0	0,00
2. Formation of explanations for the phenomena based on evidence	60	37,97
3. Connection of evidences with the claims allegedly (expression of reasoning)	0	0,00
4. Claim wording	93	58,86
5. Use evidence for supporting or refutation an explanation	4	2,53
6. Identification of emptiness or weaknesses in an explanation	1	0,63
total	158	

Table 8. Distribution of subcategories of scientific practice "obtaining, evaluating, and communicating information" that are appeared in the content of the textbook

SP8 OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION: SUBCATEGORIES	**N**	**N %**
1. Oral communication ideas	1	0,35
2. Written communication ideas	283	99,29
3. Communication of ideas through tables and diagrams	1	0,35
4. Communication of ideas through extensive discussions with peers	0	0,00
5. Drawing upon meanings of scientific articles and texts	0	0,00
6. Drawing upon meanings of scientific information presented verbally	0	0,00
7. Evaluation of the reliability of scientific information	0	0,00
total	285	0,00

4. Discussion

Almost all the analysis units of the textbook pertain to the scientific practices: obtaining, evaluating, and communicating information (see Table 2) (SP8) (more than nine out of ten analysis units). The presence analysis and interpretation of data (SP4) (nearly seven out of ten analysis units) is also very prominent. The scientific practices of planning and carrying out investigations (SP3) and constructing explanations (SP6) follow closely (five out of ten analysis units). On the contrary, the scientific practices of using mathematical and computational thinking (SP5) (four out of a hundred analysis units), and developing and using models (SP2) (3 out of 100 analysis units) are hardly presented. Asking questions (SP1) and argumentation with evidence (SP7) are not evident into any analysis units of content whatsoever.

The overwhelmingly high frequency of scientific practice SP8: obtaining, evaluating, and communicating information (see Table 2) can be attributed to the method that is proposed and followed by the textbook's authors i.e. Guided Research Teaching Model [13]. The Guided Research Teaching Model consists of the following stages: introductory stimulus – hypothesis formulation, experimental approach of the task, consolidation and generalization. Students in each lesson, according to the development of the process, record their observations during the experimental approach of the task and word the conclusion that they write in to the blank of their textbook. In this way each unit of analysis is connected with its respective subcategory: written communication of ideas (see Table 8) of the scientific practice of obtaining, evaluating, and communicating information (283 appearances to 285). Two other subcategories of the remaining seven of the above scientific practices are hardly involved: the oral communication ideas (1 to 285) and the communication of ideas through tables and diagrams (1 in 285) in units of content analysis. Students of the higher grades of primary school need to acquire the ability to read and understand books and articles of Science. The provided knowledge from these sources must be aligned with students' prior knowledge in order to enrich their vocabulary, to evaluate the information, to communicate them verbally with fruitful discussions and to incorporate them into that information that they already possess [5]. In conclusion, although the above practice holds the majority of appearances, there is not a pluralistic distribution of the respective subcategories.

Analysis and interpretation of data (SP4 demonstrates a high frequency in units of analysis (206 to 313). The exclusive connection of units of analysis to the subcategory of SP4 that is recognition of the important characteristics and trends in the data (164 to 206 appearances) is remarkable (see Table 5). The appearance of the subcategory, use of illustration for the comparison, the summarizing and data management (26 to 206) is limited but not as restricted as the subcategory, using tables for the comparison, data summary and management (12 to 206). The others subcategories of the above scientific practice SP4 are not shown in the units of analysis. In conclusion, there is no regularity in the subcategories' distribution.

The scientific practice planning and carrying out investigation (SP3) is the second more frequent in terms of the scientific practices' appearances (160 to 313). It is important to mention that the scientific practice's subcategory (see Table 4) *observation and collection of data used to describe a phenomenon* overwhelmingly enters into the units of analysis compared to the other subcategories' appearances of the same scientific practice (151). Three of the remaining ten subcategories declare their tenuous presence in the same practice: observation and collection of data that check an existing theory and explanations (4), checking how variables can be observed or measured (2) and the planning for individual study (1), while the seven subcategories that complement the above scientific practice are not shown in the units analysis (see Table 4). It seems that the distribution of subcategories of SP3 is attributed again to the textbook's structure and the teacher-followed model, since the investigation is not planned by the students, but by the authors. There is also guidance on the recording of data, without providing motivation and incentives to the students, in order for them to act voluntarily and designedly. According to reference [7] the students of primary school need opportunities to plan and carry out investigation so as to understand what should be measured, observed or monitored, which variables are independent or dependent, which tools will be used to carry out the data collection, how the data are recorded, how to become accustomed to making measurements with the greatest possible accuracy to minimize the error, etc. and to gain experience in the above practice. These ideas are aligned with the basic positions of learning, which has sprung from educational research and are widely held especially in recent years in primary education. [3].

The wording of claim, the scientific practice's subcategory (SP6) (see Table 7) *constructing explanations* seems to enter into extensive (93 appearances to 158) units of analysis linked with SP6. What follows is the subcategory's appearance *constructing explanations for the phenomena based on evidence* (60 appearances). The subcategory *use of evidence to support or discard an explanation* displays a very limited frequency (4 views) and finally the subcategory *identification of emptiness or weaknesses in an explanation* comes last (one appearance). The remaining two subcategories are not shown. The wording of claim coincides with the stage of conclusion wording in the Guided Research Teaching Model in this textbook. Analysing the content activities few activities linked with the subcategories of SP6 were identified. Reference [11] argues that the students need opportunities to participate in the creation and critique of explanations. Students must be encouraged to form explanations during their investigation, to evaluate their explanations as well as to develop their capacity to evaluate explanations of their peers [11]. The development of the aforementioned abilities calls for the expansion of students' investigation, for instance: the effect that a variable's isolation would have on their observations, how a variable affects the other measurements etc. [11]. Also, it is essential for students, to compare their explanations supporting them with evidence, to discern the gaps or weaknesses of their explanations, to review them, to revise and enrich them repeating their investigation and under different conditions [20]. The successful management of the explanation seems to lead to conceptual change [20]. In the units of analysis of this textbook which is linked with the above scientific practice the aforementioned actions are not detected.

The construction of claims and mainly explanations based on students' evidence, constitutes an essential aim of science education [2]. Also, the wording of conclusion based on scientific evidences constitutes a core axis of students' scientific literacy [10]. However, the students word claims which are not usually accompanied by adequate and sufficient evidence to link them with their claims [15] and do not construct reasoning that connect evidence with their reasoning [18]. Research findings indicate that the students' involvement in the planning and carrying out of investigation contribute to the development of their ability to produce documented explanations [14,16].

The appearances of scientific *practice use of mathematical and computational thinking* (SP5) are very few (12 appearances see Table 6) compared with the appearances of the above scientific practices. The SP5 enters into units of analysis that belong only to the first chapter of the textbook concerning the properties' computation of matter: mass, volume, density. Activities that activate the students with more practice are noticeably absent. This occurs because a) the formalism in the analytical curricula of Science education of primary school has not been introduced b) absence of core ideas of science education from the curriculum, and therefore from the textbook. According to reference [7] the students of primary school have to be familiar with Sciences with the aid of mathematics as maths will contribute to a better understanding of Sciences. Students can use numbers to measure, find or describe standards. They should learn, also, to use math tools for measuring and defining the characteristics of variables.

Almost the same appearance frequency (9 see Table 3) is encountered in the scientific practice SP2, *developing and using models* which is only shown in activities related to the electricity's chapter. It seems that the authors of textbook do not adopt the development and use of models into the content activities of the remaining chapters. The engagement of students with the construction of models helps them to construct and revise mental models of the phenomena, and to be able to better understand and strengthen the scientific logic [7]. Also, the use of models helps students to ask scientific questions, to construct explanations and communicate their ideas [9].

As was aforementioned no unit analysis is connected with scientific practices SP1and SP7.

The absence of appearance of SP1 (asking questions) can be attributed, on the one hand, to the structure of the Guided Research Teaching Model that was adopted by the textbook authors. In this model the authors are the ones to word the scientific questions and hypotheses, not the students. On the other hand, authors probably identify with the opinion that the capacity development of students to ask questions is a time-consuming process, which limits the teaching time that is provided by the curriculum (three hours per week). According to reference [7] asking questions is the most important and fundamental stage of scientific investigation as the questions strengthen the incentive to carry out an investigation. Students reading texts, observing models and characteristics of the phenomena enter the process of asking questions [7]. Also, they have to get used to asking each other questions and in the long run to ask more sophisticated and targeted questions using the appropriate terminology [7].

Reference [12] argues that the absence of argumentation in Science' teaching is remarkable. Teachers and students construct explanations for phenomena and concepts which are supposed to be true [11]. The argument, however, is a different process; it is an attempt to establish the truth. However, due to the rush to present the main characteristics of a natural phenomenon or a concept, most of the arguments that are required for the understanding of knowledge are elided either by teachers either by the curricula or by textbooks [12]. So, the students are led to learn the knowledge or to obtain the science ideas as "divine law" without investigation. The result from this situation is the creation or retention of misunderstandings [12]. The authors of this textbook do not seem to escape from the 'highroad' (9 see Table 3). The scientific practice SP7 related to *the argument based on evidence* is not evident in any content activity. However, the researching data show that the argumentation's development is possible using appropriately designed educational material, even in young children [6].

From the findings concerning the scientific practices that enter into units of analysis one can identify that the following trends, that is the three above-led activities are followed extensively throughout the content of textbook, without giving any initiative to the student to ask investigational questions, to plan investigation, to choose experiments for the verification of their hypothesis, to interpret their own findings, to construct explanations. These trends seem to be due to the methodological approach of Guided Research Teaching Model [13] that the authors use and suggest, because performing experiments, observing phenomena and making inferences are stages of this approach. However, this hypothesis needs to be investigated.

5. Conclusions

In connection with the above discussion it is concluded that the extent of scientific practices, that are included in the units of analysis of the textbook "Research and Discover - Workbook", does not seem to be satisfactory because:

a) All scientific practices, which are recommended by the reference [7], do not enter into units of analysis in this textbook. However, scientific practices (6 to 8) that enter into content activities present only some aspects (subcategories), whereas other crucial aspects do not.

b) The practices of asking questions (SP1) and engaging to arguments (SP7) don't enter into units of analysis. It is worth noting that the above scientific practices constitute fundamental stages of investigation in the science field. The above ascertainment is due to the fact that the authors wrote a textbook based on Guided Research Teaching Model. Authors don't provide the student with freedom and autonomy to ask questions, to plan and carry out investigations, to find answers with evidence and to argue for the answers.

c) Concerning the existing scientific practices, the results showed an incomplete "picture" of units of analysis, since there is not a normal distribution of subcategories of all scientific practice. On the one hand, half subcategories and sometimes more than half of existing scientific practices do not appear in the units of analysis. On the other hand, a subcategory or some subcategories of each scientific practice are involved in the units of analysis to a very large extent.

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