Dimensions of Scientific Literacy in Greek Upper Secondary Education Physics Curricula

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Abstract

There has been limited research focusing on the analysis of secondary education science curricula in terms of scientific literacy dimensions. This study aims to investigate dimensions of scientific literacy in Greek physics curricula of upper secondary education (Greek Lyceum). Physics curricula of first, second and third years were analysed in terms of the dimensions of scientific literacy based on the PISA 2015 framework (knowledge, competences and contexts). As a unit of analysis was chosen each objective set by physics curricula. Data analysis showed that content knowledge dominates in physics curricula, whereas the occurrence of the other two kinds of knowledge (procedural and epistemic knowledge) is limited. Regarding the competences, it has been found that physics curricula mainly focus on the ability to recall and apply scientific knowledge. The presence of the other competences - relating to evaluate and design scientific enquiry as well as to interpret data and evidence scientifically - is limited. As regards to the contexts included in physics curricula, it has been found that there are only a few correlations with the contexts for the PISA 2015 scientific literacy assessment. The paper concludes with a discussion as well as recommendations for future research.

Keywords: Scientific Literacy, Physics Curricula, Science Learning

1. Introduction

The choice of the content of curricula, the disciplines of science that should be included in them, the arrangement and sequence of these disciplines, the transition rate, and the choice of appropriate learning strategies play an important role in science education (Dimopoulos & Koulaidis, 2003). Knowing how effective a curriculum is, and for whom and under what conditions it is effective, constitutes a valuable and irreplaceable source of information for decision makers, whether they are classroom teachers, parents, district curriculum specialists, school boards, state adoption boards, curriculum writers and evaluators, or national policy makers. Therefore, it is necessary to systematically study and analyze science curricula.

In modern societies, it is necessary to build up basic scientific knowledge and develop competences and attitudes that will enable students to effectively cope with the problems of everyday life and participate in the society as active citizens (OECD, 2006). To describe this set of knowledge, competences and attitudes, the concept of "scientific literacy" is used. Scientific literacy is closely linked with attempts to redefine the main objectives of science education so that scientific knowledge is understood and used by all individuals (DeBoer, 2000).

The research focusing on the analysis of science curricula as to the dimensions of scientific literacy is limited (Sothayapetch et al., 2013). This paper deals with the dimensions of scientific literacy included in upper secondary education (Lyceum) physics curricula in Greece (for pupils aged 15-18). Lyceum physics curricula constitute an important part of science curricula since Lyceum is the upper level of secondary education and thus formulates - to a great extent - the scientific knowledge which tomorrow's citizens will be equipped with.

2. Theoretical Framework

2.1. Curriculum

Curriculum is the formal expression of the educational policy of a country (Ball & Cohen, 1996). This includes the knowledge and skills that the state deems necessary to pass on to future generations. It contains the syllabus, the general goals, the specific objectives for each subject taught in school and sets the guidelines which teachers have to follow (Chen et al., 2009). It sets -directly or indirectly- the content of the teaching process as well as the evaluation procedures of teaching. On a practical level, the curriculum of a subject answers the questions of which content, for what purpose, in what grade and in what order this should be taught or what knowledge should be transmitted to the students of a school grade or a school type (Marek, 2004).

In most countries, the curriculum of subjects is closely linked with school textbooks. They give the curriculum concrete content alongside which they make up the official conditions of the educational process (Chen et al., 2009). Curricula and textbooks provide a direction in the way these topics are taught (Martínez-Gracia et al., 2006). Many teachers rely on the curriculum and textbook in deciding what and how to teach, especially when they are teaching outside their area of expertise (Stern & Roseman, 2004).

Curricula can be rendered in diverse types. A common extensive distinction is among the three levels of the intended curriculum, the implemented curriculum, and the attained curriculum (Keeves, 1972). The intended curriculum is concerned in terms of learning objectives, subject topics, teaching methods and materials, the implemented curriculum focuses on the practice in the classroom and the attained curriculum deals with the fruitful phase of education designating knowledge and competences that student has internalized from learning process (van den Akker, 2003).

Focus on this study falls on the intended curriculum particularly on learning objectives. Learning objectives are crucial for the intended curriculum providing a clear description of what student should learn at appropriate age.

2.2. Scientific Literacy

The concept of scientific literacy attempts to summarize all the essential objectives of science education (NRC, 2012; OECD, 2006). It is the knowledge a person needs in order to understand public issues involving science (DeBoer, 2000). However, there is no generally accepted definition of scientific literacy; rather, “the many characterizations of scientific literacy discussed in the literature include varying elements of competencies in science inquiry, content knowledge, and attitudes toward science” (Fives et al., 2014, 550).

Scientific literacy is conceptualized in the subsequent ways: knowledge of the content of science and the ability to distinguish between science and nonscience (NRC, 1996), understanding science and its applications (DeBoer, 2000), understanding the nature of science (Shamos, 1995), ability to think scientifically (DeBoer, 2000), ability to use scientific knowledge and processes in problem solving (NRC, 1996), and ability to think critically (Shamos, 1995).

Scientific literacy, according to the PISA 2006 assessment framework, refers to the scientific knowledge of the student and “the ability to use this knowledge to recognize scientific questions, acquire new knowledge, explain phenomena in a scientific way, and draw conclusions based on scientific evidence” (OECD, 2006, 12). According to the PISA 2015 assessment framework, “a scientifically literate person should be willing to engage in reasoned discourse about science which requires the competencies to: explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically” (OECD 2013, 7). Scientific literacy, as described in the PISA 2015 framework, included the following dimensions: scientific contexts, scientific competencies, domains of scientific knowledge, and student attitudes toward science (see the section: “Analysis Framework of Science Curricula”).

Pelger and Nilsson (2015) quote from Roberts (2007) drew attention to two visions of scientific literacy; vision I and vision II. Vision I was described as being scientist-centered with a focus on science content knowledge (the products and processes of science). Vision II was described as being more student-centered and context driven, moving beyond seeing science as only facts and knowledge, and instead connecting it to conditions that students are likely to contact as citizens (Roberts, 2007).

3. Literature Review

The study of the relevant research literature shows that there have been several studies focusing on the analysis of school science textbooks regarding the dimensions of scientific literacy (e.g., Tamir &Lunetta, 1981; Elliott et al., 1987; Pizzini et al., 1991; Hamm, 1991; Chiappetta et al., 1991; Chiang-Soong &Yager, 1993; Wilkinson, 1999). Furthermore, there have been studies analyzing science curricula with regard to the dimensions of scientific literacy (BouJaoude, 2002; Wei & Thomas, 2006; Park, 2006; Nampota& Thompson, 2008; Chabalangula et al., 2008; Yuenyong & Narjaikaew, 2009; Dillon,2009; Eijck, 2010; Ferreira & Morais, 2011; Cansiz&Turker, 2011; Erdogan & Koseoglu, 2012; Thorolfsson et al., 2012; Erduran & Wong, 2013; Tamassia & Frans, 2014; Fives et al., 2014). The researchers found that the "science as accumulation of knowledge" theme was the most highlighted theme in curricula, whereas "inquiring nature of science" and "science as a way of thinking" themes were not sufficiently highlighted in curricula.

There is very limited research which uses the PISA assessment framework of scientific literacy to analyze science curricula. Sothayapetch, Lavonen and Juuti (2013) analyzed the Finnish and Thai science curricula at primary school according to the PISA 2006 Scientific Literacy Framework. The most interesting findings deal with the balance between concepts and processes. The Thai curriculum emphasizes PISA related processes while the Finnish curriculum emphasizes concepts. Another interesting finding is related to contexts. The Finnish curriculum emphasizes contexts more than the Thai curriculum does.

However, there are no studies analyzing science curricula in terms of the PISA 2015 framework for assessment of scientific literacy (OECD, 2013). Therefore, there is no research relating to the analysis of physics curricula regarding the PISA 2015 assessment framework of scientific literacy. Theabove reveal the necessity for such research.

4. Purpose and Research Questions

The present study aims to analyze the Greek physics curricula of upper secondary education (Greek Lyceum) regarding the dimensions of scientific literacy (knowledge, competences, and contexts) as described in the PISA 2015 framework.
In particular, the research questions of this study are the following:

(a) To what extent are the dimensions of scientific literacy included in the Greek physics curricula of upper secondary education?
(b) Are there any differences -regarding the dimensions of scientific literacy- among the three physics curricula (for A, B and C grades of Greek Lyceum)?

5. Methodology

5.1. Design of the Study and Sample

The research is quantitative and was conducted in three stages. The first stage comprised: (a) the identification of the content to be analyzed, (b) the determination of the analysis unit, (c) the formulation of an analysis framework based on the framework of PISA 2015 and (d) the application of the analysis framework to the analysis units of the curricula. In the second stage the data were analysed and presented on tables. In the third stage conclusions were drawn in relation to the dimensions of scientific literacy involved in the physics curricula. As a research method content analysis was chosen. The material analyzed in this study is the curricula of the three the three physics curricula (for A, B and C grades of Greek Lyceum), which were implemented during the year the study was conducted (2014-2015).

As a unit of analysis was regarded each learning objective, namely each statement with a complete meaning, as found in the physics curricula. The reason for selecting this analysis unit -and not the page or the paragraph- is that the Greek curriculum is structured around learning objectives.

A total of 260 units of analysis in the Greek Lyceum Physics curricula have been identified. Of these, 35 units of analysis were found in the curriculum of A grade, 103 in the curriculum of B grade and 122 in the curriculum of C grade.

5.2. Analysis Framework of Science Curricula

The PISA 2015 scientific literacy framework (OECD, 2013) was used as an analytical frame for the analysis. Three main dimensions (knowledge, competences, and contexts) are emphasized in the PISA 2015 science framework (OECD, 2013). The categories of all three dimensions are shown in Table 1.

Table 1: Analysis framework of science curricula: dimensions and categories

Dimensions	Categories
Knowledge	Content knowledge
	Procedural knowledge
	Epistemic knowledge
Competences	Explain phenomena scientifically
	Evaluate and design scientific equity
	Interpret data and evidence scientifically
Contexts	Health and Disease
	Natural Resources
	Environmental Quality
	Hazards
	Frontiers of science and technology

Knowledge is classified into three types. The first type is the knowledge of facts, concepts, ideas and theories about the natural world (OECD, 2013). This type of knowledge is referred to as *content knowledge.*In particular, such knowledge includes both knowledge of the natural world and technological artefacts. The knowledge of procedures and strategies used by scientists to obtain reliable and valid data (knowledge of the procedures and strategies used in all types of scientific enquiry) is defined as *procedural knowledge* (OECD, 2013). The third type of knowledge is the *epistemic knowledge*, which is the knowledge of the structures and of defining the characteristics which are necessary in the process of developing and justifying scientific knowledge (OECD, 2013).

The competences proposed by the PISA 2015 framework are the following three (OECD, 2013):

(a) *explain phenomena scientifically* (which includes recalling and applying appropriate scientific knowledge, identifying, using and creating interpretation models and representations, making and justifying appropriate predictions, formulating interpretative assumptions, and explaining the possible impact of scientific knowledge on society)

(b) *evaluate and design scientific equity* (which includes determining the questions to be addressed in a scientific study, distinguishing questions that can be addressed scientifically, proposing a scientific method of addressing a question, evaluating the scientific method of addressing a question, and describing and evaluating a number of methods that scientists use to ensure the reliability of data and the objectivity of explanations)

(c) *interpret data and evidence scientifically* (which includes converting data from one representation to another, analyzing and interpreting the data and drawing appropriate conclusions, identifying the assumptions, evidence and reasoning in scientific texts, distinguishing between arguments based on scientific evidence and theories and those based on speculations, and evaluating scientific arguments and evidence of various sources).

The PISA program evaluates competences and knowledge in specific contexts (life situations involving science and technology. These contexts are not limited to teaching science at school. The situations that students are asked to deal with are placed within a personal, local, national and global context. These situations relate to oneself, family and peers (personal), the community (local and national), as well as life around the world (global). Topics can be derived from historical contexts as well. They come from a wide variety of situations in life and are relevant to students' lives. The areas of application are (OECD, 2013): health and disease, natural resources, environmental quality, hazards, and the frontiers of science and technology.

These are areas in which scientific literacy is of particular value to individuals and communities for strengthening and preserving quality of life as well as developing public policy.

5.3. Data Collection and Analysis

First, physics curricula (for A, B and C grades of Greek Lyceum) were collected. Then, the learning objectives were identified which are included in each curriculum and were numbered separately for each grade. Afterwards, frequencies and percentage frequencies for each dimension of the analysis framework were computed.The analysis was carried out by two researchers who worked independently. The percentage of agreement was about 92% concerning the dimensions of scientific literacy. Then, disagreements were resolved through discussion.
The relationship between the dimensions of scientific literacy and the three physics curricula was investigated through χ^2 test. The identification and interpretation of the correlations were based on χ^2 and standardized residual values (Blalock, 1987).

6. Results

The results carried out in three parts. The first part refers to knowledge of science. The second part focuses on science competences. The third part focuses on contexts.

6.1. Knowledge of Science

Table 2 shows the distribution of units of analysis (objectives) of the physics curricula (for A, B and C grades of Greek Lyceum) in relation to the three types of knowledge of the PISA 2015 framework. The comparative study of the three physics curricula shows that content knowledge dominates whereas the appearance of procedural knowledge and epistemic knowledge is particularly limited.

Table 2: The categories of knowledge in the physics curricula: frequencies (f & f%)

Categories of Knowledge	AGrade		B Grade		C Grade	
	f	f%	f	f%	f	f%
Content Knowledge	33	94.3	102	99.0	122	100
Procedural knowledge	5	14.3	1	1.0	0	0.0
Epistemic knowledge	5	14.3	17	16.5	3	2.5

Additionally, there is a statistically significant relation between the categories of knowledge (content knowledge, procedural knowledge, epistemic knowledge) and the physics curricula (for A, B and C grades) (χ^2=34.55, df=4, p<0.0001). This relation is due to the following tendencies (see Table 3): the category of epistemic knowledge tends to appear in the physics curriculum of B grade and the category of procedural knowledge tends to appear in the physics curriculum of A grade.

Table 3: Frequencies of the three categories of knowledge in each grade and corresponding standardized residuals

Categories of Knowledge	A Grade	B Grade	C Grade
Content Knowledge	33 [-0.87]	102 [-0.49]	122 [+0.99]
Procedural Knowledge	5 [+4.34]	1 [-0.94]	0 [-1.61]
Epistemic Knowledge	5 [+0.66]	17 [+2.04]	3 [-2.38]

6.2. Science Competences

Table 4 shows the distribution of the units of analysis of physics curricula (for A, B and C grades of Greek Lyceum) in relation to the categories of competences as defined in PISA 2015 framework. The comparative study of the curricula of the three grades shows that the kind of competence that prevails is the scientific explanation of phenomena.

Table 4: The three categories of competences in the physics curricula: frequencies (f & f%)

Categories of Competences	A Grade		B Grade		C Grade	
	f	f%	f	f%	f	f%
Explain phenomena scientifically	35	100	102	99	121	99.2
Evaluate and design scientific equity	0	0.0	0	0.0	0	0.0
Interpret data and evidence scientifically	10	2.9	0	0.0	12	9.8
Not associated with any of the above categories	0	0.0	1	1	1	0.8

Additionally, there is a statistically significant relation between the categories of competences (explain phenomena scientifically, interpret data and evidence scientifically) and the physics curricula (for A, B and C grades) (χ^2=8.32, df=1, p=0.0039). This correlation is due to the following tendency (Table 5): the competence concerning interpret data and evidence scientifically tends to appear in the curriculum of A grade and not in the curriculum of B grade.

Table 5: Frequencies of the categories of competences in each grade and corresponding standardized residuals

Categories of Competences	A Grade	B Grade	C Grade
Explain phenomena scientifically	35 [-0.93]	102 [+0.78]	121 [-0.14]
Interpret data and evidence scientifically	10 [+3.17]	0 [-2.65]	12 [+0.48]

6.3. Contexts

Table 6 shows the distribution of the analysis units in relation to the categories of the contexts of PISA 2015 framework (OECD, 2013). The comparative study of the physics curricula of the three grades shows that the contexts of the analysis units of physics curricula are not associated with the contexts of PISA 2015 framework.

Table 6: The contexts in the physics curricula: frequencies (f & f%)

Categories of Contexts	A Grade		B Grade		C Grade	
	f	f%	f	f%	f	f%
Health and Disease	0	0.0	0	0.0	0	0.0
Natural Resources	0	0.0	0	0.0	0	0.0
Environmental Quality	0	0.0	0	0.0	0	0.0
Hazards	0	0.0	1	1.0	2	1.6
Frontiers of science and technology	0	0.0	0	0.0	0	0.0
Not associated with any of the above categories	35	100	102	99	120	98.4

7. Discussion and Conclusions

The study analyzed Greek physics curricula of upper secondary education (Greek Lyceum) regarding the dimensions of scientific literacy (knowledge, competences, and contexts) according to the PISA 2015 framework. Regarding the dimension of knowledge, it was found that the three physics curricula are dominated by content knowledge whereas the presence of the other two types of knowledge, the procedural and the epistemic knowledge, is particularly limited. Moreover, it was shown that the units of analysis which prevail are related to the competence of "explain phenomena scientifically" whereas the presence of other two types of competences ("evaluate and design scientific equity" and "interpret data and evidence scientifically") is particularly limited. In relation to the dimension of the contexts, it was found that there are only a very few correlations between the contexts of the Greek physics curricula and the contexts of PISA 2015 framework. The comparative study of the three Greek physics curricula showed that there are no differences among the curricula as far as content knowledge and the competence of "explain phenomena scientifically" (these dimensions prevail in the curricula). It was found that the least number of analysis units related to the epistemic knowledge tends to appear more often in the curriculum of B grade, whereas the units of analysis related to the procedural knowledge tend to appear more often in the curriculum of A grade. Furthermore, it was found that the least number of analysis units classified in the competence of "interpret data and evidence scientifically" appears more often in the curriculum of A grade.

Therefore, the distribution of the dimensions of scientific literacy in the Greek physics curricula, as it was found in the study, does not familiarize Greek students with important aspects of the dimensions of scientific literacy. More particularly, the limited presence of the dimension of procedural knowledge deprives students of the possibility to familiarize themselves with the procedures which are employed in scientific research in order to acquire knowledge, such as the determination of variables (dependent, independent and control variables), the selection of appropriate kind of measurement and representation, the selection of ways to assess and minimize uncertainty (repeating and averaging measurements), as well as the selection of mechanisms which ensure repeatability (closeness of agreement between repeated measures of the same quantity) and accuracy of data (the closeness of agreement between a measured quantity and a true value of the measure) (OECD, 2013). Furthermore, students do not realize that a suitable way to present data (using tables, graphs and charts) is chosen for each scientific topic as well as that a suitable scientific method is searched for depending on the type of scientific question (Osborne, 2014).

The limited presence of the dimension of epistemic knowledge does not allow students to learn ways to justify new knowledge, for example, how to support claims from evidence and reasoning, to understand how this knowledge has come up and what the nature of scientific observations, facts, models and theories is (Osborne, 2014). The limited presence of this dimension possibly does not introduce students to the values of science (e.g., a commitment to publication, objectivity and the elimination of bias) and the ways of reasoning employed in them (e.g., deductive, inductive, analogical, and model-based). It does not help students to learn about the function of different forms of empirical enquiry in establishing knowledge, their goal (to test explanatory hypotheses or identify patterns) and their design (observation, controlled experiments, correlational studies) as well as about the effects of measurement errors on the degree of confidence in scientific knowledge, and the role of collaboration and critique and how peer review helps to establish confidence in scientific claims (OECD, 2013). In addition, it does not present students with the use and the role of theoretical models and their boundaries as well as the role of scientific knowledge along with other forms knowledge in identifying and addressing societal and technological issues (Osborne, 2014).

Regarding the dimension of competences, the students' familiarization solely with the competence which refers to recalling and applying knowledge does not help students develop critical thinking and formulate interpretative presuppositions about the phenomena and the way they could be investigated scientifically. As a result of the absence of the dimensions of competences -as described in the PISA program- from the Greek curricula, it is the cultivation of the abilities to identify the question explored in a given scientific study, distinguish questions that are possible to investigate scientifically, propose a way of exploring a given question scientifically, evaluate ways of exploring a given question scientifically as well as the cultivation of the ability to describe and evaluate a range of ways that scientists use to ensure the reliability of data and the objectivity of explanations, which is not promoted (OECD, 2013).

Students are not helped to develop the ability to transform data from one representation to another, analyse and interpret data and draw appropriate conclusions, identify the assumptions, evidence and reasoning in science-related texts, distinguish between arguments which are based on scientific evidence and theory and those based on other considerations as well as the ability to evaluate scientific arguments and evidence from different sources (Osborne, 2014).

It has been highlighted that the development of a competence in formulating justified explanations and arguments is necessary not only for those students planning to follow a profession which is related to a certain scientific field but also for all students and future citizens (NRC, 2012; OECD, 2013). It is essential that citizens formulate –orally or written– a point of view of theirs and justify it in order to convince of its rightness (Duschl et al., 2007). Most importantly, though, it is essential that they evaluate the justification of a point of view they are presented with in written form on the internet, in the newspapers and magazines, or orally on the television and the radio (Krajcik& McNeill, 2009).

Furthermore, the context is shown to be very limited in the curricula depriving students of the variety and the beauty of knowledge about the whole natural world and its explanations, alienating knowledge from the various contexts that it can appear (Sothayapetch et al., 2013). In this way, a distinction between school knowledge and knowledge of everyday life is created, with the result that the usefulness of scientific knowledge which is included in the school context cannot be understood.

The remarks above can explain -to a certain extent- the low performance of Greek students in the PISA program (OECD, 2010) since Greek students have not come in touch with many of the dimensions of the scientific literacy set by the PISA framework through the science curricula and by extension through the science school textbooks.

The findings of this study can be utilized both in the field of research and in that of teaching practice. More particularly, the analysis framework which was formulated in the present study can be used by other researchers in conducting similar studies. Moreover, the findings of the study can be used by both the designers of the curricula in order to create new curricula for the citizens' education which will promote scientific literacy and by teachers to apply to activities which will involve the dimensions of scientific literacy in teaching practice.

In the light of the findings of the present study new proposals for research come up. It would be of interest to analyze the physics curricula of lower secondary education (Gymnasium) as well as of Primary School so that continuity between these curricula and thus, between grades of education is explored. Also, it would be interesting to analyze the chemistry and biology curricula of both upper and lower secondary education so that they can be compared with the physics curricula analyzed in this study regarding their common or different pursuits. Furthermore, the school science textbooks in primary and secondary education could be analyzed. This analysis could help in comparing the school textbooks to each other as well as to the curricula so that we form a complete picture of the science curricula and the school science textbooks.

References

Ball, D. L.& Cohen, D. (1996). Reform by the book: What is -or might be- the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher,* 25(9), 6-8.

Blalock, H. (1987). *Sosial statistics*. Singapore: Mc Graw Hill.

BouJaoude, S. (2002). Balance of scientific literacy themes in science curricula: The case of Lebanon. *International Journal of Science Education,* 24(2), 139-156.

Cansiz, M.&Turker, N. (2011). Scientific literacy investigation in science curricula: The case of Turkey. *Western Anatolia Journal of Educational Sciences*. Special Issue, 359-366.

Chabalengula, V., Mumba, M., Lorsbach,T. & Moore, C. (2008). Curriculum and Instructional Validity of the Scientific Literacy Themes Covered in Zambian High School Biology Curriculum. *International Journal of Environmental and Science Education,* 3(4), 207-220.

Chen, J. C., Reys, B.&Reys, R. (2009). Analysis of the learning expectations related to grade 1-8 measurement in some countries. *International Journal of Science and Mathematics Education*, 7(5), 1013-1031.

Chiang-Soong, B.&Yager, R. (1993). The inclusion of STS material in the most frequently used secondary science textbooks in the US. *Journal of Research in Science Teaching*, 30(4), 339-349.

Chiappetta, E., Fillman, D.&Sethna, G. (1991). A method to quantify major themes of scientific literacy in science textbooks. *Journal of Research in Science Teaching*, 28(8), 713-725.

DeBoer, G. E. (2000). Scientific Literacy: Another Look at its Historical and Contemporary Meanings and Its Relationship to Science Education Reform. *Journal of Research in Science Teaching,* 37(6), 582—601.

Dillon, J. (2009). On Scientific Literacy and Curriculum Reform.*International Journal of Environmental and Science Education*, 4(3), 201-213.

Dimopoulos, K.&Koulaidis, V. (2003). Science and Technology Education for Citizenship: The potential role of the Press. *Science Education,* 87(2), 241-256.

Duschl, R., Schweingruber, H. &Shouse, A. (2007). *Taking science to school: learning and teaching science in grades K-8*. Washington, DC: National Academies Press.

Eijck, V. M. (2010). Addressing the Dynamics of Science in Curricular Reform for Scientific Literacy: The case of genomics. *International Journal of Science Education*, 32(18), 2429-2449.

Elliott, D., Carter Nagel,K. & Woodward, A. (1987). Scientific illiteracy in elementary school science textbook programmes. *Journal of Curriculum Studies,* 19(1), 73-76.

Erdogan, Nur M.&Koseoglu, F. (2012). Analysis of School Physics, Chemistry and Biology Curriculums in terms of Scientific Literacy Themes. *Educational Sciences: Theory & Practice,* 12(4), 2899-2904.

Erduran, S.& Wong, S. L. (2013). Science Curriculum Reform on "Scientific Literacy for All" Across National Contexts: Case studies of Curricula from England and Hong Kong. In Nasser Mansour and Rupert Wegerif(Eds.),*Science Education for Diversity in Knowledge Society* (pp. 179-201). Dordrect: Springer.

Ferreira, S.&Morais, A. (2011). The Nature of Science in Science Curricula: Methods and concepts of analysis. *International Journal of Science Education,* 35(16),2670-2691.

Fives, H., Huebner, W., Birnbaum, A.&Nicolich, M. (2014). Developing a Measure of Scientific Literacy for Middle School Students. *Science Education,* 98(4), 549–580.

Hamm, M. (1991). Textbook portrayals of science and technology issues in a television age. *Science, Technology & Human Values,* 16(1), 88-98.

Krajcik, J.& McNeill, K. (2009). Designing Instructional Materials to Support Students' in Writing Scientific Explanations: Using Evidence and Reasoning across the Middle School Years. Paper Presented at the annual meeting of the National Association for Research in Science Teaching, Hyatt Regency Orange County, Garden Grove, CA.

Keeves, J. (1972). *Education Environment and Student Achievement*. Stockholm: Almguiat and Hiksell.

Marek, R. (2004). *Opportunities in social science careers*. New York: Mc Graw-Hill.

Martínez-Gracia, M. V., Gil-Quílez, M.&Osada, J. (2006). Analysis of molecular genetics content in Spanish secondary school textbooks. *Journal of Biological Education,* 40(2), 35–60.

Nampota, D.& Thompson, J. (2008). Curriculum continuity and school to university transition: science and technology programmes in Malawi. *Compare: A Journal of Comparative Education,* 38(2), 233-246.

National Research Council [NRC]. (1996). *National Science Education Standards*. Washington D.C.: National Academy Press.

National Research Council [NRC]. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, D.C.: The National Academies Press.

Organisation for Economic Co-operation, and Development [OECD]. (2006). *Assessing Scientific, Reading and Mathematical Literacy: A Framework for PISA 2006*. OECD Publishing.

Organisation for Economic Co-operation, and Development [OECD]. (2010). *PISA 2009 Results: What Students Know and Can Do: Student Performance in Reading, Mathematics and Science (Volume I)*. Paris: OECD Publishing

Organisation for Economic Co-operation, and Development [OECD]. (2013). PISA 2015 Draft Science Framework. Retrieved from http://www.oecd.org/pisa/pisaproducts/Draft%20PISA%202015%20Science%20Frame work%20.pdf.

Osborne, J. (2014). Scientific practices and inquiry in the science classroom. In Norman Lederman, and Sandra Abell*Handbook of Research on Science Education*, Volume II, (pp. 579–599). New York: Routledge.

Park, D-Y. (2006). Curriculum Reform Movement in the US Science Education. 1st Pacific Rim Conference on Education. Hokkaido University of Education, Hokkaido, Japan, October 21-23.

Pelger, S.& Nilsson, P. (2015). Popular Science Writing to Support Students' Learning of Science and Scientific Literacy. *Research in Science Education,* 46(3), 439-456.

Pizzini, E., Shepardson, D.& Abell, S. (1991). The inquiry level of junior high activities: Implications to science teaching. *Journal of Research in Science Teaching,* 28(2), 111-121.

Roberts, D. (2007). *Scientific Literacy/Science Literacy*. In Sandra Abell and Norman Lederman (Eds.),*Handbook of Research on Science Education*,(pp. 729-780), New York: Routledge.

Shamos, M. (1995). *The myth of scientific literacy*. New Brunswick, NJ: Rutgers University Press.

Sothayapetch, P., Lavonen, J.&Juuti, K. (2013). A comparative analysis of PISA scientific literacy framework in Finnish and Thai science curricula. *Science Education International,* 24(1), 78-97.

Stern, L.& Roseman, J. (2004). Can middle school science textbooks help students learn important ideas? Findings from Project 2061' curriculum evaluation study: Life science. *Journal of Research in Science Teaching,* 41(6), 538–568.

Tamassia, L.& Frans, R. (2014). Does integrated science education improve scientific literacy? *Journal of the European Teacher Education Network,* 9, 131-141.

Tamir, P.&Lunetta, V. (1981). Inquiry-related tasks in high school science laboratory handbooks.*Science Education,* 65(5), 477-484.

Thorolfsson, M., Finnbogason, G. & Macdonald, A. (2012). A perspective on the Intended Science Curriculum in Iceland and its "Transformation" over a Period of 50 Years. *International Journal of Science Education,* 34(17), 2641-2665.

Van den Akker, J. (2003). Curriculum perspectives: an introduction. In Jan van den Akker, Wilmad Kuiper and UweHameyer (Eds.),*Curriculum Landscapes and Trends*, (pp. 1-10). Dordrecht: Kluwer Academic Publishers.

Wei, B.& Thomas, G. (2006). An Examination of the Change of the Junior Secondary School Chemistry Curriculum in the P. R. China: In the View of Scientific Literacy." *Research in Science Education,* 36, 403-418.

Wilkinson, J. (1999). A Quantitative Analysis of Physics Textbooks for Scientific Literacy Themes. *Research in Science Education*, 29(3), 385-399.

Yuenyong, C.&Narjaikaew, P. (2009). Scientific Literacy and Thailand Science Education. *International Journal of Environmental and Science Education,* 4(3), 335-349.