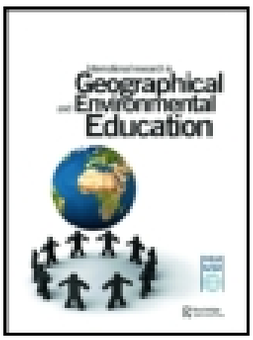

International Research in Geographical and Environmental Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rgee20

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To cite this article: Athanasios Mogias, Theodora Boubonari & Theodoros Kevrekidis (2021): Examining the presence of ocean literacy principles in Greek primary school textbooks, International Research in Geographical and Environmental Education, DOI: 10.1080/10382046.2021.1877953

To link to this article: https://doi.org/10.1080/10382046.2021.1877953

Published online: 01 Feb 2021.

INTERNATIONAL RESEARCH IN GEOGRAPHICAL AND ENVIRONMENTAL EDUCATION
https://doi.org/10.1080/10382046.2021.1877953

Examining the presence of ocean literacy principles in Greek primary school textbooks

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ABSTRACT

This study aims to add to the mapping of the presence of ocean sciences issues in national curricula and textbooks worldwide, investigating the inclusion of ocean literacy principles and their fundamental concepts in Greek primary science textbooks according to the Ocean Literacy Framework. Content analysis was implemented in both textual and pictorial material. The textbook analysis revealed that although all Ocean Literacy Principles are presented to some extent in the textbooks under study, most of their supporting fundamental concepts are absent for most of the principles. Only principles 1 and 6 are well represented, while principles 4 and 7 show the weakest appearance. The alignment of the principles and concepts in the textbooks with the Scope and Sequence of the Ocean Literacy Framework showed an apparent inconsistency, revealing that they are partially represented and superficially introduced. The implications of this study add to this mapping and aim to help curriculum designers and marine educators worldwide to cooperate for the inclusion of ocean literacy topics into the curricula which will potentially lead to students' improved knowledge about the marine environment and the enhancement of their ocean literacy and responsible environmental behavior concerning ocean conservation.

KEYWORDS

Content analysis; ocean conservation; ocean literacy; primary education; science textbooks

Introduction

Research consistently affirms the vital role of the ocean in maintaining the unity of our world, and, in addition, its ecological, social, and economic value (Costanza, 1999). To ensure sustainable use of ocean resources there is a need for responsible policies, regulations and management strategies (Mora et al., 2009), as well as individual responsible behavior by ocean-literate citizens who have some level of knowledge on ocean sciences topics, understand how attitudes and values impinge upon a topic and are empowered to take action around the topic (Strang, DeCharon, & Schoedinger, 2007). Ocean literacy has been defined as "an understanding of the

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

ocean's influence on you, and your influence on the ocean," (Cava, Schoedinger, Strang, & Tuddenham, 2005) after an extensive process of continuous meetings in 2004. This process resulted in the development of the Ocean Literacy Framework (OLF) which consists of the essential principles and fundamental concepts of ocean sciences (National Oceanic & Atmospheric Administration, 2013) and a more detailed Scope and Sequence for grades Kindergarten to 12th (K-12) (National Marine Educators Association, 2010).

Along the same lines, the OLF is now largely accepted and has been an inspiration for several initiatives worldwide (Fauville, Strang, Cannady, & Chen, 2018). The need for ocean literate people becomes even more imperative to meet the expectations of the lately introduced Education 2030 Agenda by UNESCO, with the seventeen Sustainable Development Goals; the Goal 14, "Life below Water," concerns sustainable development of oceans, seas, and marine resources and highlights the increase in student demand for a sustainability-centered education as a significant driver for changes in curriculum and teaching practice (UNESCO, 2017). In this context, ocean literacy principles (OLPs) must be integrated into educational practice and textbooks to achieve an ocean literate society (Tran, Payne, & Whitley, 2010).

School textbooks actually form the curriculum, since they heavily influence the content, the teaching style, and the didactics (Caravita et al., 2008). Textbooks offer context-based disciplinary knowledge, explore and present information, highlight relationships among concepts, and show the processes of knowledge building (Caravita & Valente, 2013). Furthermore, teachers tend to rely primarily on them (Kesidou & Roseman, 2002).

In this context, literature review revealed the scarcity of research worldwide concerning the presence of ocean sciences issues in school curricula and textbooks with regard to the OLF. Specifically, Hoffman and Barstow (2007) reported the limited presence of OLPs in Earth Science Standards in the 50 states of the U.S.A, and Lal (2017) underlined the very weak representation of oceans and rivers literacy in the social science textbooks in Fiji. Gough (2017) concluded that ocean and marine topics are marginalized in the national curricula in England, New Zealand, and Australia. Moreover, McPherson, Wright, and Tyedmers (2018) revealed the limited inclusion of ocean concepts throughout the high school science curriculum in Nova Scotia, Canada.

In Greece, the school system mainly supports a textbook-led instruction. The Greek Ministry of Education provides students in all grades with only one free of charge textbook, along with a workbook, per course, which is common across the country for both public and private schools. Therefore, the Ministry retains the full responsibility of the textbooks used, curricula maintain their highly centralized character and textbooks their national implementation (Stamelos, Karachontziti, & Paivandi, 2017).

Considering the international effort for the enhancement of ocean literacy, the present study aims to add to the mapping of the presence of ocean sciences issues in national curricula and textbooks worldwide, investigating the presence of OLPs and their fundamental concepts in Greek primary science textbooks according to the OLF. This mapping aims to help curriculum designers and marine educators cooperate in a wider scale towards the inclusion of ocean literacy topics into the curricula.

This potentially leads to students' improved knowledge about the marine environment and the enhancement of their ocean literacy and responsible environmental behavior concerning ocean conservation.

The ocean literacy framework

The concept of Ocean Literacy was born at the beginning of this century, while interest in issues related to education and aquatic subjects is much older. Although the need for marine and aquatic education had been underlined (e.g., Fortner & Wildman, 1980; McFadden, 1973), its marginalization had led to marine education being taught only rarely and in a very local context (Strang, 2008). When the US National Science Education Standards were published in 1996, ocean scientists and marine educators realized that state standards did not include much about the ocean, coasts, or watersheds (Schoedinger, Tran, & Whitley, 2010). All the above led to a new attempt for a rebirth of the marine education movement in the U.S., henceforth designated as Ocean Literacy.

The OLF consists of the essential principles and fundamental concepts of ocean sciences (NOAA, 2013), which represent the major ideas that high school graduates should know and understand about the ocean and its significance in the earth system. The guide identifies seven essential principles of ocean literacy underpinned by a series of fundamental concepts, which all students should understand by the end of high school (NOAA, 2013) (Table 1).

The OLF also includes a more detailed Scope and Sequence for grades (K-12) (NMEA, 2010). Scope and Sequence generally has the role of providing continuity between the academic content and skills that are considered essential for students to study, and also the order in which the content will be studied (Stoltman, 2002). Thus, the Scope and Sequence of Ocean Literacy provides guidance as to what students need to comprehend in grade bands K-2 (5–8 years old), 3–5 (9–11 years old), 6–8 (12–14 years old), and 9–12 (15–18 years old), to achieve a full understanding of the essential principles.

Materials and methods

The corpus of the study

The material analyzed in the present study consists of the textbooks developed for teaching natural sciences in the Greek primary education, More specifically, three series of textbooks comprised the corpus under study: (a) *Study of the Environment* (grades 1–4), (b) *Physica* (grades 5–6), and (c) *Geography* (grades 5–6). Each of the three series consists of two separate books, a student reading book and a workbook. The last is used as complementary learning material within which students are expected to complete the assignments as a revision of their learning (Liu & Treagust, 2013).

Study of the Environment recommends a single domain of learning with an interdisciplinary character, as elements from the natural, social, religious, cultural, historical, and economic environment are incorporated (Institute of Educational Policy,

Table 1. The seven Principles of the Ocean Literacy Framework and their fundamental concepts. Concepts are given concisely.

Principles	Concepts
1. The Earth has one big ocean with many features	**1a.** one ocean, seven basins, 70% of planet **1b.** geological features of the seafloor **1c.** ocean circulation **1d.** sea level changes caused by tides, plate tectonics, temperature of water **1e.** properties of water **1f.** water cycle **1g.** connection of the ocean to all watersheds **1h.** large and finite ocean, limited resources
2. The ocean and life in the ocean shape the features of Earth	**2a.** earth materials originate in ocean **2b.** sea level changes shape the land surface **2c.** erosion in coastal areas **2d.** carbon cycle, dissolved carbon used by sea organisms **2e.** tectonic activity, sea level changes, force of waves influence the coast
3. The ocean is a major influence on weather and climate	**3a.** interaction of oceanic and atmospheric processes controls weather and climate **3b.** absorbs most of solar radiation **3c.** heat exchange between ocean and atmosphere, El Nino, La Nina **3d.** most rain from tropical ocean, evaporated water from warm seas, energy for hurricanes and cyclones **3e.** carbon cycle, primary productivity in ocean **3f.** ocean absorbs, stores and moves heat, carbon, water **3g.** changes in ocean-atmosphere system result in climate change
4. The ocean made Earth habitable	**4a.** most oxygen on earth from photosynthesis in ocean **4b.** ocean is the cradle of life **4c.** provides water, oxygen, nutrients
5. The ocean supports a great diversity of life and ecosystems	**5a.** ocean life ranges in size **5b.** microbes the most important primary producers **5c.** most major groups of organisms in ocean **5d.** important relationships among organisms **5e.** most of the living space in ocean, unique ecosystems **5f.** ocean life not evenly distributed due to abiotic factors **5g.** deep ecosystems independent of sunlight **5h.** vertical zonation pattern along coast and in open ocean **5i.** estuaries
6. The ocean and humans are inextricably interconnected	**6a.** affects every human life, freshwater, most oxygen, moderates climate **6b.** provides food, medicine, mineral and energy resources, transportation, jobs, national security **6c.** inspiration, recreation, discovery **6d.** humans affect ocean, laws, resource management, pollution, physical modifications, removed most large invertebrates from ocean **6e.** changes in ocean temperature and ph due to human activities **6f.** most human population in coastal areas, susceptible to natural hazards from ocean **6g.** individual and collective actions for ocean protection
7. The ocean is largely unexplored	**7a.** less than 5% of ocean explored 7b. exploration, experimentation to better understand ocean systems 7c. should understand ocean resources' potential 7d. new technologies to explore ocean 7e. develop models to understand ocean complexity 7f. interdisciplinary scientific approach in ocean exploration

2014). *Physica* aims to develop students' understanding of fundamental concepts, laws, and models of science education and technology and engage them in scientific processes and research (IEP, 2014). In the first four grades, *Geography* is hosted in the *Study of the Environment* course and becomes a stand-alone subject matter in the last two grades; among the main goals of its curriculum are students to (a) think in terms of spatial analysis and use maps, (b) relate the interactions of the natural and man-made environment through specific examples, (c) develop behaviors that will contribute to the protection of the environment and the perspective of the sustainable development, and (d) realize the importance of collective action on a local, national and global scale to solve problems (IEP, 2014).

The analytical framework of the study

Considering that textbook analysis is a major element in the evaluation of how the educational goals are implemented at school level (Tracana, Carvalho, Ferreira, & Ferreira, 2008), content analysis (Downe-Wamboldt, 1992; Krippendorff, 2004; Weber, 1990) was implemented on both textual and visual (pictorial) material to assess the information regarding (a) the presence of ocean literacy elements in the textbooks under study according to the OLF, and (b) the alignment of the textual and pictorial material to the Scope and Sequence of the Framework.

Presence of ocean literacy elements

The present study examines the manifest content which describes only the visible or obvious components, and not the latent one which concerns the underlying meaning of each passage of the text (Downe-Wamboldt, 1992; Potter & Levine-Donnerstein, 1999). Our focus remains on what textbooks can explicitly provide to the learner, without taking into consideration the extent to which teachers can drive the respective content. In this study, the unit of analysis is the theme which refers to clusters of words or categories with different meanings or connotations that taken together refer to a single theme or issue (Weber, 1990). Thematic distinctions are rich in information and productive, and therefore preferable to all other kinds of distinctions (Krippendorff, 2004). The systematic coding of messages is made by means of construction of categories. In this study, a deductive coding scheme was followed (Stemler, 2001), according to categories already existing in the ocean literacy field. Thus, the seven essential principles and the forty-five fundamental concepts of Ocean Literacy were utilized as a categorical framework for analyzing the 16 textbooks.

To ensure the validity of the research (e.g., Downe-Wamboldt, 1992), the system of categories applied in the present study was created through a process of consultation by experts working on subject matter related to marine and education issues. Stability and reproducibility, which both concern reliability, were applied according to Krippendorf's (2004), Stemler's (2001), and Weber's (1990) methodology. Regarding the former, the same text was analyzed and reanalyzed after a while (test-retest design) (Binns, 2013), and as for the latter, Krippendorff's alpha index was used, as it can be applied with any number of coders, with or without missing data, satisfying all of the important criteria for a good measure of reliability (Hays &

Krippendorff, 2007). More specifically, after the authors were trained on the coding system, they were randomly assigned a total of 50 pages from all textbooks. Then, inter-coder reliability statistics were calculated to assess agreement by using Krippendorff's alpha index, resulting in high reliability ($a = 0.78$).

Alignment to the scope and sequence

This study also examined the alignment of the textual and pictorial material to the Scope and Sequence in terms of its level of agreement. Specifically, Scope and Sequence provides charts which indicate how each grade band should align with each OLP, presenting three levels of alignment: blank = no alignment; x = mentions concepts; XX = addresses concepts in depth (NMEA, 2010). According to these recommendations, the explicit inclusion of every single element of each concept in each grade band, regardless of the textbook, was considered as an in-depth alignment; the cases where only partial or no information per concept appears were also indicated.

Statistical treatment of the data

The analysis of the data in this study remained mainly descriptive, aiming to give an account of the ocean sciences concepts being taught in the Greek primary school system, according to the OLF. As such, frequency tables were performed using the cross-tabulation routine in the Statistical Package for the Social Sciences v.23.

Results

General considerations

Textual material related to ocean sciences issues was included in 112 out of 1,077 pages (10.4%) of the examined reading books (*Study of the Environment*, *Physica*, and *Geography*), and 33 out of 654 pages (5.0%) of the corresponding workbooks. Regarding pictorial material, 217 out of 3,762 illustrations (5.8%) included in the examined reading books and 93 out of 1,733 (5.4%) in the corresponding workbooks, were related to the ocean sciences issues. Among textbooks, *Geography* displayed the highest percentage of presence of ocean sciences in both manuals, comprising almost one-fourth of the total pictorial corpus in the workbooks (Table 2).

Presence of ocean literacy elements

Textbook analysis of both textual and pictorial material revealed that although all OLPs are presented in the textbooks under study, most of their supporting fundamental concepts are absent for most of the principles (Table 3, Figure 1). Specifically, OLPs 1 and 6 are the principles best represented in all three textbook series. Several issues referring to almost all their fundamental concepts are included throughout all grade levels, except for 1h and 6a (Tables 1 and 3). OLPs 4 and 7 are the least represented, as elements of only one fundamental concept per principle are mentioned exclusively in grades 5 and 6 (4a and 7d); principles 2 and 3 miss many of their fundamental concepts (Tables 1 and 3, Figure 1). The most common concepts appearing

Table 2. Frequency of pages and number of references contained in the textual material, and frequency of illustrations related to ocean sciences issues per grade and textbook.

		Grade 1	Grade 2 Study of the	Grade 3 Environment	Grade 4	Grade 5			Grade 6			**Grades 1-6**
						Physica	Geography	Total	Physica	Geography	Total	
Reading book	**Textual material**	4/145 (2.8%)	10/ 135 (7.4%)	9/142 (6.3%)	11/ 141 (7.8%)	5/104 (4.8%)	29/ 147 (19.7%)	34/ 251 (13.5%)	21/ 118 (17.8%)	23/ 145 (15.9%)	44/ 263 (16.7%)	**112/ 1,077 (10.4%)**
		7	11	11	16	5	40		31	28		
	Pictorial material	32/ 766 (4.2%)	25/ 470 (5.3%)	22/ 487 (4.5%)	22/ 405 (5.4%)	9/522 (1.7%)	24/ 223 (10.8%)	33/ 745 (4.4%)	45/ 663 (6.8%)	38/ 226 (16.8%)	83/ 889 (9.3%)	**217/ 3,762 (5.8%)**
Workbook	**Textual material**	2/45 (4.4%)	3/44 (6.8%)	1/47 (2.1%)	3/49 (6.1%)	2/174 (1.1%)	11/ 64 (17.2%)	13/ 238 (5.5%)	1/162 (0.6%)	10/ 69 (14.5%)	11/ 231 (4.8%)	**33/ 654 (5.0%)**
		5	3	1	3	3	13		1	15		
	Pictorial material	15/ 211 (7.1%)	2/90 (2.2%)	2/93 (2.2%)	11/ 100 (11.0%)	4/516 (0.8%)	6/26 (23.1%)	10/ 542 (1.8%)	50/ 684 (7.3%)	3/13 (23.1%)	53/ 697 (7.6%)	**93/ 1,733 (5.4%)**

Table 3. Number of references related to ocean literacy fundamental concepts in both textual-pictorial materials of Greek primary Reading Books (RB) and exercises of the respective Workbooks (WB) (OLP 1–7, ocean literacy principles; T, textual material; P, pictorial material; EX, workbook exercises).

		Grade 1			Grade 2			Grade 3			Grade 4			Grade 5						Grade 6					
		Study of the Environment												Physica			Geogr.			Physica			Geogr.		
		RB		WB	RB		WB	RB		WB	RB		WB	RB		WB	RB		WB	RB		WB	RB		WB
	Concepts	T	P	EX	T	P	EX	T	P	EX	T	P	EX	T	P	EX	T	P	EX	T	P	EX	T	P	EX
OLP1	a				1	1					1	1		1						1			4	21	7
	b			1	1												1						5	2	3
	c																			1	1		1	1	2
	d																				1		1		
	e				2	1					1			1	1	1				1			1		
	f				2	1	1										1			1	1				1
	g	1	1	1	2	1		1	2			1					2		1				4	2	
	h																								
OLP2	a																								
	b								1								1							2	
	c													1	1		3	2	1				1	1	1
	d																								
	e																6	1	2				2	3	4
OLP3	a				2	1												1	1	1			3	3	
	b																5	1	3				3	2	2
	c																								
	d																						2		
	e																								
	f																			1					
	g				1						1														
OLP4	a																			1					
	b																								
	c																								
OLP5	a		11	2	2	9		4	7		1	9	1	2	3		1	3		17	28	18			
	b																			1					
	c																								
	d				1			3	1	1	1									5	2	7			
	e							1												1	1				
	f															3									
	g																								
	h																								

(*continued*)

Table 3. Continued.

		Grade 1			Grade 2			Grade 3			Grade 4			Grade 5						Grade 6					
		Study of the Environment												Physica			Geogr.			Physica			Geogr.		
		RB		WB	RB		WB	RB		WB	RB		WB	RB		WB	RB		WB	RB		WB	RB		WB
	Concepts	T	P	EX	T	P	EX	T	P	EX	T	P	EX	T	P	EX	T	P	EX	T	P	EX	T	P	EX
	i																3						1		
OLP6	**a**																								
	b	3	4	2	4	9	1	5	8	1	6	5	4		3		16	12	8	4	6	9	6	3	3
	c	1	11	6	1	6			2	1	1	2					6	2	2	4	6	1	2	3	
	d	1	8	2	1	1	1	2	3		8	4	4				3	1		1	2	1	4	1	2
	e																			1		1			
	f					1					1						1	2	1						
	g	1	1	1		1	2				4	1	1				1	1	2	1			1		
OLP7	**a**																								
	b																								
	c																								
	d													1	1	1							1		
	e																								
	f																								

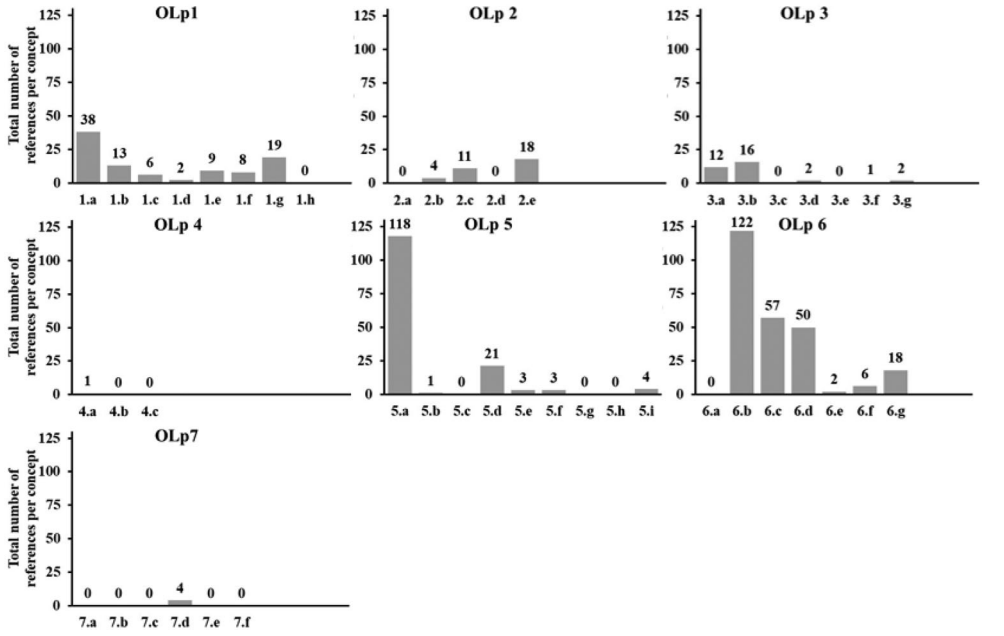

Figure 1. Total number of references per Ocean literacy principle and concept.

in all textbooks are 1g, 5a, 6b, 6c, 6d, and 6g (Tables 1 and 3). Mainly grades 5 and 6 appear to gather most of the concepts' high presence (Table 3). The reading book in all courses presents an increasing trend both in number of principles and concepts for textual and pictorial materials from grade 1 to 6, while no such trend was detected in the workbooks. In terms of the textual and pictorial formats, a certain trend appears to exist with the first three grades revealing a bias in favor of images, while grades 4–6 seem to present a rather equal number of both formats referring to ocean sciences issues (Table 3).

On the basis of the three textbook series, they cover almost all concepts of OLPs 6, 1, and 5, while the rest principles have a reduced or no presence at all (Table 3). Specifically, *Study of the Environment* covers most of the concepts of OLPs 6 and 1 (Table 3), while it deals much less with OLPs 2 and 3, and not at all with OLPs 4 and 7. *Physica* mostly deals with specific concepts of OLPs 5 and 6, and *Geography* includes mostly concepts from OLPs 1 and 6.

Alignment to the scope and sequence

The alignment of the related material under study with the Scope and Sequence of the OLF is shown in Table 4, following the already proposed grade bands (1–2, 3–5, and 6) for the specific needs of our study. In grades 1–2, elements of 15 out of the suggested 27 concepts (55.6%) are mentioned, while information of one additional concept, (3 g) is added to the list; no concept appeared to be addressed in depth in this grade band (Table 4). In grades 3-5, issues referring to 19 out of 34 recommended concepts (55.9%) were incorporated, while elements of additionally 4 new ones were added (2b, 2e, 3f, 3g). Moreover, the analysis showed an in-depth reference

Table 4. Alignment of the related, to ocean literacy fundamental concepts, textual and pictorial materials of Greek primary textbooks with the Ocean Literacy Scope and Sequence (blank: no alignment; x: mentions concepts; XX: addresses concepts in depth).

		Grades 1–2		Grades 3–5		Grade 6	
	Concepts	Scope & Sequence	Greek Textbooks	Scope & Sequence	Greek Textbooks	Scope & Sequence	Greek Textbooks
OLP1	a	x	x	x	x	XX	XX
	b	x	x	XX	x	XX	XX
	c	XX		XX		XX	x
	d					x	x
	e	x	x	x	x	XX	x
	f	x	x	XX	x	x	x
	g	x	x	XX	x	XX	x
	h						
OLP2	a			XX		XX	
	b				x	XX	x
	c	XX		XX	x	XX	x
	d	x		XX		XX	
	e	x			x	XX	x
OLP3	a	x	x	XX	x	XX	x
	b	XX		XX	x	XX	x
	c					XX	
	d	x		x		x	x
	e					XX	
	f				x	XX	
	g		x		x	x	
OLP4	a			x		XX	x
	b			x		XX	
	c*						
OLP5	a	x	x	x	x	XX	XX
	b			x		XX	x
	c	x		x		XX	
	d	x	x	XX	x	XX	x
	e			XX	x	x	x
	f	x	x	XX	x	XX	
	g	x	x	x		x	
	h					XX	
	i			x	x	x	x
OLP6	a	x		x		XX	
	b	x	x	XX	XX	XX	x
	c	x	x	x	x	x	x
	d	x	x	XX	XX	XX	x
	e	XX		XX		XX	x
	f	x	x	x	x	XX	
	g	XX	x	XX	x	XX	x
OLP7	a			XX		XX	
	b	x		x		XX	
	c	x		x		XX	
	d			XX	x	XX	x
	e						
	f	x		XX		XX	
Alignment (%)		**55.6%**		**55.9%**		**59.5%**	

*the revised version (March, 2013) of ocean literacy fundamental concepts is not yet aligned with the Scope and Sequence of the OLF, which still comprises 44 concepts (4c is excluded).

only to 2 out of 19 proposed concepts, i.e., 6b and 6d. As for grade 6, information about 25 fundamental concepts of ocean literacy are included in the Greek primary textbooks out of the 42 recommended ones (59.5%), while from the 34 proposed concepts to be examined in-depth, only 3 seem to be in accordance with the framework (1a, 1b, and 5a) (Table 4).

For example, all elements of the concepts 1a and 1b (i.e., one big ocean, covers 70% of the earth's surface, seafloor features) are addressed in depth in *Geography*, grade 6, in verbal and visual material (e.g., charts, tables), being in alignment with the recommendations of Scope and Sequence (Table 4). On the contrary, concept 1c, which refers to the ocean circulation, lacks any kind of reference in grade bands 1–2 and 3–5, despite the recommendations of Scope and Sequence, while in grade 6 there are only some of its elements, namely the transfer of energy (heat) and the consequences of ocean circulation on climate (Table 4); its elements concerning Coriolis effect, the water density differences, the shape of ocean basins and adjacent land masses, as well as the transport of matter and organisms are absent, although, according to the Scope and Sequence, they all should be addressed in this grade band.

Discussion

The results of the study revealed that the presence of ocean sciences issues in Greek formal primary education textbooks is limited with regard to the OLF (NOAA, 2013), although recent research concludes that ocean sciences issues should be adequately reflected in a curriculum since they are critically important for understanding our planet as a system and for promoting an environmentally literate society (e.g., UNESCO, 2017). Ocean concepts are difficult to find in the curricula of other countries too, e.g., England, New Zealand, Australia (Gough, 2017), Canada (McPherson et al., 2018), and Fiji (Lal, 2017).

More specifically, our findings, showing that the elements of almost all fundamental concepts of OLPs 6 and 1 are almost fully represented, are consistent with McPherson's et al. (2018) findings. Additionally, Lal (2017) also found principle 6 being the only well-represented one through all grades in Fiji's textbooks. Moreover, many concepts of OLP 6 which underline how the ocean affects every human life are included in the textbooks, being considered important, and this possibly indicates an anthropocentric view in the selection of the principles included. On the contrary, the concepts of this principle which concern human impact on the ocean and constitute a type of knowledge necessary for making informed decisions about important socio-scientific ocean issues are less presented. This fact corresponds to studies which have noted that youth has limited knowledge of issues concerning human impact on the ocean (e.g., Boubonari, Markos, & Kevrekidis, 2013; Guest, Lotze, & Wallace, 2015).

The fact that most concepts of OLP 1 are included probably indicates that the ocean features are considered important knowledge of oceanography and they are possibly the first coming to mind when talking about knowledge of the ocean, instead of geochemical cycles (included in OLP 2) or ocean circulation and climate change (OLP 3). Concept d, which is much less represented, and concept h, which is missing, both point out the sensitivity of the ocean and are critical in helping students recognize the impacts of their daily actions on it.

Geography textbooks displaying the highest percentage of presence of ocean sciences in both manuals could probably be explained by the fact that many concepts of OLPs 1 and 6 conform to the main goals of the Greek geography curriculum (IEP, 2014). This finding indicates that OLF could be successfully embraced in the

geography curriculum. Besides, geography curricula have been keeping up with rapidly changing issues that impact humankind, such as topics of environmental change and globalization and aim to help students learn skills and shape attitudes that will help them in the 21st century (Chang & Kidman, 2019). Along the same lines, ocean literacy is a vehicle to ensure the protection and the sustainable use of the ocean developing individual responsible behavior by ocean-literate citizens.

Our findings about the almost absent OLPs 4 and 7 in the textbooks under study are also consistent with McPherson's et al. (2018) findings. The insufficient representation of OLP 4 elements in the textbooks could be explained by the fact that concepts of this principle entail that students possess adequate knowledge of the complex biogeochemical processes, as well as the theory of evolution, to be able to comprehend the deep meaning of phrases such as *the ocean is a cradle of life,* which is included in this principle. Indeed, the theory of evolution is inadequately introduced into Greek primary education (Prinou, Halkia, & Skordoulis, 2011), while in various countries the teaching of evolution in secondary education meets with difficulties (Kim & Nehm, 2011), evidently affecting its introduction into primary education (Prinou et al., 2011).

Also, the presence of OLP 7 is extremely limited in the textbooks, probably because its concepts do not concern pure ocean scientific knowledge, but rather point out perspectives about the development of ocean exploration. However, new and innovative technology for marine exploration, as well as learning about local economic marine issues, among which issues about fisheries and aquaculture, should be of great interest for youth especially in coastal countries, taking into account the job opportunities and careers in the maritime sector (McPherson et al., 2018).

The findings regarding Principle 5 show that there is a preference for concepts concerning animal life and biodiversity (5a and 5d), which, indeed, attract young students' interest (Marrero, 2010). On the other hand, references to deep ocean ecosystems which are less found and/or never seen, e.g., hydrothermal vents and methane cold seeps, are missing probably indicating that there is a prioritization in the selection of the concepts included in the curricula, which might, among others, derive from their frequency of occurrence and the human accessibility to them. Along the same lines, case studies and themes related to the terrestrial ecosystems and life are more often met in textbooks than those related to the ocean. Principle 2 which appears mostly with concepts 2c and 2e and principle 3 with concepts 3a and 3b, both miss their concepts referring to biogeochemical cycles such as the carbon cycle, which constitute essential knowledge for understanding the earth systems and their connection. This type of knowledge requires systems thinking and, therefore, is rather difficult and challenging for primary level students (Assaraf & Orion, 2005). Since the carbon cycle is missing from all science textbooks, it is probably inevitable that students cannot understand ocean acidification and therefore cannot easily establish clear links between their daily actions concerning their carbon footprint and the health of the ocean.

The number of the existing concepts or elements of them found in the textbooks under study suggests that the contained information is fragmented when seen in alignment with the Ocean Literacy Scope & Sequence (NMEA, 2010). The curricula

concerning these courses provide a progression in the concepts taught in the six years of primary school; however, the concepts of ocean literacy are not clear and definite in this progression (IEP, 2014). The lack of a coherent succession of these concepts in each textbook series potentially creates gaps in the construction of knowledge and, thus probably, misconceptions. Along the same lines, Guest et al. (2015) found that students often confuse concepts, explaining one concept using the knowledge they had acquired on a related topic, which may also result in misconceptions. In replay, the Ocean Literacy Scope and Sequence defines exactly what primary children need to know and understand about oceans by age 12 (NMEA, 2010).

Furthermore, the extended usage of images in the first grades, compared to the textual material, is probably expected since they seem to be the most frequently used ones in primary science textbooks, helping young learners with limited background information understand scientific phenomena, before proceeding to more complicated domain knowledge (Liu & Khine, 2016). Progressing with grades, the frequent use of more demanding types of illustrations, such as maps and charts, so as a more scientific knowledge to be better communicated, explains the rather equal presence of both textual and pictorial material in grades 4–6.

Lack of in-depth and coherent presentation of OLPs and concepts in formal curricula may consequently result in students' low levels of ocean literacy and, thus, of their responsible marine environmental behavior, which is crucial for the protection of the marine environment. Indeed, recent studies concerning students' levels of ocean literacy revealed that students have a low to moderate level of ocean literacy and school curricula and formal education are not the main source of students' knowledge of the marine environment (e.g., Boubonari et al., 2013; Guest et al., 2015; Mogias, Boubonari, Markos, & Kevrekidis, 2015; Mogias et al., 2019;). This implies that the systematic integration of ocean sciences issues in formal education, which is currently lacking, may indeed contribute in students' ocean literacy improvement (Guest et al., 2015; McPherson et al., 2018; Tran et al., 2010).

Conclusions

Overall, all OLPs are presented in the textbooks under study but only with a limited number of their supporting fundamental concepts, most of which are absent for most of the principles. The alignment of the principles and concepts presented in the textbooks under study with the Scope and Sequence of the OLF showed an apparent inconsistency, revealing that the fundamental concepts are partially represented and superficially introduced, potentially creating gaps in the construction of knowledge and, thus probably, misconceptions.

The present study, which establishes a baseline providing detailed information about which principles and concepts are covered in the current Greek science textbooks and which are not, can inform the development of a blueprint for revising and strengthening these textbooks regarding Ocean Literacy. Based on this analysis, the challenge for ocean literacy is to show how its subject can contribute to children's literacy development and, thus, recommendations for the inclusion of more concepts of

the OLPs are made. These recommendations do not concern only Greek school textbooks, but they could further be used worldwide.

- Any inclusions should be based on the OLF and should not be a replacement of other science content, neither should be stressing too much curriculum content considering the limited time in the general primary school curriculum, but rather consist an interdisciplinary addition, which will highlight the importance of the ocean systems in the understanding of the earth system in general.
- Taking into account that recent researches underline that geography textbooks should give more emphasis to the human role in solving the pollution problems and contributing to improve pupils' citizenship (Tracana et al., 2008), case studies, especially from concepts of principles 6 and 7, concerning the protection of the ocean and its sustainable use, could be included in the geography textbooks to serve the shift from a knowledge-based curriculum towards a more skills-based curriculum.
- A supplementary guide with (a) a chart for quick reference and easy tracking of the principles and concepts of ocean literacy across its full scope and through its sequence by grade clusters, and (b) case studies and scenarios from ocean literacy content, based on an integrated approach could be useful for teachers in planning their lessons either for Language, Maths, Physics, Geography or Arts. These scenarios could be either used stand-alone or attached to proposed units of the textbooks. Ocean literacy could also be promoted through appropriate pre- and in-service teachers' training, as already has been suggested for similar environmental issues (Papadimitriou & Probald, 2000).

Finally, the present research is limited to primary education textbooks responsible for the teaching and learning of natural sciences. The corresponding manuals of secondary education should also be analyzed to point out and eventually evaluate subject matter knowledge with regard to ocean literacy essential principles and fundamental concepts included in formal primary and secondary education as well as its progression through school grades. Moreover, since education is not just about teaching knowledge and students have to learn to apply concepts, principles, and skills that are part of their knowledge (Slater, Graves, & Lambert, 2016), there is a need to consider inquiry pedagogies and differentiated learning and therefore pedagogic discourse analysis should also be applied in all these textbooks.

Disclosure statement

We have no conflicts of interest to disclose.

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