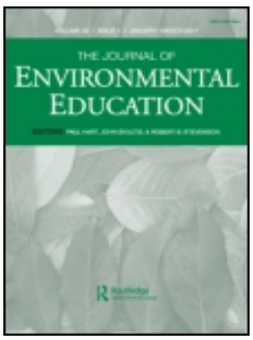

The Journal of Environmental Education

ISSN: 0095-8964 (Print) 1940-1892 (Online) Journal homepage: http://www.tandfonline.com/loi/vjee20

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To cite this article: Athanasios Mogias, Theodora Boubonari, Angelos Markos & Theodoros Kevrekidis (2015) Greek Pre-Service Teachers' Knowledge of Ocean Sciences Issues and Attitudes Toward Ocean Stewardship, The Journal of Environmental Education, 46:4, 251-270, DOI: 10.1080/00958964.2015.1050955

To link to this article: http://dx.doi.org/10.1080/00958964.2015.1050955

Published online: 16 Sep 2015.

THE JOURNAL OF ENVIRONMENTAL EDUCATION, *46*(4), 251–270, 2015

ISSN: 0095-8964 / 1940-1892 online
DOI: 10.1080/00958964.2015.1050955

Routledge
Taylor & Francis Group

Greek Pre-Service Teachers' Knowledge of Ocean Sciences Issues and Attitudes Toward Ocean Stewardship

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Greek pre-service teachers' level of ocean literacy was assessed using a revised questionnaire concerning ocean content knowledge and an instrument about ocean stewardship. Rasch analyses showed that the items of both measures were well targeted to the sample. Pre-service teachers possessed a moderate knowledge of ocean sciences issues and positive attitudes toward ocean stewardship; they obtained most information on ocean content from the Internet and mass media and less from formal education, nongovernmental organizations, books, and out-of-school settings. Students who mostly preferred the Internet and mass media scored significantly higher on the knowledge questionnaire. The results could contribute to the enhancement of teachers' ocean literacy.

Keywords *attitudes, information sources, Internet, knowledge, ocean literacy*

INTRODUCTION

The ocean is the dominant feature of the planet, covering 71% of the earth's surface; it regulates weather and climate, supplies nearly all earth's oxygen, supports a great diversity of life, and feeds much of the human population (Cava, Schoedinger, Strang, & Tuddenham, 2005). Thus, one cannot effectively understand geography without teaching about seafloor bathymetry, plate tectonics without seafloor spreading, the climate system without the ocean's role in climate variability and cycles, productivity without marine photosynthesis and chemosynthesis, and biodiversity without marine ecosystems (Strang, DeCharon, & Schoedinger, 2007). In brief, understanding the ocean is essential to understanding and, thereby, protecting the planet on which we live (Cava et al., 2005), and ocean literacy is intrinsic to scientific literacy (Strang et al., 2007). Ocean literacy has been defined as "the understanding of the ocean's influence on you and your influence on the ocean" and, furthermore, the essential statements about a desirable state of knowledge for the ocean have been identified (Cava et al., 2005, p. 5). An ocean literate person must have some level of content knowledge, understand how attitudes and values impinge upon the topic, and be empowered to take action around the topic (Strang et al., 2007). In this context, to achieve an ocean literate society, these ocean literacy statements must be integrated into educational practice, research, curricula, textbooks, and assessments (Tran, Payne, & Whitley, 2010).

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Classroom teachers play a key role in the environmental literacy of future generations (World Commission on Environment and Development, 1987); specifically, the environmentally educated teachers have been characterized by UNESCO-UNEP as the "priority of priorities" (Fien, 1995;Tilbury, 1992;). Teachers are more likely to produce students who are environmentally literate when they are themselves environmentally knowledgeable, have positive attitudes toward the environment and show concern for environmental problems (Payne & Zimermann, 2010); Tuncer, Tekkaya, Sungur, & Cakiroglu, 2009). Particularly, secure teacher knowledge is considered a prerequisite for most effective teaching (e.g., Summers, Kruger, & Childs, 2000). It has been claimed that teachers' knowledge of the content affects both what teachers teach and how they teach it, emphasizing those areas in which they are more knowledgeable and avoiding or de-emphasizing the areas in which they have relatively less content knowledge (Grossman, 1995). Indeed, Australian pre-service secondary teachers have expressed feelings of disillusionment and disempowerment to teaching environmental education issues, because they believed that the responsibility was too great and that they would not be able to make a difference due to the absence of preparation to engage with environmental education (Jenkins, 1999/2000). In addition, teachers are the main instrumental factors in the shaping of attitudes and values needed to preserve and protect the environment (Said, Ahmadun, Paim, & Masud, 2003), considering that the formation of these attitudes begins at an early age (Said et al., 2003), and education, even at a primary level, can play a significant role in it (Strong, 1998).

Hence, it is a reasonable assumption that successful integration of ocean literacy in schools requires the commitment of teachers who have a secure knowledge of ocean literacy statements and positive attitudes toward the marine environment. However, it is a question whether teachers are ocean literate and ready to address this challenge, and to what extent teacher education programs prepare prospective teachers for it. The small body of literature regarding teachers' education on aquatic issues, most of them having taken place in the United States, generally reveals their lack of understanding on marine and, generally, aquatic systems. Early studies revealed that U.S. teachers possessed low to relatively moderate knowledge of aquatic topics, whereas their curriculum priority to aquatic topics depended on their level of knowledge about them, having been mostly low (Beiswenger, Sturges, & Jones, 1991; Fortner & Meyer, 1989; Rakow, 1983/84). More recently, teachers in the same country reported that toxic chemicals, water quality, uses, and conservation and environmental responsibility are of highest priority among water topics and they wanted to know more about them (Fortner & Corney, 2002). In addition, Israeli pre-service science teachers' knowledge concerning wetlands was insufficient, presenting them as filthy hazardous places that should be drained for improving the public health (Tal, 2004). Greek pre-service teachers were found to possess a relatively moderate level of knowledge of marine pollution, though holding misconceptions; also, they demonstrated very positive attitudes toward the protection of the marine environment, as well as moderate individual action and limited collective action related to marine pollution issues (Boubonari, Markos, & Kevrekidis, 2013). On the other hand, while little research exists on teachers' knowledge of aquatic topics, as far as we know, there is no essential information concerning in-service or pre-service teachers' knowledge of all told ocean literacy statements along with attitudes toward the marine environment.

Teachers' knowledge of ocean sciences issues and attitudes toward the marine environment are of particular importance in Greece. Greece is a country characterized by the relatively great length of its coastline and the many islands, where the sea provides important economic benefits such as marine transportation and trade, coastal tourism, commercial fishing, aquaculture, as well as providing recreation for boaters, fishermen, beachgoers, etc. Because the sea is an important

part of most Greeks' everyday life, informed teachers and their pupils, who eventually become the future decision makers, could play a significant role in the protection of the Greek marine environment and, thus, the protection of the ocean.

This study constitutes the first attempt to assess pre-service teachers' knowledge of ocean literacy statements along with their attitudes toward the marine environment. Particularly, Greek pre-service primary teachers' knowledge and attitudes were assessed, and the relationship of knowledge with attitudes and background factors was additionally examined. The assessment of knowledge and attitudes could provide guidance in the development of courses and workshops designed to enhance pre- and in-service teachers' ocean literacy, and could, also, contribute to an overall strategy for the development of ocean literacy.

THE OCEAN LITERACY FRAMEWORK

Ocean literacy was officially born at the beginning of this century, while the interest among issues related to education and aquatic issues is much older. The need for marine and aquatic education was already underlined and studied in the past (e.g., Charlier & Charlier, 1971; Dresser & Butzow, 1981; Fortner, 1985; Fortner & Lyon, 1985; Fortner & Wildman, 1980; Goodwin & Schaadt, 1978; Linsky, 1971; Madrazo & Hounshell, 1980; McFadden, 1973; Picker, 1980; Rakow, 1983/84; Schweitzer, 1973) and a framework for an aquatic curriculum development was created, consisting of a conceptual scheme for aquatic studies, a scope, and a sequence (Picker, Millman, & Aspinwall, 1984).

However, marine education became marginalized and if, and when, it was taught, it was often presented in a very local context (Strang, 2008). When the U.S. National Science Education Standards were published in 1996, various ocean scientists and marine educators realized that there was little mention of ocean topics, and furthermore that state standards did not include much about the ocean, coasts, or watersheds (Schoedinger, Tran, & Whitley 2010). All of the previous findings have led to a new attempt for a rebirth of this educational area.

The ocean literacy movement was born about 2004 in the United States. To address the need for communication and a way to build community consensus on ocean literacy, a diverse group of representatives, with expertise in the ocean sciences, ocean education, and/or education policy, joined in a series of workshops and conferences. The purpose of these gatherings was to draft a common framework in order to define the meaning of ocean literacy and to develop statements about a desirable state of knowledge for the ocean. The result of this extensive process was the development of the ocean literacy framework comprising a guide about Ocean Literacy (National Oceanic and Atmospheric Administration, 2013), and a more detailed Ocean Literacy Scope and Sequence for Grades K—12 (National Marine Educators Association, 2010).

The guide (NOAA, 2013) defines ocean literacy as "the understanding of the ocean's influence on you and your influence on the ocean." The guide identifies the seven essential ocean literacy statements, referred to as principles in the guide, which all students should understand by the end of high school:

1. The Earth has one big ocean with many features.
2. The ocean and life in the ocean shape the features of Earth.
3. The ocean is a major influence on weather and climate.
4. The ocean made Earth habitable.

5. The ocean supports a great diversity of life and ecosystems.
6. The ocean and humans are inextricably interconnected.
7. The ocean is largely unexplored.

Each of the statements is underpinned by a series of fundamental concepts, overall 45 concepts (NOAA, 2013), which support and explain them. According to the guide, an ocean literate person understands the essential statements about the ocean, can communicate about the ocean in a meaningful way, and is able to make informed and responsible decisions regarding the ocean and its resources (NOAA, 2013).

The Ocean Literacy Scope and Sequence (NMEA, 2010) provides information and guidance as to what students need to comprehend in Grades K–2, 3–5, 6–8, and 9–12, in order to achieve full understanding of these statements. These progressions show how students' thinking about the ocean may develop in ever more complex ways across many years of thoughtful, coherent science instruction. The Scope and Sequence, represented in a series of conceptual flow diagrams that include cross-references, also shows how concepts about the ocean are interconnected (NMEA, 2010).

METHODOLOGY

Participants

A cross-sectional study was conducted to a group of 436 students attending a Primary Education Department at Democritus University of Thrace. In Greece, pre-service teacher education is carried out in four-year University training programs, which prepare either professionals as generalist teachers with no subject specialization, graduating with a bachelor of education degree and a teaching certificate, obtaining the ability to teach in primary schools (grades 1–6), or professionals with a certain subject specialization, graduating with a bachelor of science, mathematics, or linguistics and a teaching certificate, obtaining the ability to teach in junior high and high schools (grades 7–12), respectively. Fifteen participants gave incomplete questionnaires and were dropped from the study. As a result, the final sample consisted of 421 pre-service teachers (365 females, 56 males). This proportion reflects the average gender distribution of pre-service primary teacher population in Greek education departments; this bias seems to be common across the globe (Watson & Halse, 2005).

Instruments

Ocean Content Knowledge

A revised version of the SOLE—Survey of Ocean Literacy and Experience scale—(Greely, 2008) was used to measure pre-service teachers' conceptual understanding about general ocean content. The SOLE questionnaire was originally developed in English as part of a doctoral dissertation project at the University of South Florida (Greely, 2008) to assess ocean content knowledge, and was applied to 13-14 year-old girls. Content selection of the original SOLE was based mainly on the seven essential statements and the 45 fundamental concepts from the Ocean Literacy guide (NOAA, 2013). Fifty-seven items in total were written as multiple-choice

questions. The items in the questionnaire were close-ended, which made the instrument easy to use, code, and score for statistical analyses. The original SOLE was piloted among a sample of marine science graduate students and a sample of high school students enrolled in marine science courses. According to Greely (2008), the instrument provided reliable ocean content knowledge measures and could effectively distinguish between individuals with different levels of understanding.

In the current study, the original SOLE scale has been revised and translated. The Greek version of the SOLE was developed using translation and back-translation (Brislin, 1970), by a marine biology professor and a marine educator. Differences in translation were resolved through consensus. The scale was then examined both in terms of content and construct validity. In revising the scale, the researchers first considered the ocean content issues presented in the Greek national science curricula for elementary and middle-school students. The original SOLE items were reviewed for clarity, accuracy, and the extent to which they represent the associated ocean literacy statements. Because of the revision process, two items were eliminated as specific to the United States and one as ambiguous. In addition, 13 items were rephrased for clarity, mostly due to confusing or inadequate response options.

The revised Greek version of the SOLE contained 54 items and was the one used for data collection. Each correct response received a numeric value of 1, and incorrect responses were coded 0. In an effort to limit guessing, each knowledge question included an "I don't know" option.

Student responses in the revised SOLE scale were evaluated using the Rasch model for dichotomous items through Winsteps v3.71 (Linacre, 2011) and this allowed person and item measures to be expressed on a unidimensional scale. Item reliability was 0.99 and item separation was 9.52, which implied a broad continuum of measurement. Person reliability was found to be 0.86 and person separation was 2.44, indicating that the 54 items could reliably distinguish at least two ability levels of the participants in our sample (Smith, 2001). The average standard errors of persons (0.17 logits) and items (0.13 logits) were low. Item fit statistics were acceptable, except for two items. Item 8 "The ocean is connected to all the earth's water reserves (supplies) via . . ." and Item 9 "What approximately is the maximum depth of the ocean?" had large outfit values (1.73 and 1.51, respectively), indicating unexpected response patterns. Closer examination revealed that the two items were among the most difficult for our sample and received unexpectedly correct answers by less able respondents. These items are considered unproductive for measurement construction (Wright, Linacre, Gustafson, & Martin-Löf, 1994) but not degrading to the overall analysis, and were thus retained. A Principal Component Analysis of the standardized residuals was calculated after controlling the Rasch dimension, in order to test for the unidimensionality assumption required by the Rasch model. The first component explained 42.3% of the total variance with an eigenvalue of $2.67 < 3$, which represents a residual variance of 4.8% and is below the value of 5% proposed by Linacre (2011). This suggests that the standardized residuals have no additional systematic information and suggest the unidimensionality of the revised SOLE scale.

Ocean Stewardship Attitudes

Stewardship attitudes were measured using a 15-item instrument (SOS-15), part of the Survey of Ocean Stewardship (SOS) questionnaire (Greely, 2008). The scale items correspond to beliefs

TABLE 1
Groups of SOLE and SOS-15 Questions in Alignment with the Seven Essential Ocean Literacy Statements

Essential statement	*No. of questions*	*Concept measured*	*Instrument*
1. Size of ocean	16	15 general ocean content 1 stewardship	SOLE (1–14, 19) SOS-15 (5)
2. Oceans & its life shape Earth	7	6 general ocean content 1 stewardship	SOLE (15–17, 20–21, 24) SOS-15 (4)
3. Weather & climate	9	9 general ocean content	SOLE (18, 23, 26–32)
4. Habitability	2	1 general ocean content 1 stewardship	SOLE (37) SOS-15 (9)
5. Biodiversity	13	13 general ocean content	SOLE (33–36, 38–46)
6. Human connections	15	6 general ocean content 9 stewardship	SOLE (22, 25, 50, 52–54) SOS-15 (3, 6–8, 11–15)
7. Oceans largely unexplored	4	4 general ocean content	SOLE (47–49, 51)
Total essential statement questions	66		

about protecting the ocean, as described in Cudaback (2006). Subjects were asked to indicate their degree of agreement on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

The Rasch rating scale model with Winsteps v3.71 was used to determine dimensionality, scale use, targeting and reliability of student responses in the SOS-15. Results show item separation was 13.62 with high reliability (0.99), which indicates stable item difficulty estimates. Person separation was 1.90 with a reliability of 0.78, which represents an acceptable level of separation. The average standard errors of persons (0.26 logits) and items (0.07 logits) were low. Moreover, infit and outfit statistics for all fifteen items fell within acceptable ranges, specifically between 0.70 and 1.37 logits. A Principal Component Analysis of the standardized residuals showed that the variance explained by the measures was 68.0%, and the unexplained variance in the first contrast had eigenvalue of <2.0, suggesting unidimensionality of the scale.

Table 1 contains a summary of the number of questions asked in each one of the two instruments and their alignment with the seven essential ocean literacy statements.

Background Factors

The questionnaire also included questions about student's age, gender, and the frequency of use of seven information sources about ocean sciences issues.

Data Collection

Participants were informed about the purpose of the study and the voluntary basis of participation. Questionnaires were group administered during a lecture period in winter semester of the academic year 2012–13. Completion time ranged from 35 to 40 minutes.

Data Analysis

The data analysis consisted of two main steps. In the first step, data from the revised SOLE and SOS-15 scales were analyzed using the Rasch models for dichotomous and polytomous responses. Rasch analysis was selected in order to obtain interval-level scores for both items and persons on the same unidimensional scale. The analysis of student responses was based both on a separate analysis of each specific item and by combining the individual items into a summary index. The goal was to generate two measures that reflect an individual's overall knowledge of the ocean and attitudes toward ocean stewardship, respectively. The overall scores can then be used in analysis of variance and regression more readily than the raw total score, which has floor and ceiling effects. Further analyses included the assessment of item reliability, person reliability, item mean square residual (MNSQ) outfit and person MNSQ outfit. Construct validity was assessed through the plotting of item calibrations along a logit scale. The locations of items along each of the instrument traits were compared to that which was predicted prior to data analysis. An instrument that is well targeted to the intended sample will show that the cluster of the persons is located opposite to the cluster of items (Bond & Fox, 2007). The merits and strengths of Rasch analysis in the field of science education research have been extensively outlined by Boone and Scantlebury (2006) and Boone, Townsend, and Staver (2011), among others.

The second step of the analysis involved the investigation of the correlation between knowledge and attitude factors. One-way ANOVA and t-test evaluations were also used to further investigate possible effects of student background information on ocean content. Statistical analyses were performed using IBM SPSS Statistics v19.

RESULTS

Background Data

The mean ($\pm$ standard deviation) age of pre-service teachers was 20.33 ± 0.96 years; females constituted 86.7% of the participants.

Information Sources on Ocean Sciences Issues

The Internet scored highest as the students' primary information source on ocean sciences issues, immediately followed by mass media, whereas books and out-of-school settings had the lowest scores. A summary of the ratings of information sources as contributors to participants' knowledge of environmental topics is provided in Table 2.

Ocean Content Knowledge

A review of the ordering of knowledge items from Rasch analysis suggests an interesting pattern of responses. Figure 1 presents part of the 54 ocean content knowledge items on the linear logit scale. Items at the top of the scale were the hardest ones to correctly answer. Those items at the base of the scale were the easiest for the pre-service teachers to correctly answer. The ordering of ocean content knowledge revealed that participants of this study had the most difficulty in

TABLE 2
Greek Pre-service Teachers' Ratings of Information Sources as Contributors to Their Knowledge of Ocean Sciences Issues

Information source	M	SD
Internet	2.91	1.08
Mass media	2.75	0.88
School	2.31	0.79
In-school program	2.23	1.00
Non-governmental organization	2.17	0.92
Books	1.93	0.93
Out of school settings	1.85	0.99
Total	2.30	0.59

Note: Pre-service teachers scored information sources using a 5-point Likert-type scale ranging from 1 (not at all) to 5 (a lot). $n = 421$; M: mean value; SD: standard deviation.

correctly identifying the percentage of Earth's water which is fresh and unfrozen (Figure 1, item 7). In the case of this item, about one-fourth of the students thought that it was between 10% and 20%, whereas only one-twentieth of the participants gave the correct answer (1%). Item 45 concerned the identification of deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. For this item, a significant percentage of pre-service teachers identified submarine hot springs as deep ocean ecosystems; another significant group indicated both submarine hot springs and methane cold seeps, whereas most participants missed hydrothermal vents. Two of the most difficult items (30 and 23) pertained to the earth's carbon cycle. For item 30, respondents commonly selected one of two response options: approximately 30% or 70% of primary production on earth takes place in the sunlit areas of the ocean. Contrary to these difficult-to-answer items, items 1, 19, and 21 were generally easy for respondents to answer. Out of these, item 19 (water cycle) was perceived as the easiest item to correctly answer (83% of the respondents). Also, most of the students in the sample were able to correctly identify that the ocean covers about 70% of the surface of our planet (item 1) and that surface temperatures would be more extreme than they are now, in case our planet were without its ocean (item 21).

For the data in the present study, the item measures ranged from –2.37 to 2.46 logits, while person measures ranged from –2.77 to 2.35 (Figure 1). The revised scale is well targeted to the participants, with similar mean locations for items (0.00) and persons (–0.17). With a mean person score of –0.17, students in this study displayed a slightly lower average knowledge score than the average of the scale, which indicates only a rather moderate knowledge of ocean issues. The overlap between the range of the person trait levels and that of item difficulty levels indicates that the 54 items are adequate to assess pre-service teachers' knowledge of ocean issues. That is, the items are reasonably well targeted to the sample.

Ocean Stewardship Attitudes

In general, results from the analysis of SOS-15 revealed positive attitudes toward ocean stewardship. The distribution of attitude items on the linear logit scale is presented in Figure 2. Items are organized from easier to agree with (base of the scale) to hardest to agree with (top of the scale).

	Item	Measures (logits)	Error (logits)	Selected Items
Hardest items	7	2.46	0.23	Approximately how much of the earth's water is fresh and unfrozen (neither ice nor ocean)?
	45	2.43	0.20	Deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms are…
	30	2.35	0.19	The ocean dominates the earth's carbon cycle. Approximately how much primary production on earth takes place in the sunlit areas of the ocean?
	23	2.11	0.18	The ocean dominates the earth's carbon cycle. Approximately how much of all the carbon dioxide in the atmosphere is absorbed by the ocean?
	8	1.76	0.16	The ocean is connected to all the earth's water reserves (supplies) via…
	9	1.73	0.15	What approximately is the maximum depth of the ocean?
	47	1.57	0.15	The ocean is the last and largest unexplored place on earth. How much of the ocean remains unexplored?
	52	-1.30	0.11	What does the statement, the ocean and humans are inextricably connected mean?
	14	-1.35	0.11	Which of the following are transported by rivers from watersheds to estuaries and to the ocean?
	41	-1.68	0.12	In the ocean living spaces and habitats are found…
	35	-1.86	0.12	What happens to sunlight in the ocean as depth increases?
	21	-2.00	0.13	If our planet were without its ocean but otherwise the same as it is today, would surface temperatures be more extreme than they are now (warmer summers and colder winters) or less extreme, or what?
Easiest Items	1	-2.07	0.13	Approximately how much of the earth is covered by ocean?
	19	-2.37	0.14	Water moves from the ocean to the atmosphere to the land and back again to the ocean by a process called…

FIGURE 1 Revised Survey of Ocean Literacy and Experience (SOLE) scale items displayed on the linear logit scale.

Pre-service teachers agreed more strongly that the health of the ocean is important to human survival (Figure 2, item 9) and that individual citizens should be responsible for protecting marine environments (item 14). The strongest level of disagreement was with statements that we do not need to worry about the health of the oceans, because we will develop new technologies to keep them clean (item 10), and that what I do in my life doesn't impact the ocean at all (item 11).

Items were distributed along the attitude continuum from –1.88 to 2.07 logits (Figure 2). Given a person mean of –0.50, pre-service teachers found it easy to agree with most of the items, with person estimates ranging from –2.68 to 1.94 logits. Although respondents expressed positive

Difficult	Item	Measures (logits)	Error (logits)	Items
to agree with	10	2.07	0.06	We do not need to worry about the health of the oceans, because we will develop new technologies to keep them clean.
	11	2.05	0.06	What I do in my life doesn't impact the ocean at all.
	7	1.44	0.05	The ocean and coastal regions overall are so vast and healthy that they can continue to absorb pollution and other kinds of man-made stresses for the foreseeable future.
	6	1.43	0.05	I have enough background knowledge to write a substantive letter to my congressional representative about an issue affecting the ocean.
	5	0.96	0.05	I am familiar with the issues facing the global ocean.
	4	0.74	0.05	I am familiar with the environmental issues facing the coastal areas in my home state.
	3	0.08	0.06	I know some specific things I could do to help the ocean.
	15	-0.47	0.06	Agriculture and forestry should be responsible for protecting marine environments.
	1	-0.50	0.06	My actions can have a significant effect on the health of oceans and coastal areas.
	2	-0.72	0.07	I have a personal responsibility to work for the health of oceans and coastal areas.
	8	-0.87	0.07	Human-made stresses are endangering coastal regions and the ocean's ability to sustain itself and may well be leading to long-term damage and serious problems.
	12	-1.37	0.08	Business and industry should be responsible for protecting marine environments.
	13	-1.40	0.08	Government should be responsible for protecting marine environments.
Easy to agree with	14	-1.56	0.08	Individual citizens should be responsible for protecting marine environments.
	9	-1.88	0.09	The health of the ocean is important to human survival.

FIGURE 2 Survey of Ocean Stewardship (SOS-15) scale items displayed on the linear logit scale.

ocean stewardship attitudes, the difficulties of the items were relatively well targeted against the respondents and covered the scale's range adequately. However, given that 43 of the respondents had a lower logit value than –2.00, the scale might benefit from the addition of items that are more difficult to agree with.

TABLE 3
Relationship Between Greek Pre-service Teachers' Ocean Content Knowledge and Information Sources

Information source	n	M	SD	F	df	p
School				0.171	2, 411	ns
A	270	−0.20	0.92			
B	117	−0.13	0.99			
C	25	0.04	0.66			
Total	412	−0.17	0.93			
In-school program				0.789	2, 410	ns
A	277	−0.20	0.92			
B	86	−0.02	0.97			
C	48	0.09	0.93			
Total	411	0.17	0.93			
Out of school settings				0.502	2, 406	ns
A	315	−0.20	0.96			
B	56	−0.15	0.77			
C	36	0.08	0.79			
Total	409	0.17	0.94			
Non-governmental organization				2.377	2, 408	ns
A	282	−0.20	0.96			
B	91	−0.14	0.75			
C	36	0.05	0.88			
Total	409	0.17	0.93			
Mass media				3.845	2, 410	0.022
A	172	−0.30	0.96			
B	164	−0.17	0.92			
C	75	0.15	0.83			
Total	411	0.17	0.93			
Internet				3.146	2, 411	0.044
A	154	−0.30	0.98			
B	143	−0.03	0.85			
C	114	0.18	0.90			
Total	411	0.17	0.93			
Books				0.626	2, 408	ns
A	316	−0.20	0.88			
B	66	−0.11	1.17			
C	27	0.05	0.88			
Total	409	0.17	0.93			

M: mean; SD: standard deviation; F: value of the F-statistic; df: degrees of freedom; A: not at all / a bit; B: neutral; C: a lot; ns = non-significant.

Relationship of Ocean Content Knowledge With Background Factors and Ocean Stewardship Attitudes

Use of Information Sources

Table 3 presents the mean knowledge scores in relation to the frequency of use of information sources as contributors to participants' ocean content knowledge. Students who rated the Internet

and mass media as highly used sources of ocean environmental information, scored significantly higher on the SOLE questionnaire, compared to their peers who reported infrequent use ($F(2, 410) = 3.845, p = 0.022$ and $F(2, 411) = 3.146, p = 0.044$, respectively). The effect sizes of these differences were small ($\eta^2 = 0.018$ and $\eta^2 = 0.015$, respectively). A positive, but insignificant trend was noted for the remaining information sources (Table 3).

Relationship Between Ocean Content Knowledge and Ocean Stewardship Attitudes

Ocean content knowledge and attitudes about ocean stewardship were found to be significantly and positively associated ($r = 0.234$, $p < 0.01$). This also provides some evidence for the knowledge test's convergent validity.

DISCUSSION

Greek pre-service teachers were found to possess moderate knowledge of ocean sciences issues. This finding seems to be in line with the few existing studies concerning teachers' knowledge of marine and aquatic issues worldwide (Beiswenger et al., 1991; Fortner & Corney, 2002; Fortner & Meyer, 1989; Rakow, 1983/84; Tal, 2004), and particularly Greek pre-service teachers' knowledge of a specific issue of ocean literacy, marine pollution (Boubonari et al., 2013). Furthermore, most of the most difficult and the easiest items of the present study also perplexed or facilitated respectively the respondents in the study conducted by Greely (2008). This consistency of the item-difficulty hierarchy between the two studies further supports the construct validity of the knowledge instrument. Particularly, respondents of both studies were familiar with some features of the ocean (its surface coverage on earth, the hydrological cycle, the transportation of nutrients, salts, sediments and pollutants from rivers to oceans), which are concepts frequently mentioned and widely discussed. On the other hand, they knew less about others (percentage of fresh and unfrozen earth's water, maximum depth of the ocean), probably because these are more specialized concepts. Such concepts are included in the ocean literacy brochure and considered requisite knowledge for an ocean literate person (NOAA, 2013), although this type of knowledge is not necessarily needed for making informed decisions about important socioscientific ocean issues. Moreover, although respondents understand ocean's major influence on surface temperatures, they do not conceptualize the ocean's dominant role in the earth's carbon cycle, possibly because this is a more complex biogeochemical concept. It has been found that physical and chemical ocean concepts are difficult to be elaborated and differentiated (Brody, 1996). Furthermore, they obviously understand that sunlight decreases with depth, but they did not know that hydrothermal vents are also deep ocean ecosystems probably because they, also, concern a more specialized concept. Actually, the multiple-choice questionnaire used allows only assumptions about the respondents' reasoning; further studies could provide a more comprehensive picture of student understanding of ocean concepts and conceptual relationships, which will be the aim of a future study.

The observation that Greek pre-service teachers possess moderate knowledge of ocean sciences issues indicates an inadequate implementation of ocean science topics in both elementary-secondary school curricula and teachers' preparation programs. This statement is supported by

the finding that the respondents appear to derive little information from formal education. The centralized Greek educational system is mainly based on independent teaching of the various disciplines. Each discipline is characterized by its general scope, cognitive axes, and purposes. The requisite internal consistency between the different disciplines and the integrated horizontal interconnection and development of the contents are achieved with the interdisciplinary approach of knowledge; in the same context, there is an autonomous environmental education framework, although it is not applied in schools as a different discipline (Institute of Educational Policy, 2003). Thematic sections concerning the water cycle, the water as a source of life, surface waters, and groundwater, causes of degradation of water quality, water pollution, aquatic biotopes, soil erosion, food webs, effects of human interventions in the extinction of species, the waste management, the management of solid waste, waste water, toxic waste, growing personal and social responsibility, self-discipline and action on environmental and social issues, which are included in the axes of the sciences education curricula and the environmental education framework, align with some fundamental concepts of the seven essential ocean literacy statements. However, in general, explicit references or connections to the oceans are rare in any of the thematic sections of the sciences' education curricula or of the environmental education framework and the content represented by these statements does not fall neatly within particular disciplines.

In terms of school environmental programs, since teachers and students participate voluntarily in environmental education programs, not all schools implement environmental education and not all students take part in them; furthermore, their themes vary and only few of them are related to the marine environment (Boubonari et al., 2013). The previous addressing issues could be linked to the fact that ocean literacy is not yet identified in the national curriculum of primary and secondary education through defined criteria or standards, which could outline the minimum knowledge required for someone to be considered ocean literate.

With reference to teacher preparation programs, albeit all institutions in Greece provide at least one course of environmental education, this may not be compulsory and is mainly characterized by theoretical content (Boubonari et al., 2013), without including any real world problem solving. Furthermore, additional optional courses relevant to ocean sciences issues are generally not provided at the education departments. As a result, Greek pre-service teachers generally do not receive the long term, continuous, methodological exposure to the subject that is necessary for developing ocean literacy.

Out-of-school settings had the lowest score as a source of information for the respondents. This finding probably reflects the low visits of schools to the few existing aquaria, as well as the lack of such informal settings in Greece. Actually, there are only two aquaria, both located on islands and, therefore, it is time consuming and expensive to visit from the mainland. It has been revealed that visits to aquaria and zoos have a measurable impact both on knowledge and attitudes (Falk & Adelman, 2003; Falk et al., 2007). As Ballantyne (2004) argued, such informal settings are well-placed to address misconceptions by designing exhibits, which accurately demonstrate various phenomena and help children distinguish between them. Kim, Snively, and Kool (2007) reported that many aquaria in the United States and Canada provide diverse educational programs for students and for the public, and develop a wide range of marine curriculum resources for teachers. Walters (2006) additionally stated that school field trips to aquaria and museums have been a profound part of K-12 education in the United States.

The low score of non-governmental environmental organizations, as a possible source of information on ocean sciences issues, could be explained by the fact that pre-service teachers are

not active in environmental organizations that work on marine conservation issues (Boubonari et al., 2013). The members of an organization have more opportunities to acquire knowledge of environmental issues and environmental action strategies through meetings, friendship with knowledgeable people, bulletins, action alerts, etc. (e.g., Hsu & Roth, 1998). Moreover, Greece has only a few environmental organizations, among which very few specialize on the protection of the marine environment, while there are some local environmental groups for the protection of marine areas or species, which rely mostly on volunteers and operate with minimal resources (Daut, 2009).

Books were not found to be a significant source of information for ocean sciences issues, perhaps because the advances in Internet and information technologies have brought about a structural change in the way information is aggregated, transformed, and then disseminated, resulting in the migration of print readers, especially the young, to online sources for their information needs (Tandon, 2007). This finding, also, could be explained by a general decline among youth in reading habits, considering that they mostly prefer watching TV and surfing on the Internet to reading (Loan, 2009). Furthermore, a high prevalence of aliteracy, the ability to read but a disinterest in personal reading, has also been found among current and prospective teachers; although they acknowledge the importance of reading for teachers, they do not themselves exhibit investment in personal reading (Nathanson, Pruslow, & Levitt, 2008).

Greek pre-service teachers obtain information mostly from the Internet and mass media. Furthermore, students who rated the Internet and mass media as highly used sources of information concerning ocean issues scored significantly higher on the SOLE test. This suggests that media could be an effective way to educate the public about the environment, as has been previously argued (Brothers, Fortner, & Mayer, 1991; Fortner, 1985; Fortner & Lyon, 1985). Chan (1999) has concluded that the more often adolescents watch TV news, the more general and local environmental knowledge they acquire. Moreover, it has been noted that regular Internet use enhances environmentalism, providing individuals with background knowledge and enabling them to be more informed about or more committed to the environment (Nistor, 2010). The Internet is considered an immediate, available anytime medium for the access of environmental information, which delivers the exact current information faster and easier than other forms, with the potential to provide more details about topics that other media cannot provide (Haklay, 2002). However, it is questionable whether all of the ocean-related literature available on the Internet is trustworthy. It has been argued that children's ideas acquired mainly through the media are not properly tested against those of their peers or mentors, and therefore misconceptions may arise from misinterpretation of information (Boyes & Stanistreet, 1997; Çakır, Irez, & Kivilcan, 2010). Individuals could be more critical toward ocean-related literature available on the Internet if they have primarily fundamental ocean content knowledge, which could have been constructed and tested at school. In this context, teaching students how to deal with the media in a constructive manner is needed; this is complicated and requires a more diverse approach, incorporating practical activities such as keeping media diaries, and investigating one's own interpretations of media content (Rosenbaum, Beentjes, & Konig, 2008). The fact that the Internet and mass media are our respondents' most important source of information about ocean sciences issues is consistent with other studies concerning pre-service teachers' environmental information sources (e.g., Boubonari et al., 2013; Cakir et al., 2010; Oztas & Kalipci, 2009).

The observation that the respondents revealed very positive attitudes toward the protection of the ocean is in line with other studies concerning environmental attitudes of pre-service teachers in different cultural contexts (e.g., Boubonari et al., 2013; Esa, 2010; Muda, Nazifah Shaik, Turiman, & Noriati, 2011; Ogunyemi & Ifegbesan, 2011; Ozsoy, Ozsoy, & Kuruyer, 2011; Taylor, Doff, Jenkins, & Kennelly, 2007; Tuncer Teksoz, Boone, Yilmaz Tuzun, & Oztekin, 2014). This finding could be partly attributed to the widely publicized environmental issues (e.g., Fortner, 1985; Good, 2006; Holbert, Kwak, & Shah, 2003; Lee, 2011; Nistor, 2010; Shanahan, Morgan, & Stenbjerre, 1997), as well as to the increasing environmental education movement, which makes people, especially youngsters, more aware and concerned about the current environmental crisis (e.g., Esa, 2010; La Trobe & Acott, 2000). In addition, pre-service teachers' positive environmental attitudes toward ocean stewardship might reflect their desire to identify with what they intuitively accept as correct values; this is plausible, considering that they compose a population oriented toward a values-laden profession such as education (Pe'er, Goldman, & Yavetz, 2007). Their very positive attitudes toward the protection of the ocean are potentially an important characteristic of future teachers in order to engage their students in ocean stewardship.

Our results suggest the existence of an association between ocean science content knowledge and attitudes about the protection of the ocean and support previous findings about the importance of both cognitive and affective elements in the development of environmental literacy. A number of previous studies explicitly reported that increasing environmental knowledge results in more positive attitudes toward the environment (e.g., Bradley, Waliczek, & Zajicek, 1999; Esa, 2010; Muda et al., 2011), while others simply presented such a relationship (e.g., Boubonari et al., 2013; Pe'er et al., 2007; Yavetz, Goldman, & Pe'er, 2009) and in other cases this association was not detected (e.g., Cummins & Snivelly, 2000; Tuncer et al., 2009). However, the causal direction of the knowledge-attitudes relation was not investigated and, therefore, should be the focus of future research.

CONCLUSIONS

In conclusion, Greek pre-service primary teachers possess moderate knowledge of ocean sciences issues. They obtain information mostly from the Internet and mass media and less from formal education, indicating both the potential of the Internet and mass media to educate the public about the environment, as well as an inadequate implementation of such topics in elementary–secondary school curricula and teacher preparation programs. They obtain much less information from out-of-school settings and non-governmental environmental organizations, reflecting the lack of such settings and organizations in Greece. They reveal their limited preference on books as a potential source of information about ocean sciences issues, probably due to the advances in Internet and information technologies, and a general decline among youth in reading habits. Greek pre-service teachers demonstrate very positive attitudes toward the protection of the ocean, which is an important characteristic of future teachers in order to engage their students in ocean stewardship. Finally, there appears to be an association between ocean science content knowledge and attitudes about the protection of the ocean, both elements being important in order for achievement of a more secure ocean literacy.

The principal recommendations arising from this research are that ocean sciences need to be brought more fully into formal education, and informal environmental education particularly concerning ocean sciences issues need to be developed and expand. Specifically,

- The essential ocean literacy statements and their fundamental concepts could be integrated as new thematic sections or as extensions of the already reported sections, fulfilling and going beyond the existent scopes, cognitive axes and purposes of the sciences education curricula and the environmental education framework in primary and secondary education.
- Along the same lines, ocean literacy statements could be incorporated in both sciences and environmental education courses already provided in teacher education programs, mostly as inquiry-based and real world problem-solving projects, so as to create for the students the opportunities to gather information and to work on public marine issues.
- Marine educators should focus their interest on making better use of traditional and new media and on creating supportive social and media environments to promote ocean content knowledge, e.g., an online, free ocean observing curriculum delivery platform designed for students, or a network concerning local, regional, national, and global marine issues problems, educational material concerning ocean science subjects, with continuous research updates, and studies and programs concerning them.
- Government should facilitate the access of schools and public to aquaria, while aquaria should strengthen and enrich their educational services by developing educational programs based on grade levels and themes, teachers' programs and teaching resources. They should, also, provide outreach programs for schools and communities that are located a long distance from the aquarium.
- The foundation of centers for ocean science education around Greece could serve a catalytic role by engaging ocean scientists directly with teachers, nonformal educators, aquaria, environmental education providers, and curriculum designers and by creating areas of cooperation between schools and marine environmental organizations and aquaria. These centers could offer opportunities for pre- and in-service teachers to improve ocean and, generally, aquatic science education.

The present study, limited to only one primary education department in Greece, cannot easily lead to generalizations. Moreover, the multiple-choice questionnaire used provides only a simple insight into how students conceive of ocean literacy, while in-depth interviews, which could provide a more comprehensive picture of student understanding of concepts and conceptual relationships will be the focus of future research. However, as far as we know, this is the first global attempt to assess pre-service teachers' knowledge of the essential statements and fundamental concepts of ocean literacy, along with their attitudes toward the marine environment. Considering teachers' key role in environmental education, comparable studies should be conducted in other countries, too, in order to map out teachers' level of ocean literacy. The findings of the present study along with those of future research could contribute to an overall, global strategy for the development of ocean literacy.

ACKNOWLEDGMENTS

Special thanks go to the executive editor and the two anonymous reviewers for their valuable comments.

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