Contributions from Biology Education Research

Konstantinos Korfiatis
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Chapter 12
Evaluating the Effectiveness of a Teaching Intervention in a Marine Biology Course: The Case of Greek Vocational Students

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12.1 Introduction

The ocean covers 71% of our planet and holds 97% of the Earth's water. It supports life on Earth and provides us with tremendous economic, social, and environmental benefits (Costanza, 1999). Moreover, the ocean has intrinsic value for its own sake and its inhabitants. However, human activities continue to threaten the health and integrity of the marine environment (e.g. Derraik, 2002; Lotze et al., 2006; Worm et al., 2006). Since this fact can be attributed to the lifestyles, decision-making, and choices of individuals, as well as governments and industry, among others, the involvement of each and every person in understanding the importance of the ocean and the need to protect it is essential. Therefore, to ensure sustainable use of ocean resources, there is a need for individual responsible behaviour by ocean-literate citizens. Ocean-literate citizens 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 et al., 2007).

The need for ocean literate people is fully aligned with the recently introduced Education 2030 Agenda by UNESCO, a framework providing guidance for the implementation of seventeen Sustainable Development Goals (SDGs); SDG 14, "Life below Water", is among these goals and concerns the sustainable development of oceans, seas, and marine resources, highlights cognitive, socio-emotional, and behavioural learning objectives concerning the oceans, and notes the increase in student demand for a sustainability-centered education as a significant driver for changes in curriculum and teaching practice (UNESCO, 2017). To serve this need,

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ocean literacy should be integrated into educational practice, research, curricula, textbooks, and assessments (Tran et al., 2010).

Promotion of ocean literacy in elementary and secondary education is vital since children represent the future citizens and consumers, who will make decisions that will inevitably affect the environment (Visbeck, 2018). Youth, apart from performing responsible environmental behaviours themselves directly, can also influence the environmental knowledge, attitudes, and behaviours of peers, family, and of the wider community (Hartley et al., 2015).

However, literature reviews reveal that knowledge on ocean sciences issues is inadequate (e.g. Boubonari et al., 2013; Chen & Tsai, 2015; Gelcich et al., 2014; Guest et al., 2015; Mogias et al., 2015; The Ocean Project, 2009). Specifically, published research on elementary and secondary school students revealed low levels of knowledge of ocean issues (e.g. Ballantyne, 2004; Brody, 1996; Brody & Koch, 1986; Guest et al., 2015; Lambert, 2006; Plankis & Marrero, 2010; Rodriguez-Martinez & Ortiz, 1999). This students' lack of familiarity with the ocean could be attributed to the fact that ocean concepts are rarely represented in the formal science education curriculum (e.g. Gough, 2017; Lal, 2017; McPherson et al., 2018; Mogias et al., 2019).

Therefore, research and assessment of teaching interventions concerning ocean literacy could help fill this gap. The literature also reveals that there are some learning activities, school programmes, and teaching interventions concerning ocean literacy, which underline students' knowledge improvement, especially after first-hand experiences on ocean-related topics (e.g. Cummins & Snivelly, 2000; Fortner & Teates, 1980; Hartley et al., 2015, 2018; Lambert, 2005, 2006; Stepath, 2007; Plankis & Marrero, 2010; Winks et al., 2020). Some of these studies discuss how specifically ICT tools and social media could probably enhance ocean literacy (Brennan et al., 2019; Fauville et al., 2019).

12.2 Aims of the Study

In this context, the aim of the present study is to (a) estimate vocational students' knowledge on a specific principle of ocean literacy before and after a teaching intervention, and (b) examine whether and how the teaching intervention actually helped the students. The results of this study will help researchers improve the teaching intervention and continue the study with a larger sample. This effort cumulatively will contribute to the design and implementation of programmes concerning principles of ocean literacy, and these could be integrated into the educational practice.

12.3 The Ocean Literacy Framework

Ocean literacy was launched at the beginning of this century. Although the interest in marine issues in education was much older, marine education became marginalized and often presented in a very local context (Strang, 2008). When the US

National Science Education Standards were published in 1996, various ocean scientists and marine educators realized that there was little mention of ocean topics. Furthermore, state standards did not include much about the ocean, coasts, or watersheds (Schoedinger et al., 2010). All the above have led to a new attempt for a rebirth of this educational area.

The ocean literacy movement was born in about 2004 in the U.S. 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 to draft a common framework. This framework would define the meaning of ocean literacy and develop principles about a desirable state of knowledge for the ocean. The result of this extensive process was two documents comprising the Ocean Literacy Framework: (a) the Essential Principles and Fundamental Concepts of Ocean Sciences (National Oceanic and Atmospheric Administration, 2013), and (b) The Ocean Literacy Scope and Sequence (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", and identifies the seven essential ocean literacy principles, which all students should understand by the end of high school as follows:

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 principles is underpinned by a series of 45 fundamental concepts (NOAA, 2013), which support and explain them. According to the guide, an ocean literate person understands the essential principles 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 a full understanding of these principles. 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). These guidelines, developed to help implement an ocean-dedicated curriculum in the USA, are now largely accepted and have been an inspiration for several initiatives worldwide (Fauville et al., 2019).

The present study focuses on Ocean Literacy Principle 5 (OLP5). This principle refers to marine biology issues, such as marine organisms, all marine ecosystems found in the ocean, the relationships among them, and which and how physicochemical factors influence them (Table 12.1).

Table 12.1 The fifth principle of the Ocean Literacy Framework and its fundamental concepts. Concepts are given concisely

Principle	Concepts
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 the ocean, unique ecosystems
	5f. ocean life not evenly distributed due to abiotic factors
	5g. deep ecosystems independent of sunlight
	5h. vertical zonation pattern along the coast and in the open ocean
	5i. estuaries

12.4 Methodology

12.4.1 The Participants

The current study was conducted in December 2019 with a convenience sample of 24 first-grade (15–16 year-old) male students of a public vocational senior high school in a provincial town in Northern Greece. The three-year course in Vocational High Schools offers general education knowledge, provides vocational training as a strong basis for future new professional occupations, and keeps pace with the advancement of technology and the constant changes in know-how. The first grade includes general education courses, as well as courses of related professional fields, in order to provide complete knowledge of the subjects of each field, while the other two grades are structured according to professional fields and specialties. The students of this study chose the field of mechanical engineering, which was the reason for the male gender dominance in the present study. The intervention took place within the course entitled "Research Work in Technology". The object of this course is to teach students the methodology of research and technologies.

Prior to the beginning of the intervention, the participants were informed about the purpose of the study, the voluntary basis of participation and assurance about anonymity, and the official approval of the school's principal was ensured. Therefore, the access authorization, the organizing of the field visits, and the engagement with the participants, played a key role in the selection of the sample. Their parents had not undertaken formal education beyond secondary school level. Most of the students (70.8%) had not attended a lesson or participated in a project concerning environmental education; only one student was a member of an environmental organization.

12.4.2 The Questionnaire

A structured questionnaire was administered to the students, in order to investigate their level of knowledge related to marine biology issues prior to and after the teaching intervention. The questionnaire contained a set of demographics, which concerned their parents' education and the source of information they mostly use for environmental issues, as well as 11 multiple choice questions (see Table 12.2) with five optional answers (including 'I don't know') per question concerning all fundamental concepts of OLP 5. The items of the research tool were borrowed from psychometrically valid and reliable questionnaires concerning ocean literacy (Fauville et al. 2019; Markos et al., 2017).

Table 12.2 Relative frequencies of correct answers, and *p*-values per question prior and after the intervention

	Percentage of correct answers		
Questions/Statements	Pre-test (%)	Post-test (%)	*p*-value
1. Ocean life ranges in size from the smallest living things, microbes, to the largest animal on Earth, **blue whales**	33.3	100.0	0.000
2. Most of the organisms and biomass in the ocean are **microbes**	37.5	66.7	0.050
3. Most of the major groups that exist on Earth are found exclusively **in the ocean**	45.8	100.0	0.000
4. The ocean hosts **a great diversity of life**	62.5	87.5	ns
5. The ocean provides a vast living space **from the surface through the water column, and down to, and below, the seafloor**	58.3	70.8	ns
6. Ocean ecosystems are defined by environmental factors such as **oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate, and circulation**	8.3	20.8	ns
7. There are deep ocean ecosystems, independent of energy from sunlight, **supporting limited life**	20.8	54.2	0.017
8. There are deep ocean ecosystems, independent of energy from sunlight, such as **hydrothermal vents, submarine hot springs, and methane cold seeps**	12.5	25.0	ns
9. There are deep ocean ecosystems, independent of energy from sunlight, **relying only on chemical energy and chemosynthetic organisms**	16.7	66.7	0.000
10. Factors causing vertical zonation patterns along the coast are **tides, waves, predation, substrate** among others	12.5	66.7	0.000
11. Marine habitats providing important and productive nursery areas for many marine and aquatic species are called **estuaries**	25.0	83.3	0.000
Mean	**30.3**	**67.4**	**0.000**

ns non-significant, *p*-level >0.05

12.4.3 The Intervention

A 6-h teaching intervention concerning concepts of OLP 5 was developed for the age group of the present study based on the Ocean Literacy Guide and the Scope and Sequence (NMEA, 2010; NOAA, 2013). The answers of the participants in the pre-test questionnaire about their most preferred source of information on environmental issues, as well as the teaching suggestions provided in the "One Ocean" (Mohan, 2013), a guide for teaching about the Ocean, were taken into account while structuring the intervention. One of the authors, who worked as a teacher at the senior high school of the experimental group and already knew the students, implemented the intervention.

The students worked in teams on case studies, e.g. the case study of an ecosystem, such as a coral reef, an estuary, or a deep ocean ecosystem. Case studies offer an in-depth look at how ocean concepts play out in particular locations or situations. Moreover, they provide real-life examples of how biotic and abiotic factors, as well as relationships among organisms affect natural communities. Videos and websites concerning the concepts of OLP 5 (e.g. marine organisms and ecosystems) were valuable resources to work with. These resources were sought and used by the groups with the support of the teacher. Additionally, each group of students used satellite technology to track and map migrations of ocean animals, e.g. beluga whale, and other internet resources so as to infer information about their life cycle, habitats, their diet, and reproduction. All these resources were used by each group to obtain data and answer specific questions concerning a marine ecosystem or an organism. Concept maps constructed with Cmap tools were used to summarize and synthesize all the information each group had managed to collate for its case study. Each group shared these maps and what they had learned about their topic with the rest of the groups during short feedback sessions.

12.4.4 Data Analysis

Descriptive and non-parametric inferential statistics (Wilcoxon T) were applied with the use of the Statistical Package for Social Sciences (SPSS v. 21); in terms of the latter case, results should be interpreted conservatively due to the small sample. The significance level was predetermined at a probability value of 0.05 or less.

12.5 Results

The respondents were found to possess a low level of marine biology knowledge before the teaching intervention (mean score 3.33 ± 1.523), while this was significantly increased immediately after the intervention (mean score 7.42 ± 1.717)

(Fig. 12.1). Each correct answer received a value of 1 and incorrect a value of 0; therefore, the score could vary between 0 and 11, as this was the total number of questions. Table 12.2 portrays the percentages of correct answers. Most answers showed a statistically significant difference between the two tests. As regards the source of information that students mostly use for environmental issues, the internet scored highest (mean ± SD: 3.63 ± 1.345), followed by formal education (2.33 ± 1.007), while books had the lowest score (1.58 ± 0.584). Their parents' generally did not study formally beyond secondary school and the effect of parents' education on students' knowledge was not significant at the 5% level.

12.6 Discussion

In the present study, according to the findings, the teaching intervention implemented with vocational high school students with regard to marine biology issues significantly increased their knowledge level on these issues, although they were found to be very low achievers before the intervention. Our findings seem to be in accordance with studies from other countries concerning secondary students' knowledge on marine biology issues (e.g. Brody, 1996; Brody & Koch, 1986; Greely, 2008; Guest et al., 2015; Hartley et al., 2018; Plankis & Marrero, 2010).

Participants' initial low level of knowledge in this study could be attributed to the fact that ocean sciences do not constitute a basic part of the Greek educational system (Mogias et al., 2019). Particularly, references on marine biology issues exist in the school textbooks in Greek secondary education, but these issues are only patchily and superficially touched on. In addition, there are no suitable educational

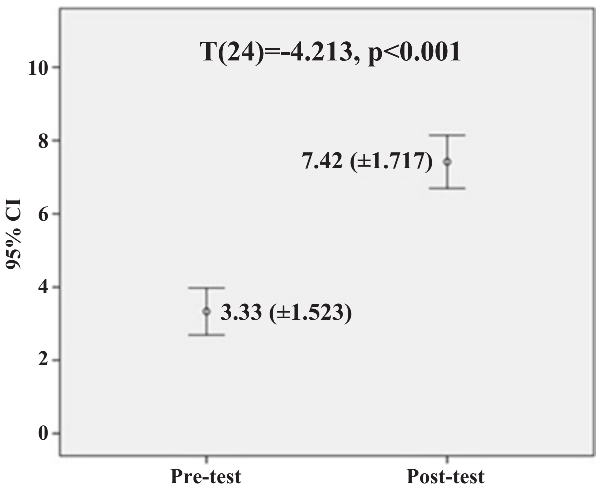

Fig. 12.1 Mean scores at the pre- and post-tests

materials to work further on these subjects. Moreover, teachers and students participate voluntarily in environmental education programmes, which could serve as a source of knowledge. However, not all schools implement environmental education programmes, and not all students take part in them. Most importantly, only a few of these programmes are related to marine biology issues. Beyond these, teachers can hardly enrich their teaching with additional knowledge, because of the strict context of the formal curriculum (Liarakou et al., 2009).

The inadequate implementation of ocean science topics in secondary school curricula is supported by the finding that the respondents appear to derive little information from formal education about these issues. On the other hand, they declare that they acquire information on these issues mostly from the internet. Our respondents' preference for the internet as a source of information for marine biology issues, suggests that this media could be an effective way to educate them about the marine environment. Therefore, it should be utilized in a teaching intervention. Along the same lines, the internet is considered as an immediate, available anytime, medium for the access of environmental information, which delivers the exact piece of current information required faster and easier than other forms. It also has the potential to provide more details about topics that other media cannot (Haklay, 2002). However, it is uncertain whether all of the ocean-related literature available on the internet is trustworthy. It has been argued that misconceptions may arise from misinterpretation of information since children's ideas acquired mainly through the media are not properly tested (Boyes & Stanistreet, 1997; Çakır et al., 2010). Therefore, students need to be taught how to deal with this source of information in a constructive manner. Moreover, appropriate and reliable links concerning marine biology issues should also be provided.

Although the average score of the pre-test was low, there was a considerable variation among questions. Species-related or biological questions (questions 1, 3, 4, 11) were generally scored higher than abiotic-related questions concerning the physicochemical factors of the marine environment (questions 6, 8) before and after the teaching intervention. This finding is consistent with the results of previous studies (e.g. Ballantyne, 2004; Guest et al., 2015; Marrero, 2010), and underlines the fact that young students hold a keen fascination for animal life. This interest in marine life could play a key role in the construction of a marine environmental programme or teaching intervention, and it could serve as a context to teach more difficult and less fascinating subjects of the marine physicochemical sciences.

The questions with the lowest score before and after the intervention (questions 6, 8) concerning physicochemical factors and deep-ocean ecosystems are subjects which can be difficult to understand, as also shown in other studies (e.g. Guest et al., 2015; Mogias et al., 2015). Their low increase in the post-test achievement score underlines the need to emphasise them and add related learning activities in the teaching intervention.

After the intervention, as was expected, the students increased their knowledge of marine biology issues. The effect sizes were high, which might be the result of their low prior knowledge. This also indicates that the teaching intervention was effective enough to make a significant difference between the pre- and post-assessments and to develop participants' knowledge.

12.7 Conclusions

In light of the findings of the current study, we conclude that:

1. Students' pre-intervention knowledge was poor, but the much improved post-intervention scores show that they have the potential to make significant learning gains in this area.
2. Students struggle with concepts concerning physicochemical factors and deep-ocean ecosystems and these topics need particular support.
3. The fascination students show with marine life, as well as their preference for the internet as a basic source of information on marine biology issues, should be thoroughly considered as an appropriate context and media respectively to enhance their knowledge on these issues and generally improve their ocean literacy.

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