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Contribution to the Special Issue: "Ocean Literacy across the Mediterranean Sea region"

Ocean Literacy across the Mediterranean Sea basin: Evaluating Middle School Students' Knowledge, Attitudes, and Behaviour towards Ocean Sciences Issues

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Abstract

The Mediterranean Sea is characterized by rich biodiversity, and its region hosts people living in several countries with a rich variety of cultures, but – at the same time – it is "under siege", due to anthropogenic pressures. To address these pressures, many actions are needed aiming, among others, at establishing Ocean Literacy (OL) across the Mediterranean countries and preparing the future generation of Mediterranean Sea-literate citizens. Towards this aim, the present cross-national study investigated OL issues in relation to content knowledge, possible common misconceptions, attitudes, and the self-reported behaviour of 2,533 middle school students from eight Mediterranean countries (Croatia, Cyprus, Egypt, Greece, Italy, Malta, Spain and Turkey), as well as certain background elements (e.g., gender, grade level, environmental education experience, sources of relevant information). The results of this study revealed that middle school students of all studied countries possess a moderate level of ocean sciences content knowledge, while they showed satisfactory pro-environmental attitudes and behaviour. These findings along with further research are expected to function as a baseline for the design, implementation, and launch of specifically targeted programmes, educational activities, teaching resources, curricula and school textbooks, which will be achieved through close collaboration between schools, universities, research institutes, and Ministries of Education, thus contributing to the future protection and sustainable development of the Mediterranean Sea region.

Keywords: Ocean Literacy; cross-national study; content knowledge; environmental attitudes; environmental behaviour; middle school students; environmental education; Mediterranean region.

Introduction

The ocean, covering two-thirds of earth's surface, generates oxygen, controls and stabilizes climate, nurtures biodiversity, captures carbon, and supports human well-being by providing food, minerals, medicine, and energy resources as well as cultural and recreational services (Cava *et al.*, 2005). The continuous increase in human population, along with the high socio-economic value of the ocean, has been instrumental to its severe health decline (e.g., Brennan *et al.*, 2019). Meanwhile, the ocean is experiencing cumulative exacerbating impacts due to human drivers and this, in combination with climate change, is affecting both human lives and their well-being (Diaz *et al.*, 2019). Societal values and actions that are related to aspects of human society, such as production and consumption patterns, are an important underlying cause of ocean health decline (Diaz *et al.*, 2019; Okumah *et al.*, 2020).

Towards this direction, the United Nations have recently declared a Decade of Ocean Science for Sustainable Development from 2021-2030 (Santoro *et al*., 2017), along with the Agenda 2030 for Sustainable Development with 17 goals, amongst which there is a stand-alone goal concerning the sustainability of the ocean and its resources (Sustainable Development Goal - SDG 14). For this goal to be achieved, people need to understand their inextricable interconnection with the ocean. Ocean Literacy (OL) has already been defined as *"an understanding of the ocean's influence on you and your influence on the ocean"* (Cava *et al.*, 2005), which means that an ocean-literate citizen should understand essential ocean issues, is able to communicate about the ocean in a meaningful way and can make informed and responsible decisions regarding the ocean and its resources (Cava *et al.*, 2005). Consequently, OL is not only about knowledge of ocean issues, but it is also about the ability of people to protect, conserve, sustainably use and manage marine resources. Only recently, however, there is a focus on "knowledge" shift to other aspects of OL such as "awareness", "attitudes", "communication", and "behaviour" (Brennan *et al.*, 2019).

The triptych of knowledge, pro-environmental attitudes and behaviour has been shown to improve environmental protection by both adults and children (e.g., Hynes *et al.*, 2014; Hartley *et al.*, 2015). However, the available literature regarding pro-environmental attitudes and behaviours towards the ocean, especially those of students, has only lately shown signs of real growth (Leitão *et al.*, 2018; Ashley *et al.*, 2019; Sakurai *et al.*, 2019). Moreover, the knowledge that students have appears to be affected erroneously by misconceptions, with predictable effects on their attitudes and behaviours. Misconceptions are commonly defined as *"any belief which is contrary to current scientific understanding"* (Francek, 2013) and are reported in different science fields (Driver *et al.*, 1985; Vosniadou, 2013). Misconceptions are also widespread and considered to be normal traits in the development of science literacy among children, teenagers, adults, and even some teachers (National Research Council, 2000; Boubonari *et al.*, 2013). As far as ocean sciences issues are concerned, misconceptions have been reported in different studies for many years (Phillips, 1991; Brody, 1996; Ballantyne, 2004; Ben-zvi-Assaraf & Orion, 2005; Mogias *et al.*, 2019; Lin *et al.*, 2020).

Since students in middle school still maintain their innate curiosity about nature, they are susceptible to new knowledge (US Commission on Ocean Policy, 2004), as well as to the shaping of their pro-environmental attitudes and behaviours (Hartley *et al.*, 2015). Moreover, regarding environmental moral reasoning, it seems that they are capable of having not only anthropocentric views (e.g., personal interests, human welfare, and aesthetics) but also biocentric conceptions (e.g., intrinsic value of nature) of living in harmony with nature (Kahn & Lourenco, 2002). In addition, the literature reveals that they can influence the adults in their family and friends and act as agents of social change and active future citizens (e.g., Hartley *et al.*, 2015). Consequently, it is fundamental that students should have adequate ocean knowledge along with pro-environmental attitudes and behaviours, in order to protect and sustainably use the ocean and make informed and responsible decisions about it later on as adults.

The rich biodiversity of the Mediterranean Sea regions has been host to many and various countries and cultures for thousands of years (Cuttelod *et al.*, 2008), and therefore has been strongly affected by human activities (Lotze *et al.*, 2018). To address the pressures placing the Mediterranean Sea under siege (Coll *et al.*, 2012), there is a very real need to establish OL across the Mediterranean countries and prepare future generations of Mediterranean Sea-literate citizens. Towards this aim, Mokos *et al*. (2020a) adapted the OL essential principles and fundamental concepts to the specific features of the Mediterranean Sea and developed the Mediterranean Sea Literacy (MSL) guide.

The present study is the first wide cross-national attempt aiming to (a) investigate the content knowledge of middle school students from eight Mediterranean countries on OL issues, and the presence of possible common misconceptions; (b) assess student attitudes and self-reported behaviour related to OL issues; and (c) examine the relationship between knowledge, attitudes, behaviour and students' background factors (e.g., gender, grade level, previous environmental education experience, sources of information). Results of this research are expected to function as a baseline for determining the level of middle school students' OL in the Mediterranean region, and could bring about the design, implementation, and launch of properly targeted curricula and school textbooks, ensuring in this way the future protection and sustainable development of the Mediterranean Sea region.

Materials and Methods

Participants

A cross-national study concerning middle school students, referring to the educational grading system

per country regardless of age, was conducted in eight Mediterranean Sea countries, located in southern Europe (Spain, Italy, Malta, Croatia, Greece, and Cyprus), western Asia (Turkey), and northern Africa (Egypt) (Fig. 1). The research employed a convenience sampling method, resulting in 2,533 students (10 to 16 years old) from more than 40 coastal and non-coastal locations around the Mediterranean Sea, while special attention was paid to obtain similar gender percentages.

Instrument

A structured questionnaire was designed and developed taking into consideration previous research (e.g., Fauville *et al.*, 2018; Mogias *et al.*, 2019; Realdon *et al.*, 2019), following the guidelines of the Ocean Literacy Framework (NOAA, 2013) and the Ocean Literacy Scope and Sequence (NMEA, 2010). The instrument consisted of four sections: a demographic section with questions about student gender, age, grade level, participation in environmental education programs, membership in non-governmental environmental organizations, parental education level, and frequency of use of certain information sources about environmental issues. The next section comprised twenty-one multiple-choice knowledge questions, aligned to the seven essential principles of the Ocean Literacy Framework (Table 1), with five distractors each, including one "I don't know" option (see Table S1). Finally, an attitude and a behaviour section, each consisting of ten Likert scale statements toward ocean stewardship, with values ranging from 1 (totally disagree) to 5 (totally agree) were applied (Tables S2 and S3).

The survey was initially developed in English as the common language among the researchers and then translated into the respective study languages. It was examined for content validity in terms of content clarity and language by a panel of marine scientists and marine educators, while its internal consistency was also checked by applying the Cronbach's α reliability index, revealing adequate values in all scales (0.67 for knowledge, 0.81 for attitudes, and 0.76 for behaviour, respectively). The questionnaire, which supported the anonymity of the participants, was administered to the students during class hours from October 2018 to March 2019; the time of completion ranged between 20 and 30 minutes.

Fig. 1: Map of the Mediterranean Sea basin illustrating the participating countries and sampling locations.

Table 1. Alignment of the survey questions with the seven essential principles of the Ocean Literacy Framework.

Ocean literacy essential principles	Questions
1. Earth has one big ocean with many features.	1, 9, 15, 17
2. The ocean and life in the ocean shape the features of Earth.	2, 12
3. The ocean is a major influence on weather and climate.	5, 13
4. The ocean makes earth habitable.	3, 10
5. The ocean supports a great diversity of life and ecosystems.	4, 6, 8, 11
6. The ocean and humans are inextricably linked.	14, 16, 18, 20, 21
7. The ocean is largely unexplored.	7, 19

Data analysis

Data analysis for knowledge, attitudes, and behaviour scales per country consisted of three main steps. The first step involved descriptive statistics to illustrate frequencies, mean values, and standard deviations, as well as correlation coefficients among the above scales. In the second step, independent samples *t*-tests and one-way analyses of variance were applied to portray whether background factors affect student knowledge level, attitudes, and behaviour toward the marine environment. Finally, multivariate analysis routines were applied to investigate similarities among countries in terms of common knowledge acquisitions and beliefs. Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS v.23), and the Primer package, developed at Plymouth Marine Laboratory; for all significant testing, the limit of 5% was set.

Results

Background data

Eight Mediterranean countries took part in this study numbering 2,533 students. With a mean value of 12.5%, the national distribution of proportions within the participants varied between 4.6% (for Cyprus) and 21.0% (for Spain), while female students with a 55.9% presence in all participants outnumbered their male counterparts; in terms of grade level, a slight decrease in proportion was detected progressing by grade (37.5% for the 1st middle school grade, 33.9% for the 2nd, and 28.6% for the 3rd, respectively) (Table 2). A majority of students (61.5%) indicated that they had participated in environmental education programmes in their schools, with percentages varying between 58.2% (for Spain) and 75.1% (for Italy), apart from Turkey (26.9%). They were also asked if they were members of a non-governmental environmental organization, revealing a small mean percentage (9.2%) of positive answers, ranging from 4.9% (for Italy) to 14.8% (for Croatia), except for Egypt which displayed a remarkable value of 49.1%. Finally, in almost all cases the Internet appeared to be the main information source regarding environmental issues with a mean value of 4.0 (min: 3.65, max: 4.29) in a 5-point Likert scale, followed by family (mean value: 3.3, min: 3.01, max: 3.77); this was not however the case for Turkey where the Internet and family exhibited almost the same values (3.6 and 3.7, respectively).

Ocean content knowledge, attitudes and behaviour

Middle school students were found to possess a moderate level of ocean sciences content knowledge as the mean relative frequency of correct answering among countries was 9.6 out of the 21 questions translated into a mean knowledge score of 45.6% in total. In this study percentages of correct answers are presented per country; since the mean values are basically detected close to the average of 50%, the term "moderate knowledge" was arbitrarily used to describe the level of students' ocean content knowledge. The percentages ranged between 54.9% for the Croatian and Italian participants and 27.4% and 33.3% for the Egyptian and Turkish participants, respectively. Table 3 presents the relative frequencies of correct answers per question for all participating countries, while Figure 2 portrays the mean knowledge scores per country.

Although variance in correct answering was revealed, nevertheless interesting patterns, regarding the most difficult and the easiest questions, could be detected. Students had the greatest difficulty in identifying the connectedness of the ocean basins when asked if certain regional seas of the Mediterranean basin (e.g., the Aegean, the Adriatic, or the Tyrrhenian Sea) are connected to all parts of the ocean (question 9). Only 15.3% of the participants, ranging from 11.2% for Malta to 23.4% for

Table 2. Participants' characteristics of the participating countries in alphabetical order (f, frequency; rf, relative frequency).

Country	Gender		Middle school grades			Total (n=2,533) f (%)
	Males f (%)	Females f (%)	1st grade f (%)	2nd grade f (%)	3rd grade f (%)	
Croatia (HR)	156 (45.1)	190 (54.9)	72 (20.8)	144 (41.6)	130 (37.6)	346 (13.7)
Cyprus (CY)	57 (48.7)	60 (51.3)	33 (28.2)	73 (62.4)	11 (9.4)	117 (4.6)
Egypt (EG)	108 (50.0)	108 (50.0)	72 (33.3)	72 (33.3)	72 (33.4)	216 (8.5)
Greece (GR)	211 (49.9)	212 (50.1)	133 (31.4)	129 (30.5)	161 (38.1)	423 (16.7)
Italy (IT)	218 (53.3)	191(46.7)	150 (36.7)	99 (24.2)	160 (39.1)	409 (16.1)
Malta (MT)	69 (42.1)	95 (57.9)	54 (32.9)	50 (30.5)	60 (36.6)	164 (6.5)
Spain (ES)	253 (47.6)	279 (52.4)	239 (44.9)	205 (38.5)	88 (16.6)	532 (21.0)
Turkey (TR)	53 (16.3)	273 (83.7)	233 (71.5)	34 (10.4)	59 (18.1)	326 (12.9)
Total	1,125 (44.4)	1,408 (55.6)	986 (38.9)	806 (31.8)	741 (29.3)	2,533 (100.0)

Table 3. Relative frequencies of correct answers per question per country.

Questions	HR	CY	EG	GR	IT	MT	ES	TK	Means
Question 1	25.4	42.7	19.0	36.9	24.2	35.4	30.6	35.6	31.2
Question 2	76.9	69.2	25.0	69.3	90.2	78.0	77.8	57.7	68.0
Question 3	75.4	53.0	27.8	55.6	83.6	67.5	5.6	22.7	48.9
Question 4	70.5	47.0	43.1	55.1	90.7	60.4	78.4	48.2	61.7
Question 5	17.6	23.1	14.8	19.9	19.6	17.7	24.6	6.4	18.0
Question 6	81.2	77.8	27.3	82.3	85.8	79.9	82.9	49.7	70.9
Question 7	60.4	56.4	24.1	45.9	52.3	62.2	63.5	17.8	47.8
Question 8	50.6	58.1	16.2	57.4	29.6	24.4	31.0	15.6	35.4
Question 9	19.7	14.5	11.6	23.4	11.2	11.0	16.7	14.4	15.3
Question 10	34.4	6.8	28.7	19.9	14.7	20.1	13.7	16.0	19.3
Question 11	48.6	47.9	44.9	45.6	56.0	51.8	61.1	31.0	48.4
Question 12	67.6	51.3	27.8	53.7	76.5	57.9	60.2	33.1	53.5
Question 13	44.2	46.2	24.5	43.7	48.7	46.3	42.9	36.2	41.6
Question 14	67.1	62.4	34.3	65.2	66.3	67.7	68.4	43.9	59.4
Question 15	62.1	65.0	27.8	77.5	77.8	67.7	75.4	51.8	63.1
Question 16	17.1	9.4	21.3	13.2	22.7	7.9	13.2	36.5	55.3
Question 17	57.8	60.7	27.3	51.5	54.0	74.4	59.0	24.5	51.2
Question 18	49.1	71.8	20.8	59.8	49.9	63.4	58.5	41.4	51.8
Question 19	73.7	60.7	36.6	51.1	62.3	62.6	53.8	44.2	55.6
Question 20	49.1	65.8	25.0	68.8	57.0	64.6	66.5	60.4	57.2
Question 21	65.9	45.3	35.6	54.1	42.5	43.9	36.8	16.0	42.5
Mean values	**54.9**	**52.2**	**27.4**	**52.6**	**54.9**	**53.5**	**50.8**	**33.3**	

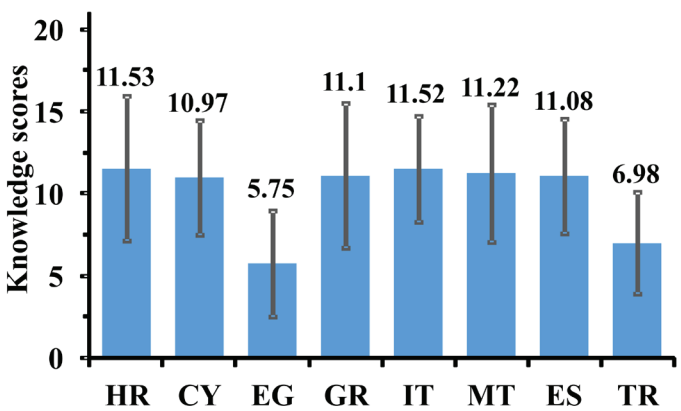

Fig. 2: Ocean content knowledge mean scores (± standard deviation) per country.

Greece, provided the correct answer, while the majority of students (30.0%) thought that the above seas are linked only to some parts of the global ocean. This lack of knowledge and/or existence of misconceptions were also detected in question 1, as the theoretical ability of a boat to travel with limitless fuel in every part of the ocean was not considered, with the mean percentage of correct answers reaching only 31.2%. Another item that proved to be difficult was question 5 which referred to the global water cycle, concerning the origin of most of the rainwater falling on land; with the percentages of correct answers ranging between 6.4% for Turkey and 24.6% for Spain, the students attributed this origin to the nearest seas and not to the remote tropical ocean. The next difficult concept pertains to the origin of the atmospheric oxygen (question 10), since only 19.3% of the answers referred to the marine photosynthetic organisms, ranging from 6.8% (Cyprus) to 34.4% (Croatia), while most of the students focused on tropical forests. Participants also had some difficulty in identifying the low number of species found in the dark deep sea (question 8); apart from Croatia, Cyprus, and Greece which had a mean percentage of 55.4%, participants from the rest of the countries demonstrated an inadequate knowledge level with correct answers varying between 15.6% and 31.0% (Table 3).

On the contrary, questions 2, 4, 6, 14, and 15 proved to

be generally easy to answer correctly for the participating students. The item with the highest mean percentage of correct answers was the one identifying the ocean as the home of organisms of many different species (70.9%); students also acknowledged that fish fossils found in the mountains were once formed in a sea or in a lake (68.0%), while they seemed to understand that the vast amount of Earth's water is found in the ocean (63.1%). They also realized that the marine environment is home to different animals depending on sea depth (61.7%), and they seemed to adequately comprehend the significance of shipping as the major transportation mean in the world (59.4%) (Table 3).

Students were also asked to state their level of agreement on an attitude and a behaviour scale. Results from both scales revealed positive attitudes and behaviour toward ocean stewardship, with the former slightly prevailing (3.87±0.18 and 3.52±0.36, respectively). In particular, regarding their attitudes, middle school students believed strongly that even if they live near the sea or far away from it, they are responsible for the protection of the ocean (4.08±1.04) (item 7). They also stated that marine ecosystems will be lost if humans do not change their behaviour toward the ocean (4.07±1.05) (item 5), and that humans are responsible for the extinction of many marine species (4.06±1.04) (item 6). Contrary to the above, they did not seem to comprehend much that human life is inextricably connected to the ocean (3.60±1.08) (item 1), or the fact that world leaders often postpone taking the necessary actions for protecting the ocean (3.69±1.41) (item 4) (Table S2).

With regard to behaviour, they firmly declared that: they collect their garbage on the beach (4.18±1.02, item 3), and recycle plastic, knowing the negative impacts on the marine ecosystem (3.99±1.09, item 5). Nevertheless, they did not seem to be willing to change their everyday habits to protect the ocean (2.99±1.19, item 9), nor did they systematically participate in organized community activities, such as a beach clean-up (3.14±1.17, item 2) (Table S3).

Considered on a country basis, both attitudes and behaviour revealed high mean values ranging from 3.59 (Turkey) to 4.09 (Cyprus) for the scale of attitudes, and 3.26 (Turkey) to 3.70 (Spain) for the scale of behaviour (Fig. 3).

On a grade basis, the results of ocean content knowledge revealed a slight variation in the progression pattern (Fig. 4). Cyprus was the only country which portrayed a gradual increase from the middle school grade 1 to 3 in students' score values (rising from 9.97±4.01 to 11.64±4.27); only Greece and Italy presented the highest values in the last middle school grade, while the rest of the countries, except for Spain, Croatia and Turkey revealed slightly higher values in the second middle school grade. Almost the same variation in attitudes and behaviour was detected in terms of the middle school grades, as similar trends are portrayed in most of the cases (i.e., in Croatia, Egypt, Italy, Spain, and Turkey) (Fig. 4).

Relationships among variables and background factors

In Table S4, Pearson r correlation coefficients among knowledge, attitudes, and behaviour scales, while significance tests (e.g., one way ANOVA, t-test) for the degree of impact of background factors to these scales for each country, are presented in detail. More specifically, with regard to the knowledge-attitudes relationship, the values varied between 0.14 for Egypt and 0.50 for Malta; regarding the knowledge-behaviour relationship, values varied between 0.06 for Cyprus and 0.32 for Malta, while as far as attitudes-behaviour relationship is concerned, between 0.44 for Malta and 0.71 for Egypt (Table S4).

In terms of gender, female students generally showed slightly higher values in all scales than their counterpart male students, except for Egypt, where male students performed better in attitudes and behaviour, Italy in knowledge, and Turkey in behaviour. Our results show high support for student participation in environmental education programmes in schools, as in almost all cases, knowledge, as well as attitudes and behaviour recorded higher values among students who had participated in such activities. Nevertheless, this was not the case for Egypt in respect of all three scales, for Greece for behaviour, and for Malta for knowledge. Involvement of students in NGO activities revealed different values, while coastal residency seems to affect only Spanish and Turkish students in terms of all three scales. Finally, a careful analysis of parental educational level revealed that fathers' education seems to have a slightly higher effect on

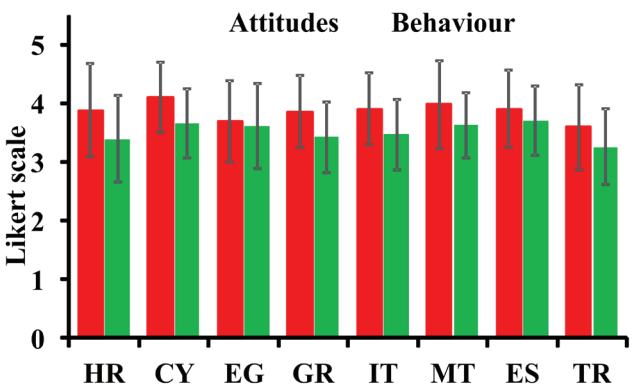

Fig. 3: Attitudes and behaviour mean values (± standard deviation) in a 5-point Likert scale per country.

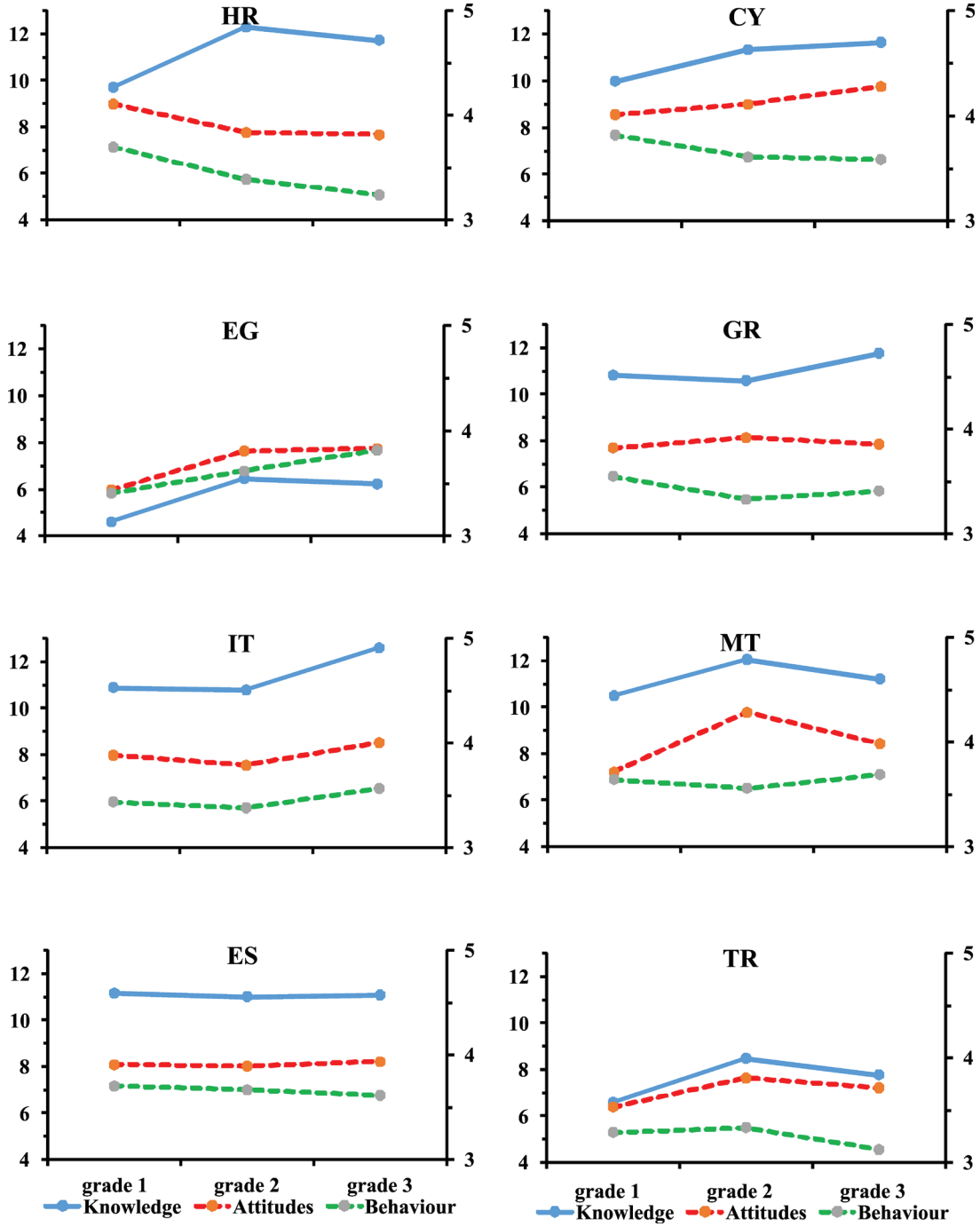

Fig. 4: Content knowledge, attitudes and behaviour mean values per country and school grade.

students' knowledge, attitudes, and behaviour (See Table S4 for statistically significant differences).

Multivariate analysis

Five significantly distinct groups were formed (Fig. 5a) based on the results from the ocean content knowledge scale (ANOSIM, global R=0.979, $p<0.01$). The first group consisted of Cyprus, Greece, and Malta, a second of Croatia and Italy, while Egypt, Spain, and Turkey were not classified in any group. According to the SIMPER technique, nine questions (2, 3, 4, 6, 12, 14, 15, 17, and 19) contributed more than 60% to the similarity of the first group, and ten questions (2, 3, 6, 12, 14, 15, 17, 18, 19, and 20) contributed more than 60% to the similarity of the second group.

The similarity dendrogram (Fig. 5b) based on the attitude scale matrix, revealed a clear separation among countries, comprising four distinct groups (ANOSIM, global R=0.965, $p<0.01$). Croatia, Italy, and Malta formed the first group, Cyprus and Greece the second one, Egypt and Turkey the third, while Spain was not classified in any group. Statements 3, 4, 5, 6, 7, and 9 contributed more than 60% to the similarity of the first group, while statements 2, 3, 5, 6, 7, and 9 to the similarity of the second one, and statements 2, 3, 6, 7, 8, and 9 to the similarity of the third group (SIMPER).

Finally, the dendrogram derived from the cluster analysis based on the behaviour scale matrix (Fig. 5c) showed

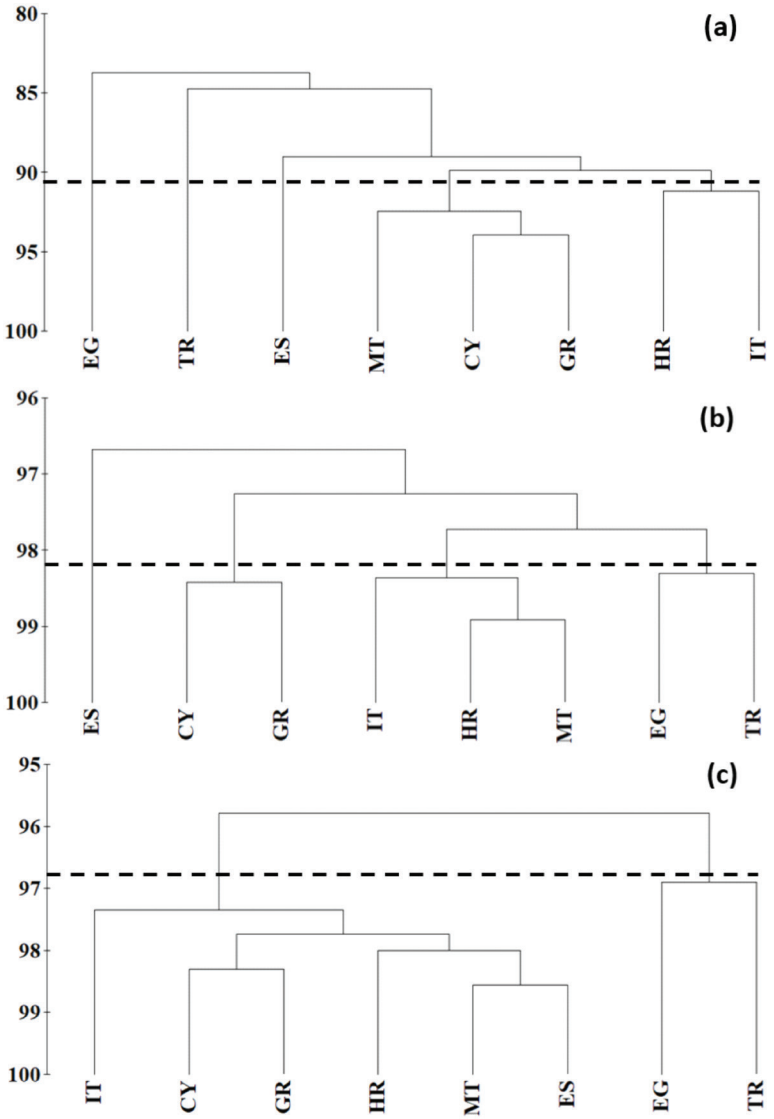

Fig. 5: Similarity dendrograms based on matrices of (a) content knowledge, (b) attitudes, and (c) behaviour, of the participating countries.

a clear separation of two distinct groups (ANOSIM, global R=0.979, $p<0.05$). The application of the SIMPER technique revealed that in the first group consisting of Croatia, Cyprus, Greece, Italy, Malta, and Spain, statements 1, 3, 4, 5, 6, and 7 contributed more than 60% to its similarity, while statements 1, 3, 5, 7, 8, and 10 contributed more than 60% to the similarity of the second one consisting of Egypt and Turkey.

Discussion

The Ocean Literacy (OL) framework consists of two documents: a) the fundamental issues that high school graduates should know and understand about the ocean (NOAA, 2013), and b) a guide as to what students should be taught and learn in different grade bands for achieving a full understanding of the OL principles and concepts (NMEA, 2010). Due to the relative novelty of this context, studies investigating knowledge, attitudes, and behaviour of elementary and secondary school students concerning the OL framework have only recently been increasing (Plankis & Marrero, 2010; Fauville *et al.*, 2018; Leitão *et al.*, 2018; Niedoszytko *et al.*, 2018; Tsai & Chang, 2018; Chang, 2019; Cheimonopoulou *et al.*, 2019a, b; Mogias *et al.*, 2019; Tsai, 2019; Realdon *et al.*, 2019; Mokos *et al.*, 2020b).

In the present study, middle school students from more than 40 coastal and non-coastal locations of eight Mediterranean countries (i.e., Croatia, Cyprus, Egypt, Greece, Italy, Malta, Spain and Turkey) were found to possess a moderate level of ocean sciences content knowledge. These results seem to be in line with studies from other countries worldwide (United States, Canada, Portugal, Japan, Taiwan) focusing on similar school grades (Plankis & Marrero, 2010; Guest *et al.*, 2015; Leitão *et al.*, 2018; Sakurai *et al.*, 2019; Lin *et al.*, 2020).

Learning may be considered to be the comprehension, acceptance, integration of new ideas, and restructuring of existing concepts that influence the ability of learners to acquire new knowledge (Vosniadou, 2002; Goris & Dyrenfurth, 2010). According to Carey (2000), *"the main barrier to learning [...] is not what the student lacks, but what the student has, namely, alternative conceptual*

frameworks for understanding the phenomena covered by the theories we are trying to teach". These alternative frameworks, also called "preconceptions" or "misconceptions", are ideas or insights based on an event or personal experience that are discordant with an accepted scientific point of view (Goris & Dyrenfurth, 2010; Soeharto *et al.*, 2019). They are widespread among students regardless of their education level and the topic in question and represent a physiological pattern of cognitive development and an important factor affecting science and other fields of learning (Carey, 2000; Goris & Dyrenfurth, 2010). Therefore, it is important to determine what are these misconceptions, before acquiring new knowledge in general (Vosniadou, 2013) or in particular in the development of a new curriculum unit (Ben-zvi-Assaraf & Orion, 2005).

In this study, question related to topics such as connectedness of the one ocean, origin of oxygen, and global water cycle, were answered incorrectly by more than 2/3 of the total middle school students. The inability of students to perceive connectedness of ocean basins is most probably a misconception evident in elementary and middle school students of different Mediterranean and other countries (e.g., Italy, Croatia, Greece, Poland), whose geography textbooks highly emphasize the presence of different oceans (Niedoszytko *et al.*, 2018; Mogias *et al.*, 2019; Realdon *et al.*, 2019; Mokos *et al.*, 2020b). However, this was not the case for most of senior high school students within the framework of an international survey (Fauville *et al.*, 2018). Taking the example of the origin of oxygen, it was not attributed to marine photosynthetic organisms according to the students of the present study, which complies with similar misconceptions that emerged among other students in several countries (Phillips, 1991; Leitão *et al.*, 2018; Mogias *et al.*, 2019; Realdon *et al.*, 2019; Mokos *et al.*, 2020b). The majority of students also failed to perceive the global dimension of the water cycle, most probably due to a lack of knowledge on this topic (Ben-zvi Assaraf & Orion, 2005; Mogias *et al.*, 2019; Realdon *et al.*, 2019; Mokos *et al.*, 2020b). Moreover, both issues of ocean connectedness and global water cycle address planetary-scale phenomena far from students' direct experience, thus requiring a level of abstraction not appropriate for these ages (National Research Council, 2006). Regarding the above, it should be highlighted that the misconceptions found in middle school students in the present study are held in common with those observed in primary school students from Italy, Croatia, and Greece (Mogias *et al*., 2019).

Another global issue, about which students of the present study evidenced low knowledge level, is the realization of exhaustible marine resources, namely fish stock, also reported in several studies, reviews, and inventories over the years (e.g., Brody, 1996; Ballantyne, 2004; Feller, 2007). The low number of species found in deep-sea ecosystems was also a topic that most of the students ignored. However, this result is probably due to a lack of knowledge in the corresponding curricula as senior high school students have proved to be more aware of this issue (e.g., Fauville *et al.*, 2018). Furthermore, misconceptions about biodiversity have been reported with reference to other ocean environments (Feller, 2007). Finally, the interesting finding of this study is that middle school students in all the Mediterranean countries under study shared the same misconceptions, regardless of the grade and the different national curricula, and thus enter senior high school with a partial and fragmented comprehension of certain ocean topics.

Apart from knowledge and understanding of ocean sciences issues, an ocean-literate person should be characterized by positive views toward the marine environment, in order to take action regarding environmental problems (Strang *et al.*, 2007). The pattern of positive correlations between knowledge, attitudes, and behaviour toward the marine environment found in this study is generally consistent with previous observations (Boubonari *et al.*, 2013; Hynes *et al.*, 2014; Donert *et al.*, 2015; Gough, 2017). Despite the inadequate level of knowledge, the majority of the students of all countries participating in the study – mostly through individual self-reported actions (behaviour statements presented in Table S3) – represent a biocentric approach of living in harmony with nature (Kahn & Lourenco, 2002). Although knowledge is strongly associated with attitudes (e.g., Pe'er *et al*., 2007), the latter are not always translated into behaviour (Yavetz *et al*., 2009) as other factors (e.g., emotions, values, politico-economic and socio-cultural aspects) are also important in achieving behavioural change (Stoll-Kleemann, 2019). Moreover, didactical interventions, another important factor influencing behavioural change, can provide solid information about how to act (e.g., Klöckner, 2013).

The students' positive attitudes toward the marine environment, even if they are not readily translated into responsible actions for its protection, are important for future citizens who can also influence relevant beliefs and opinions of their families and friends. This finding is most probably attributed to the communication of environmental issues worldwide and to the increasing demand for environmental education, which makes especially young people more aware and concerned about the current environmental crisis (e.g., Dupont & Fauville, 2017; Costa & Caldeira, 2018; Kopke *et al.*, 2019; Lee, 2019; Borja *et al.*, 2020). The majority of students seem to have a positive influence towards the protection of the marine environment though this is mostly through individual rather than collective actions (Tables S2-S4). More specifically, most of the students are too young to participate in non-governmental organizations whose members have more opportunities to act collectively, while an individual cannot take, or is not willing to take actions, due to poor personal skills or financial limits (Hsu & Roth, 1998). These findings probably reflect the common way that environmental issues are addressed by Mediterranean societies, despite their different cultures. They are probably connected to the inefficient implementation of environmental policies and low levels of trust toward institutions along with the perception that the states should be responsible for proper environmental management (Jones, 2010).

Participants' moderate knowledge could be attributed to the fact that ocean sciences constitute a minor part of the primary and secondary education national curricula in the Mediterranean region, as well as in most European countries (Water World Adventure Learning Approach, 2016). The use of the internet as the most popular source of information among students of all studied countries, with a non-constructive and pedagogical approach, seems to further contribute to misinterpretations of relevant information (Mogias *et al*., 2015). However, the results of this study highly support the beneficial effect of students' participation in environmental education programmes in schools, as these students were found to possess a relatively higher level of knowledge along with more positive attitudes and behaviour (see Table S4), though the relevant topics may vary and only a few of them are probably related to the marine environment. The positive impact of activities focusing on the marine environment on the three scales under study (knowledge, attitudes and behaviour) has recently been demonstrated by different authors (Wen & Lu, 2013; Ashley *et al.*, 2019; Cheimonopoulou *et al.*, 2019a, b; Mokos *et al.*, 2020b). Literature reveals that male students generally appear to be more knowledgeable in science content knowledge (e.g., Meinhold & Malkus, 2005; Guest *et al.*, 2015; Martin *et al.*, 2016) than female ones, while the latter seem to have more positive pro-environmental attitudes and behaviour (Eisler *et al.*, 2003; Mokos *et al.*, 2020b). In our study female students surpassed their male counterparts in terms of all three scales in almost all countries. Results relevant to students' gender have been shown in several other studies (e.g., Cheimonopoulou *et al.*, 2019b; Mogias *et al.*, 2019; Lin *et al.*, 2020). On the top of this, fathers' education level seems to have a slightly higher effect on students' knowledge, attitudes and behaviour of our study (see table S4). Despite this observation, there are cases in which mother's or both parents' higher education level favours student performance (e.g., Pe'er *et al.*, 2007; Boubonari *et al.*, 2013) or not (e.g., Tsai, 2019), leading to the assumption that other factors may be of greater importance. Finally, coastal/non-coastal residency seems not to affect students of the present study, though this has not always been the case in the literature (Müderrisoğlu & Altanlar, 2011; Lee, 2019; Mogias *et al.*, 2019; Tsai, 2019; Lin *et al*., 2020).

The United Nations proclaimed the Decade of Ocean Science for Sustainable Development for 2021-2030 to reverse the decline of ocean health and to improve its conservation status. Ocean Literacy is considered to be a cornerstone for achieving the goals and objectives of the Decade. Future research directions on Ocean Literacy should take into account that OL *"is radically evolving from its application in formal educational contexts into an approach for society as a whole"* (UNESCO-IOC, 2021) and that OL itself is an evolving concept. Apart from knowledge, attitudes and behaviour, dimensions such as "awareness", "communication", "activism", "emotions", "access, experience and proximity", social values", "motivations", "trust and transparency" have not sufficiently explored yet (Brennan *et al*., 2019; McKinley & Burdon, 2020). Further information is expected on OL baseline assessment and on the development of standards, indicators, and methods for measuring the impact of Ocean Literacy through the Ocean Decade (UNESCO-IOC, 2021).

Mediterranean national governments and international organisations should support and promote OL and relevant activities across the basin to ensure sustainability of the Mediterranean marine ecosystems, their services, and resources despite the different cultural influences. Towards this direction, some important decisions have already been taken and several efforts have been realized during the past few years on an international level. For instance, the Mediterranean Sea Literacy guide, based on the OL essential principles and fundamental concepts, has been developed for education and outreach purposes (Mokos *et al.*, 2020a) also translated in different languages of Mediterranean region; the Blue Schools network in Europe has been recently launched focusing also on Mediterranean region countries; inter-disciplinary collaborations are enhanced through specific initiatives such as the new EU agenda for the Mediterranean partnership in 2021; projects like the ERASMUS+ concerning blue challenges in schools of the Mediterranean region and networks (e.g., the Mediterranean region Working Group as part of the European Marine Science Educators Association-EMSEA, the European Global Ocean Observing System-EuroGOOS Working Group on Ocean Literacy, the EU4Ocean Coalition) are in progress; students' knowledge, and beliefs in the region are under assessment (e.g., Boubonari *et al.*, 2013; Fauville *et al.*, 2018; Cheimonopoulou *et al.*, 2019a, b; Mogias *et al.*, 2019; Realdon *et al.*, 2019; Mokos *et al.*, 2020b), while the Scope and Sequence of the MSL guide needs to be developed. Furthermore, and on a national level, common synergies should be proposed through close collaboration among schools, universities, research institutes, and education ministries for the support of a) preparation programmes for pre-service teachers; b) implementation of workshops, seminars/webinars for in-service teachers; c) development of educational activities and teaching resources; d) integration of fundamental ocean issues into the national curricula, and e) consequent revision of school textbooks toward a more ocean-friendly content across the Mediterranean countries.

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Supplementary Data

The following supplementary information is available online for the article:

Table S1. Knowledge scale (the correct answers are indicated with bold letters).

Table S2. Mean values (± standard deviation) of the attitudes scale (abbreviations stand for: HR: Croatia, CY: Cyprus, EG: Egypt, GR: Greece, IT: Italy, MT: Malta, ES: Spain, TR: Turkey).

Table S3. Mean values (± standard deviation) of the behaviour scale (abbreviations stand for: HR: Croatia, CY: Cyprus, EG: Egypt, GR: Greece, IT: Italy, MT: Malta, ES: Spain, TR: Turkey).

Table S4. Pearson r correlation coefficients between knowledge, attitudes, and behaviour and background factors effect on them (e.g., t-test, one-way ANOVA) (abbreviations stand for: HR: Croatia, CY: Cyprus, EG: Egypt, GR: Greece, IT: Italy, MT: Malta, ES: Spain, TR: Turkey, ns: non-significant difference).