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DISCOVERING THE SEA: AN ANALYSIS OF OCEAN AND POLAR LITERACY
Descubriendo el mar: análisis de los niveles de alfabetización oceánica y polar en una muestra de estudiantes universitarios

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ABSTRACT

Keywords:
Ocean and Polar literacy, SDG, Environmental Education, Socio-environmental Perception Spanish-speaking Population.

Ocean and Polar Literacy is the level of knowledge, awareness, and perception an individual has of these ecosystems. A high level of ocean and polar literacy allows for the transversal modification of behaviours across present and future generations through the development of critical thinking, promoting sustainable decision-making by. Ocean and polar literacy is therefore a fundamental tool for addressing the current environmental crisis. Nevertheless, there is limited existing evidence to diagnose the degree of ocean and polar literacy within communities, particularly in Spanish-speaking regions.

With the objective of assessing the degree of Ocean and Polar Literacy (knowledge, awareness, and socio-environmental perception), a pilot questionnaire was designed, consisting of 45 questions organized into five blocks. The instrument was constructed based on the adaptation and translation of validated questions from previous studies, complemented with newly developed questions. This tool was applied to a sample of university students in Spain and Latin America (n=273).

We observed that students pursuing studies related to geology have a better Ocean Literacy, highlighting the need to reinforce geology in the mandatory education curriculum. Better polar literacy was observed among respondents from Spain compared to those from Latin America. Contrary to expectations, no significant differences in ocean and polar literacy were found between those who have lived in coastal cities and those who have not. Despite these shortcomings, an encouraging finding is the great interest the surveyed population showed toward marine and polar ecosystems.

RESUMEN

Palabras clave:
Cultura Oceánica y Polar, ODS, Educación ambiental, Percepción Socioambiental, Población Hispanohablante.

La Alfabetización Oceánica y Polar (*Ocean* and *Polar literacy*) es el nivel de conocimiento, sensibilización y percepción que tiene una persona frente estos ecosistemas. Una buena alfabetización oceánica y polar permite modificar transversalmente las conductas de generaciones presentes y futuras, a través del desarrollo de un pensamiento crítico, promoviendo la toma de decisiones sostenibles por parte de los ciudadanos. La alfabetización oceánica y polar, es por tanto una herramienta fundamental para lidiar con la crisis ambiental actual. No obstante, son pocas las evidencias que existen para diagnosticar el grado de alfabetización oceánica y polar de las comunidades, en particular de aquellas de habla hispana.

Con el objetivo de evaluar el grado de alfabetización oceánica y polar (conocimiento, sensibilización y percepción socioambiental), se diseñó un cuestionario piloto que consta de 45 preguntas organizadas en cinco bloques. El instrumento se construyó a partir de la adaptación y traducción de preguntas validadas en estudios previos, complementado con preguntas de elaboración propia. Esta herramienta fue aplicada a una muestra de estudiantes universitarios de España y Latinoamérica (n=273).

Observamos que las personas que cursan estudios relacionados con la geología tienen una mejor alfabetización oceánica, destacando la necesidad de reforzar la geología en el currículo de educación obligatoria. Se observó una mejor alfabetización polar en los encuestados procedentes de España respecto a los de Latinoamérica. Contrario a lo esperado, no se encontraron diferencias significativas en el nivel de alfabetización oceánica y polar entre los que han vivido en zonas costeras y quienes no. A pesar de estas carencias, un hallazgo alentador es el gran interés que la población encuestada mostró hacia los ecosistemas marinos y polares.

Introduction

The Earth is the only planet in the solar system whose pressure and temperature conditions allow the existence of up to 70% liquid water on the surface. Of this water, 97% is found in the oceans, which gives them a determining role in the regulation of the earth's climate, storing large amounts of excess solar radiation in the form of latent heat and acting as the largest long-term CO^2 sink (Sabine et al., 2004). Thanks to the action of the ocean biosphere, the ocean contributes to the regulation of the chemical composition of the atmosphere, releasing approximately 50% of the oxygen we breathe, and sequestering 40% of atmospheric CO^2 emitted by human activity (Field et al., 1998; Falkowski, 2012; Sabine et al., 2004).

In economic terms, the ocean is a crucial resource for the development of activities such as fishing, tourism, trade, energy generation, and international transportation. Fifteen percent of the protein we consume comes from ocean fisheries and is the most traded natural product in the world (FAO, 2020). Additionally, more than 40% of the world's population lives in areas within 200 km of ocean and 12 out of 15 megacities are coastal (Visbeck, 2018). The global ocean economy is estimated to move about €1.38 trillion and is expected to increase to €2.7 trillion by 2030 (Sumalia et al., 2021). Unfortunately, rapid human population growth and industrial development are putting increasing pressure on marine ecosystems, degrading their productivity and biodiversity.

Polar regions are regions with permanent ice, which are fundamental in the earth's energy balance due to their high albedo index, which reduces the net energy input that reaches the earth's surface through solar radiation. In addition, they are ecologically stable areas that have developed high biodiversity and complex food webs (Gili et al., 2000). The ice caps have changed throughout the Earth's history as a function of the variation of the Earth's orbit and the amount of solar radiation received. Currently, the North Pole experiences very strong seasonal variations, which increase the ice surface of the ice floe by up to 6 times during the boreal winter compared to the summer. In contrast, seasonal changes at the South Pole are not as drastic, so Antarctica is always covered with snow, and only the surrounding ice floe varies seasonally in extent. Consequently, at present, seasonal variations at the north pole have a greater influence on the climate system (Ruddiman, 2001).

Despite their importance, both the oceans and the polar regions are suffering strong alterations as a result of intense human activity, including processes such as acidification of waters following high CO_2 emissions, loss of marine biodiversity due to overfishing of resources, eutrophication of coastal margins due to inadequate management of organic waste, or pollution due to increased microplastics (Pörtner et al., 2019). The case of the poles is particularly worrisome, because despite representing remote places for most of the population, the expansion of tourism, hydrocarbon extraction, and increased fishing have increased the environmental impact on these regions. Likewise, their natural wealth has led to increasing geopolitical tension over these regions in recent years (Seethi, 2023).

UNESCO defines *Ocean Literacy* as a person's understanding of the impact the ocean has on his or her life and the impact he or she has on the ocean. In addition, the *Polar Literacy Initiative* defines *Polar Literacy* as an understanding of the fundamental concepts of the Arctic and Antarctic, their essential role in regulating the global climate system, and the connection of their ecosystems to the rest of the world, which empowers the individual to make informed decisions about these critical environments. So far, these concepts have been treated independently in the literature and their integration into a joint framework is not yet sufficiently developed. This paper proposes the notion of “oceanic and polar literacy” as a conceptual approach that allows for an integrated analysis of the understanding of marine and polar ecosystems. Therefore, Ocean and Polar Literacy would be defined as a person's level of knowledge and perception of these ecosystems and understanding of the influence of the ocean

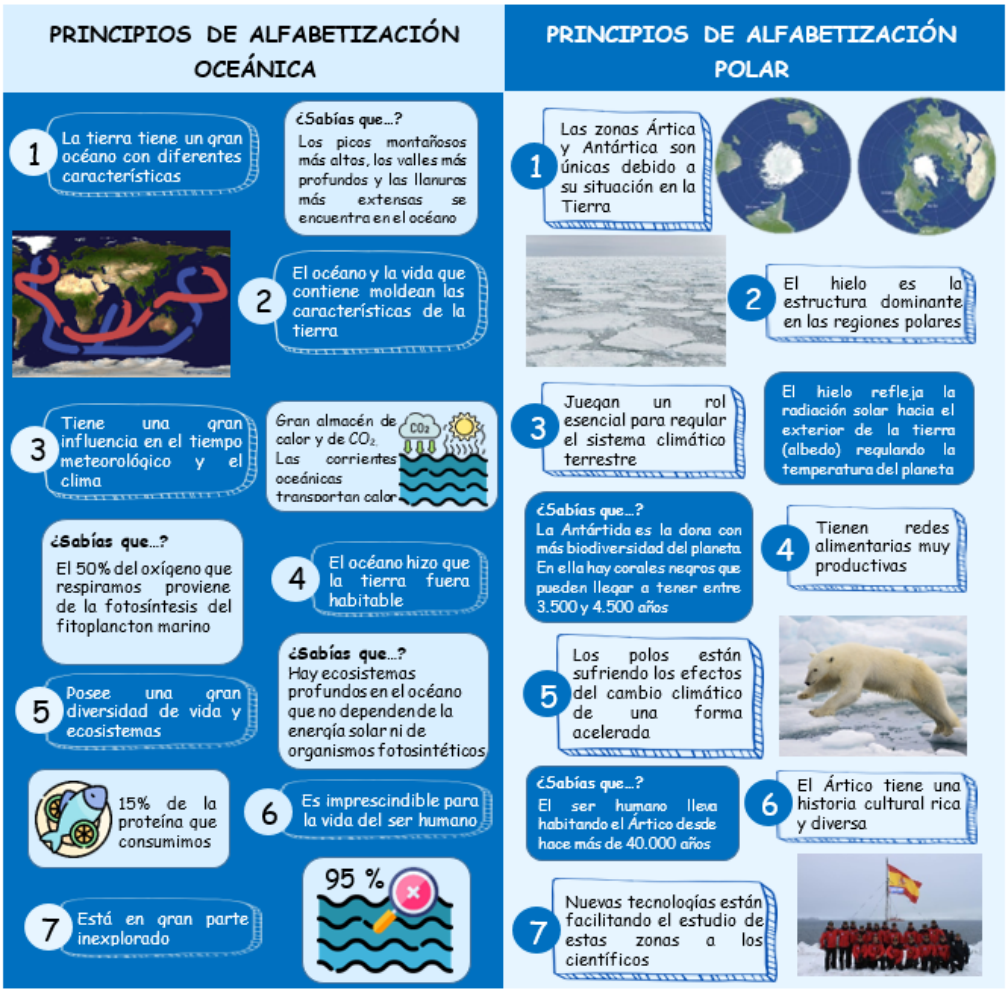
and polar regions on society and vice versa (McKinley et al., 2025; Borja et al., 2020; Schoedinger et al., 2006; Kelly et al., 2021). Adequate literacy implies awareness, sensitization and motivation to make more environmentally sustainable decisions (Cava et al., 2005), making it an essential tool for dealing with the environmental crisis, reducing the impact on oceanic and polar ecosystems.

The term Ocean Literacy was first used in 2002 by educators, researchers and policy makers belonging to the U.S. Ocean Policy Commission, who identified a total lack of public awareness of the relevance of marine and polar ecosystems (Cava et al., 2005). This problem was related, among other causes, to the absence of curricular content that appropriately addressed these issues during secondary education. Therefore, they proposed to develop a theoretical framework for education -Ocean Literacy- in order to help the next generations adopt more responsible and sustainable attitudes towards these environments, thus contributing to reducing the climate crisis.

Similar strategies and efforts to increase ocean and polar literacy have been followed by various countries and organizations (Fauville, 2018). In 2015, UNESCO consolidated the Education 2030 Agenda in which it proposed 17 Sustainable Development Goals (SDGs). In particular, Goal 4 reflects the importance of the educational response not only as a goal, but also as a means to achieve the other SDGs, and Goal 14 calls for the protection of underwater life. In Spain, the National Center for Environmental Education (CENEAM), a reference entity in education for sustainability belonging to the Ministry for Ecological Transition and Demographic Challenge, developed 7 key principles for ocean literacy proposed by Chicote and Pujana (2016) and Santoro et al. (2017), and the community of polar scientists and educators known as Polar-ICE developed 7 principles for polar literacy (polar-ice.org/polar-literacy-initiative/). These principles are summarized in Figure 1.

Figure 1

Summary of the 7 principles of ocean and polar literacy, developed by Chicote and Pujana (2016) and *Santoro et al. (2017), in Spain and the Polar-ICE group, respectively*



People's lack of knowledge about the consequences of their actions on the environment is one of the main factors that have a negative impact on biodiversity and ecosystems. Therefore, it is essential to develop communication, outreach and education initiatives that help the population to (i) know and understand the influence of the ocean and the poles on their lives, (ii) increase awareness of the climatic, economic, political, medical and cultural importance of these environments, (iii) sensitize communities to make more responsible and sustainable decisions regarding the use of these critical ecosystems, (iv) connect different sectors of society to create a common ground that allows a joint understanding and approach to the complexity of achieving a more sustainable society (Santoro et al., 2017; Fauville, 2018). However, in order to develop these communicative, informative and educational strategies, it is first essential to analyze the population's knowledge of these ecosystems and identify which areas of their knowledge about these media require further reinforcement. Most previous studies assessing oceanic and polar literacy have focused primarily on the United States, Canada, and Italy (e.g., Costa and Cadeira, 2018; Realdon et al., 2019; Ashley et al., 2019). Unfortunately, such studies are still scarce in Spanish-speaking countries, which represent 5.91% of the world's population (about 473 million people; The World Bank, 2024).

The study of ocean and polar literacy in the university population is particularly relevant, as most students have recently completed compulsory education. Analyzing their knowledge of oceanic and polar ecosystems allows us to identify possible shortcomings that should have been addressed in previous educational phases. In addition, several studies (e.g., González-Rodríguez, 2024) point out that the university is an ideal context to promote socio-environmental literacy and strengthen students' engagement with global challenges related to

oceans and climate. These learnings are essential for our society, since university students represent a key community in the generation of critical thinking, innovation and social leadership in the face of contemporary environmental challenges. Fostering in them a deep and responsible understanding of the oceanic and polar systems contributes to the development of citizens capable of promoting sustainable actions and actively participating in decision making aimed at protecting the planet. In response to these needs, the present work has three main objectives. To develop a pilot questionnaire for the measurement of oceanic and polar literacy in a sample of Spanish-speaking university population, through the collection, translation and adaptation of questions validated in the scientific literature, complementing the instrument with self-developed items. Second, to analyze oceanic and polar literacy levels in relation to educational and sociodemographic variables such as area of study, academic level, region of origin, age and time spent living in coastal areas. Finally, identify the thematic areas with lower levels of knowledge and awareness in order to guide reinforcement strategies in secondary education and foster greater understanding and awareness of these ecosystems.

Method

An anonymous pilot survey was conducted using the Qualtrics platform (https://www.qualtrics.com/) to assess the level of ocean and polar literacy of a sample of undergraduate, master's and doctoral students from Spain and several Latin American countries, mainly Argentina, Peru and Colombia. The designed pilot survey was available online from April 10 to April 30, 2024.

The questionnaire was developed from a combination of sources: questions taken and translated from previous studies that have proven useful for assessing ocean or polar literacy, modified questions, and self-developed material. Specifically, for ocean literacy, most of the content was adapted and translated from Guest et al. (2015) and, to a lesser extent, from Koulouri et al. (2022). For polar literacy, most of the questions are self-developed due to the scarcity of available evaluation studies. However, to measure awareness and socio-environmental perception of the polar ecosystem, questions were adapted from Hamilton et al. (2008). Tables 3, 4 and 5 specify, next to each item, the article from which it was taken or modified; the questions without reference are self-referenced.

Structure of the Survey

The survey consisted of 45 questions distributed in five thematic blocks (see Annex I), designed to collect information in a progressive and coherent manner with the objectives of the study:

- Block 0. Introduction and consent

This first block presented a brief explanation of the purpose and operation of the survey. In addition, it requested the informed consent of the participant to ensure their voluntary participation and verified that they were at least 18 years old, the legal age of majority in Spain.

- Block 1. Sociodemographic profile and self-perception

Consisting of 14 questions, the purpose of this block was to anonymously define the profile of the participants. Questions related to age, city of origin and residence, years lived in coastal areas, educational level and studies completed were included. Respondents were also asked to rate, on a scale of 0 to 5, how much they thought they knew about various topics: international

politics, economics, science and technology, climate change, oceans, and polar regions (north and south).

- Block 2. Ocean Literacy (Ocean Knowledge)

This block consisted of 12 questions aimed at assessing the level of knowledge about ocean ecosystems. Each correct answer was valued with 1 point, so that the total score of each participant could range from 0 to 12 points.

- Block 3. Polar Literacy (Polar Knowledge)

Composed of 6 questions, this block had the purpose of measuring the degree of knowledge about polar ecosystems. As in the previous block, each correct answer was equivalent to 1 point, with a possible final score between 0 and 6 points.

- Block 4. Awareness and socio-environmental perception

Finally, this block included 8 questions aimed at ascertaining the level of awareness and socio-environmental perception of respondents with respect to oceanic and polar ecosystems, as well as their attitudes towards global environmental challenges

Statistical Treatment of Data

From the answers to the questions in Blocks 2 and 3, a score of *Ocean knowledge* and *Polar Knowledge*was obtained for each respondent, respectively. For each question, the existence or not of a normal distribution was determined using the Shapiro test, and the presence of significant differences between the means of different population groups was evaluated using the Spearman or Krustall-Wallis test, depending on the type of question. The analyses were performed in the R program (R Core Team, 2024) and the results were plotted with SPSS software.

Sampling Method

The sampling method used was by convenience, and the selection could not be completely random due to the impossibility of exhaustively accessing all the universities. A dissemination and open invitation to participate was made, mainly to universities in Spain, Argentina, Peru and Colombia. Responses were therefore voluntary among those who chose to participate. To mitigate the limitations of this sampling, respondents were separated into groups according to key variables such as the type of studies they have completed, whether they have lived more than 50% of their life in a coastal city and their place of origin (Spain or Latin America), thus allowing an analysis of the relationships between these variables and knowledge.

A total of 460 survey responses were received, but responses from those who did not sign the initial consent form or did not complete the survey were discarded. Likewise, the responses of those who did not fall into the category of university student, those who did not specify the area of study (subject of the bachelor's, master's or doctoral program), and those who did not indicate their country of origin were discarded. After applying these exclusion criteria, the initial sample of 460 people was reduced to 273. The target population of the study, Spanish-speaking university students, is estimated at 12.7 million enrolled in 2024 (Instituto Cervantes, 2024). Therefore, for a sample of this population to be statistically representative, a sample size of 385 people is required for a confidence level of 95% with a margin of error of ±5% (Hernández Sampieri et al., 2014). Since the number of useful responses did not reach this threshold, the sample of this study cannot be considered statistically representative. Therefore,

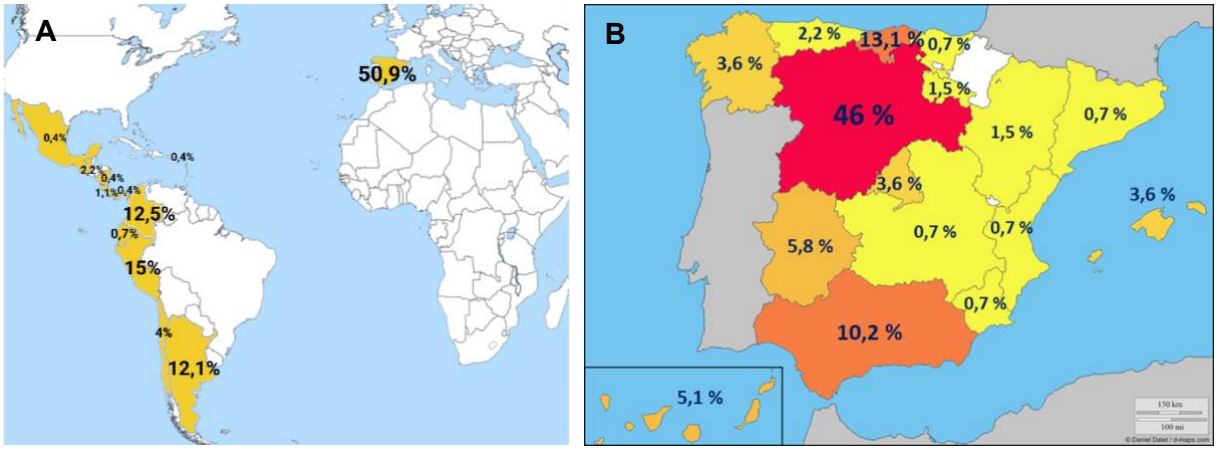
the results obtained cannot be extrapolated to the total Spanish-speaking university population. Nevertheless, this work constitutes a valuable first approach to extrapolate perceptions and knowledge levels in this population, serving as a pilot study to lay the groundwork for future research with a larger sampling effort.

Sample

Respondents came from 12 different Spanish-speaking countries (Figure 2), including Spain (50.9% of respondents), Peru (15%), Colombia (12.5%), Argentina (12.1%), Chile (4%), Guatemala (2.2%), Costa Rica (1.1%), Ecuador (0.7%), Mexico (0.4%), Nicaragua (0.4%), Panama (0.4%) and Puerto Rico (0.4%). Of the Spanish respondents to the survey, the majority (46%) were from Castilla y León. The majority of respondents are between 18 and 25 years old (60.1% of respondents), 28.9% are between 36 and 40 years old and 11% are between 40 and 100 years old.

Figure 2

A) Composition of the sample population studied according to their country of origin. B) Composition of the Spanish sample according to the autonomous community of origin.



Note. The color code refers to the percentage of respondents corresponding to each autonomous community (yellow < 2.5%; orange 2.5-10%; dark yellow 10-20%; red > 20%).

Although an effort was made to obtain relatively similar sample sizes among all Spanish-speaking countries, the sampling achieved is not uniform across countries. However, all of the subgroups discussed below (other than the country of origin) are sampled uniformly.

As shown in Table 1, the sample is mostly composed of Biology students (63.8%), coming from non-coastal regions (53.1%). In terms of geographical origin, the representation between Spain (50.9%) and Latin America (49.1%) is balanced, allowing a comparative analysis between the two contexts. Table 2 shows that the majority of participants are in the 18-25 age range (60.1 %), reflecting a young university population, followed by the 36-40 age group (28.9 %).

Table 1

Composition of the different established population groups

Sample composition										
Studies	**N**	**%**	**Bio vs Geo**			**Proximity to the coast**	**N**	**%**	**Region**	**N**	**%**
BioGeo	152	55,6	Biology	97 N	63,8 %	Coastal	128	46,9	Spain	139	50,9
			Geology	55 N	36,2 %						
Others	121	44,3				Non-coastal	145	53,1	Latin America	134	49,1

Table 2
Age of participants

Sample age		
Age range	**N**	**%**
18-25	164	60,1
36-40	79	28,9
40-100	30	11

Results

The results presented below provide a detailed view of the oceanic and polar literacy level of the surveyed university population. To ensure clarity and rigor in the analysis, the data are organized according to the thematic areas of the questions and under the heading of "ocean and polar literacy: Strengths and Weaknesses in Knowledge" shows the oceanic and polar literacy assessment of the sample.

Thematic Areas

The questions in the questionnaire were classified into different thematic areas according to their relationship with biological (marked in green in Table 3), geological (in red) and geographical (in purple) concepts. This classification makes it possible to identify with greater precision the areas of knowledge in which the surveyed university population presents greater strengths or weaknesses. As shown in Table 3, the results show that students are more familiar with the contents related to ocean biodiversity, reaching an average of 93.23% correct answers. On the other hand, items related to biochemical, physical and chemical processes, such as oxygen and carbon dioxide balance, the hydrological cycle or the chemical composition of seawater, show considerably lower percentages of correct answers (42.49%). Similarly, the geological questions, which deal with aspects such as the origin of the rocks that form the mountains or the basic characteristics of the polar regions, obtain low scores (42.71%), showing a lower mastery of these contents.

Oceanic and Polar Literacy: Strengths and Weaknesses in Knowledge

Table 3 shows the questions from the Guest questionnaire that assess ocean and polar literacy, as well as the percentage of respondents who answered each question correctly.

Table 3

Questions used to assess ocean and polar literacy.

QUESTIONS	% correct answers	
Ocean literacy		**Associated principle**
1. The oceans occupy 70 % of the planet's surface (Guest et al., 2015)	95,97%	1
2. Oceans absorb more CO_2 from the atmosphere than inland terrestrial plants (Modified from Guest et al., 2015)	71,06%	3
3. Marine microorganisms contribute more oxygen to the atmosphere than terrestrial plants	13,92%	4
4. More and more tsunamis will occur due to climate change	33,33%	
5. The majority of living beings that live in the oceans are fish	84,62%	5
6. In the deepest part of the ocean there is no life because no light reaches it (Modified from Koulouri et al., 2022)	93,77%	5
7. How deep is the deepest area on the planet? (Guest et al., 2015)	66,67%	1
8. Most of the rainwater that falls on the continent comes from: (Koulouri et al., 2022)	33,70%	3
9. The salt in the oceans comes from: (Guest et al., 2015)	27,47%	1
10. A whale is: (Guest et al., 2015)	97,44%	5
11. What is plankton? (Modified from Guest et al., 2015)	97,07%	5
12. If you find marine fossils in the rocks of a mountain, it means (Modified from Koulouri et al., 2022)	52,38%	2
Polar literacy		**Associated principle**
1. The North Pole is an ice sheet floating in the Arctic Ocean	61,9%	2
2. The melting of the North Pole will not affect Spain's climate because it is quite far away	91,21%	3
3. In the Arctic there are indigenous populations living	61,90%	6
4. Antarctica is an ice sheet floating in the ocean	64,84%	1
5. At the South Pole it is always night	78,02%	1
6. There is almost no aquatic life in the Arctic and Antarctic oceans due to extreme temperatures	83,52%	4

Note. The colors refer to the subject area of each question. The green ones evaluate biological concepts, the red ones geological and the purple ones geographical. Each question has been associated with an oceanic and polar literacy principle.

Ocean Literacy: In relation to the results presented in Table 3, and specifically with the items related to ocean literacy, it can be seen that the vast majority of respondents demonstrate adequate knowledge of basic biological aspects of the marine environment: 97.4% correctly identify that a whale is a mammal, and 97.07% understand the meaning of the term plankton. The students demonstrated a good level of knowledge regarding principle number 1 ("The earth has a large ocean with different characteristics") as 95.97% are aware of the large dimensions that the oceans occupy on our planet. Similar results were observed in other studies (Camargo, 2023). However, only 13.92% know that the oxygen that marine organisms contribute to the atmosphere is similar to that of terrestrial plants. It is also worth noting that only 27.47% know where the salt in the oceans comes from and only 33.7% know where the continent's rainwater comes from. Analysis of the results reveals that the university students surveyed have a greater knowledge of marine biodiversity than of the physical, chemical and

geological processes of the ocean. In a study conducted by Camargo (2023) in Colombia, they used a survey in which they included similar questions and students had the lowest values in the question about where most of the oxygen in the atmosphere originally came from (only 16 points out of 123) and in the question about the origin of salt in the ocean (22 points out of 123). This suggests that the data from this study are consistent with previous findings regarding knowledge deficiencies in these specific areas in Spanish-speaking countries.

71.06% of respondents are aware of the ocean's important role as a CO_2 sink. However, only 66.67% are aware of how deep the ocean can be. It is worth noting that only 52.38% are aware that part of the rocks that form continental mountains originate in the oceans, and that later, due to tectonics, after millions of years, they can be found in the mountains, sometimes finding marine fossils inside them.

As for the question referring to a tsunami, it is noteworthy that only 33.33% of the respondents answered correctly. A tsunami is mostly caused by an earthquake that takes place under the sea, without any causal relationship with the weather. It is interesting to find that there is a growing tendency in the general population to think that catastrophic events such as volcanic eruptions and earthquakes will increase due to climate change and they are unaware that considering these are not conditioned by the climate, but by the processes occurring in the interior of the Earth. This lack of knowledge is evidence of a generalized lack of training in geology throughout the secondary education process.

Polar literacy: In general, respondents scored better than for ocean literacy, although they seem to have a geographical lack of knowledge of the polar areas. 38.1% consider that all the ice at the North Pole is continental and 35.16% are not aware that the ice at the South Pole is mostly continental and their conception of Antarctica is that of an ice floe floating on the Antarctic Ocean. 91.21% are aware that the melting of the poles will have consequences throughout the world, even in the areas farthest from them, 83.52% know that Antarctica, despite being one of the places with the most extreme climate, harbors life in its waters. Finally, 78.02% recognize how seasonality works at the poles.

Study Area

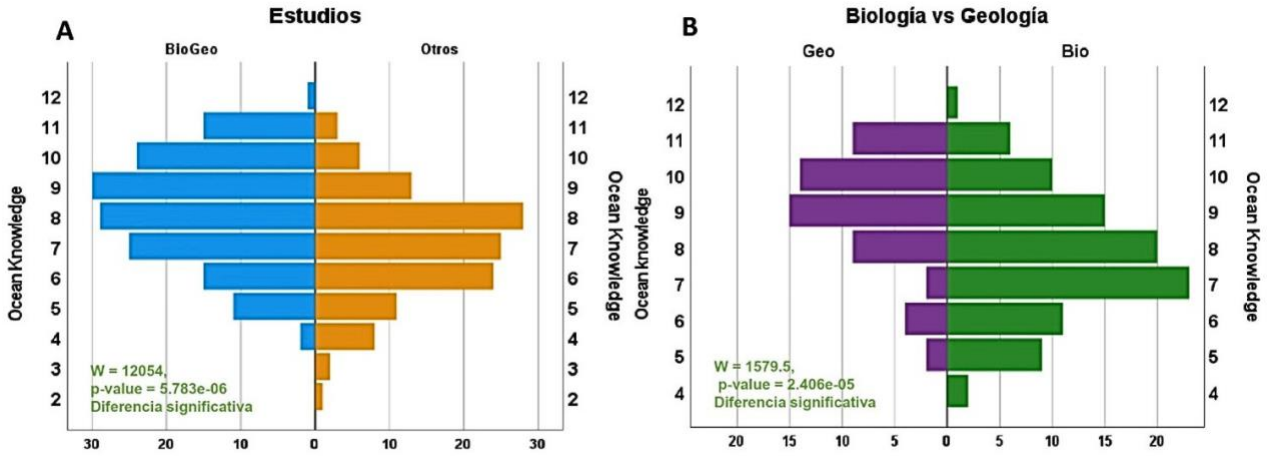
Respondents were divided into the "BioGeo" group, consisting of those studying disciplines related to biology and geology (bachelor's or master's degree in geology, biology, biochemistry, biotechnology and environmental sciences); and the "Other" group, which includes students from other disciplines. A total of 55.6% of the respondents belonged to the "BioGeo" group and 44.3% to the "Others" group (Table 1). This separation was made considering that biology and geology students should have more knowledge about the oceans and poles as these are topics specific to these disciplines. The "BioGeo" group was subdivided into those studying biology (and related subjects) and those studying geology (and related subjects). The "Biology" group constitutes 63.8% of the "BioGeo" group and the "Geology" group 36.2%.

Analysis of the results revealed a clear correlation between the area of study and the *Ocean knowledge* of the respondents. As expected, students in the "BioGeo" group showed higher *Ocean Knowledge* than those in the "Others" group (Figures 3A and 3B). However, the examination of the "Geology" subgroup with respect to the "Biology" subgroup shows a result of great relevance: the "Geology" students exhibited superior *Ocean Knowledge* . In addition, in the overall percentages of correct scores, regardless of the area of study, there are significant deficiencies in basic geological concepts. This problem seems to occur in both Spanish and Latin American schools, because geology is often overshadowed by biology, which receives much

more attention in the didactic programs. The observed results support the notion that there is a significant shortage of attractive and accessible educational resources for teaching geology, and that teachers themselves lack solid training in this subject (García-Yelo et al., 2022). This situation suggests a promising avenue for enhancing ocean literacy in the general population.

Figure 3

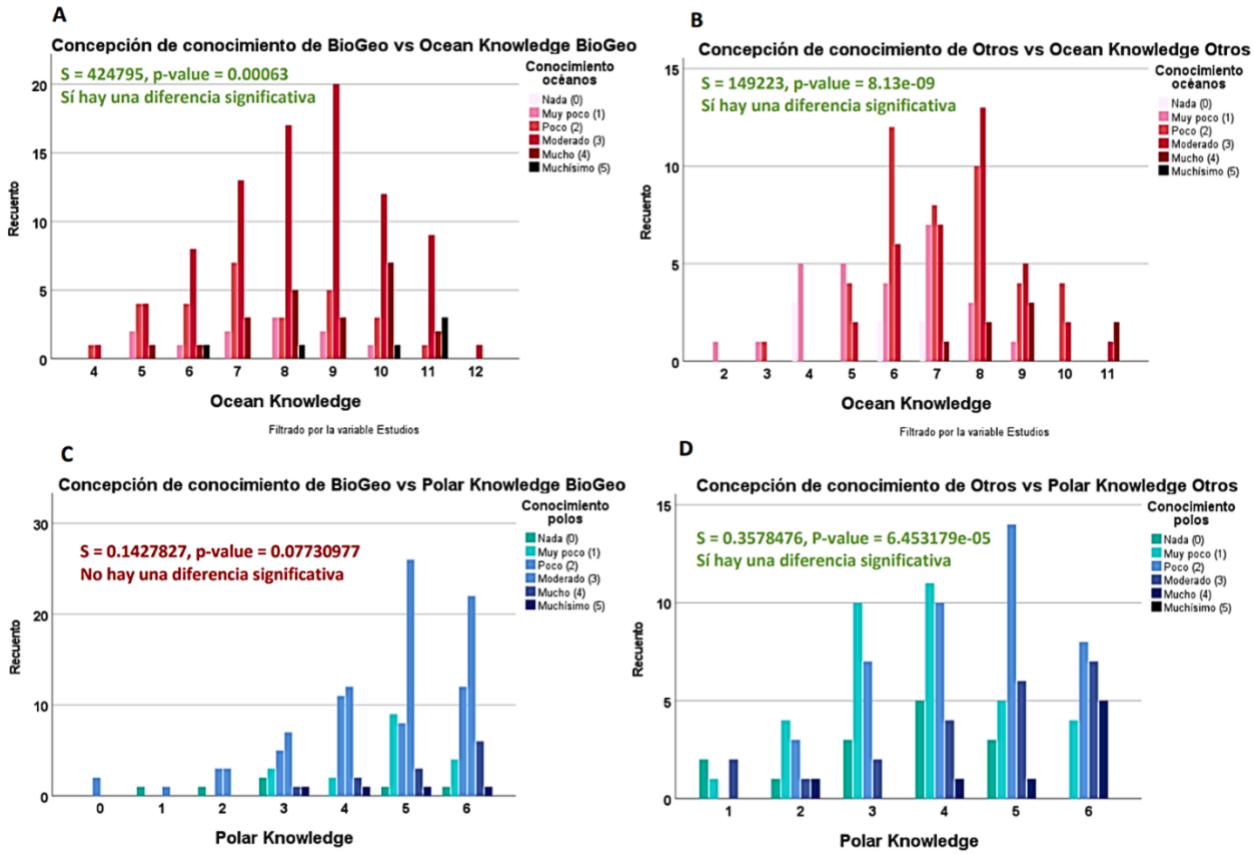
A) Ocean Knowledge score from 0 to 12 of people belonging to the "BioGeo" group (blue color) with respect to the members of the "Others" group (orange). B) Ocean Knowledge of respondents who are pursuing university studies in geology (purple color) compared to those studying biology (green color).



Differences in self-perceived knowledge about the oceans between the "BioGeo" and "Other" groups were evaluated, which allows us to know if each group's self-perceived knowledge about oceans and poles is consistent with the level of knowledge they have demonstrated in the survey. In general, members of the "BioGeo" group tend to report a higher level of prior knowledge about ocean issues compared to the "Other" group, suggesting a relationship between their academic or professional background and their confidence in this area. Figures 4A and 4B show the *Ocean Knowledge* of respondents belonging to the "BioGeo" and "Other" groups, respectively, and the color scale indicates the knowledge they previously believed they had about the oceans. Similarly, Figures 4C and 4D show the self-perceived knowledge for the *Polar Knowledge* of "BioGeo" and "Others" respectively. Similar trend is observed, with the "BioGeo" group showing a higher self-perception of knowledge compared to the "Others" group. This difference could be associated with the degree of previous exposure or familiarity with content related to polar regions. However, this is not the case for the "Others" group. This group has a lower perception of their knowledge of these ecosystems than they have demonstrated, i.e., they believe they know less than they actually do. Overall, the data indicate that the educational profile of the respondents influences their perception of their own level of knowledge of oceanographic and polar issues.

Figure 4

A) Ocean Knowledge of the "BioGeo" group regarding their conception of their knowledge about the oceans; B) Ocean Knowledge of the "Others" group regarding their conception of their knowledge about the oceans; C) Polar Knowledge of the "BioGeo" group regarding their conception of their knowledge about the poles; D) Polar Knowledge of the "Others" group regarding their conception of their knowledge about the poles.



Age Range (in Covariance by Branch of Study)

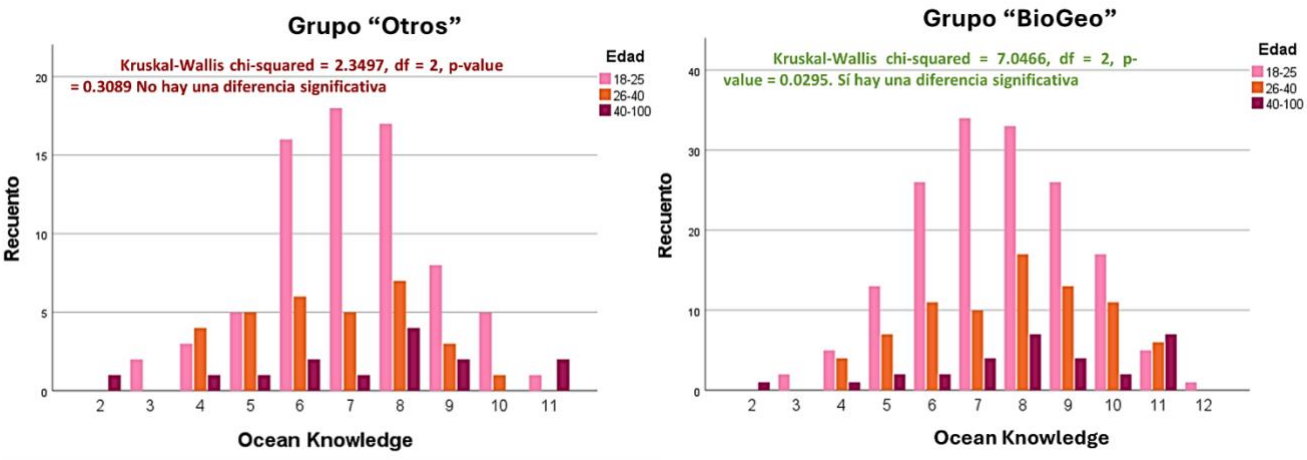
The objective of this subgroup is to assess whether there are differences in the knowledge and perception of the ocean and the poles as a function of the age of the participants. For this purpose, respondents were divided into three age ranges (Fig. 4): 18 to 25 years old (60.1% of the sample), 36 to 40 years old (28.9%) and 41 to 100 years old (11%).

Comparing the scores obtained as a function of age, no direct relationship was observed between age and Ocean or *Polar Knowledge*. However, analyzing the responses according to the age group of the respondents, it can be seen how for the "BioGeo" group both Ocean (Figure 5B) and *Polar Knowledge* have a direct relationship with age according to the Kruskal-Wallis analysis performed. As respondents have been studying these disciplines for longer, they become more ocean and polar literate. However, for the "Others" group, no relationship with age was observed (Figure 5A). Within this group, the respondents with the highest scores are those between the ages of 18 and 25. Specifically, it refers to the population group that has most recently completed compulsory secondary education. However, the score for the rest of the age groups is much lower. This highlights that in the general population there is only an age window during the secondary education stage in which the population acquires knowledge about the

ocean, poles and climate change and this knowledge does not increase with age. The same phenomenon was also observed for *Polar Knowledge*.

Figure 5

Respondents classified by age group. Those between 18 and 25 years of age are shown in pink; those between 26 and 40 years of age are shown in orange; those over 41 years of age are shown in red.



Living Time in a Coastal City

This classification is made considering whether the respondent has lived more than 50% of his or her life in a coastal city. This subgroup sought to assess whether there really is a greater knowledge and/or awareness of the ocean in the populations of coastal regions. However, after evaluating the means by group, no significant differences were found, indicating the apparent irrelevance of this variable.

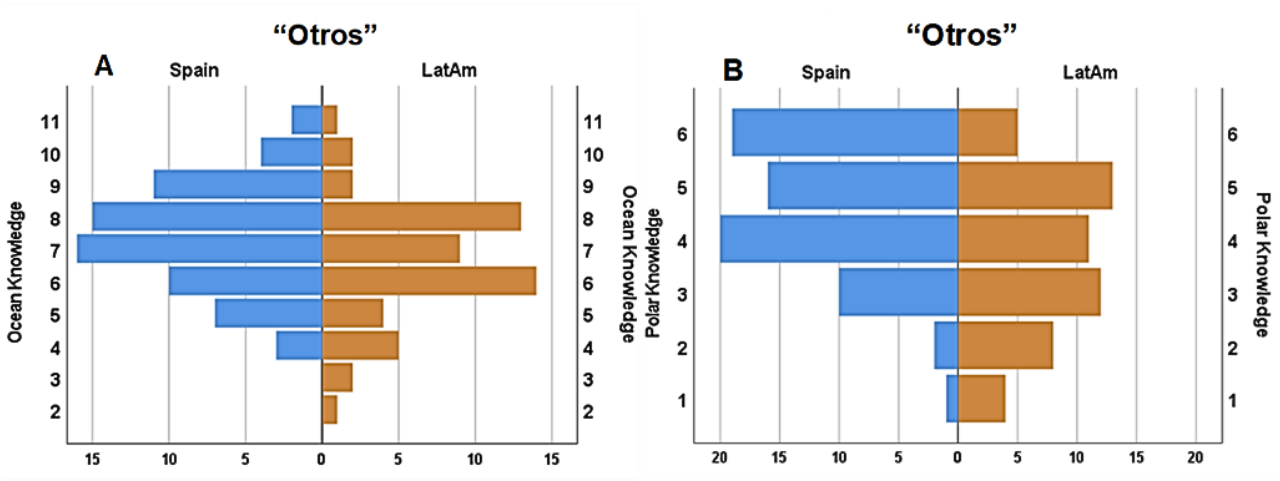
Origin (Spain or Latin America)

The survey was disseminated to different universities in Spain and Latin America. After analyzing whether there is any difference between the *Ocean* and *Polar Knowledge* of the Spanish respondents ("Spain" group) with respect to the group of people from Latin America ("LatAm" group), no significant differences were observed between groups. However, when evaluating the covariance between place of origin and the area of study of the respondent, it is observed that for the respondents of the "BioGeo" group, there is no significant difference in their *Ocean* and *Polar Knowledge* depending on whether they belong to the "Spain" or "LatAm" group. This implies that *Ocean* and *Polar Knowledge* is superior regardless of the place of origin. On the contrary, in the "Others" group, there is a significant difference between the *Ocean* and *Polar Knowledge* of students from Spain with respect to those from Latin America (Figure 6A and 6B). The former scored higher in both *Ocean Knowledge* and *Polar Knowledge*. This seems to reflect that the general university population in Latin America has lower oceanic and polar literacy than their peers in Spain. In the context of Latin America, despite countries such as Colombia that have a large coastal extension in the Sea, the progress of ocean literacy has not

been as expected since compulsory education curricula have excluded ocean topics (Mogias et al., 2019).

Figure 6

A) Ocean Knowledge score from 0 to 12 of university students belonging to the "Others" study group surveyed in Spain (blue) compared to those in Latin America (brown). B) Score from 0 to 6 of the Polar Knowledge of both groups.



Awareness and Socio-Environmental Perception

The assessment of ocean and polar literacy of a population sample is not only to assess knowledge about these ecosystems (i.e., *Ocean* and *Polar Knowledge*), but also to consider and assess the attitude, behavior and awareness of the respondents with respect to these ecosystems.

In this sense, the questions in Block 4 (Tables 4 and 5) focused on evaluating these aspects. Overall, it seems that most respondents are aware that the ocean plays an important role in their lives (63.97%) and 51.1% would be interested in knowing much more about it. Most of them seem to be aware of climate change since 85.66% responded that they did not consider that the climate crisis was being exaggerated. As for the factors on which humans depend mainly on the oceans, the most voted were "Food" with 28.49%, "Climate Regulation" with 26.34% and "Source of Oxygen" with 21.68%. These values suggest that the surveyed university population is aware of the large role the ocean plays in our lives.

The questions "In what year is the extinction of polar bears expected?" and "The ice at the North Pole will be completely thawed" are intended to assess the level of alarmism of the surveyed population regarding these two phenomena closely related to climate change (i.e., loss of biodiversity and sea level changes). For the bear response, 54.41% answered "I don't know", and for the statement on the melting of the North Pole, the responses were almost 50% affirmative and negative. Although there is a slight predominance of affirmative responses, it can be concluded that there is no alarmism. However, it is noteworthy that when the results are considered with respect to the "studies" variable, people in the "BioGeo" group (58.28%) show a somewhat more alarmist view of the melting of the North Pole than those in the "Others" group (48.33%). This increased alarmism and awareness could be linked to the greater oceanic and polar knowledge (*Ocean* and *Polar Knowledge*) demonstrated by this group in the survey.

Finally, the question "Would you support Antarctica being reserved for:" is intended to show respondents' awareness of this place. Considering that greater awareness implies responding that they would support reserving Antarctica for "none of these purposes" and/or for "scientific purposes only", when analyzing the responses according to the "studies" variable, we find that both the "BioGeo" and "Other" groups are sensitized to this place. A 77.5% of the "Others" group said that they would reserve it only for scientific purposes compared to 80.13% of the "BioGeo" group, while 2.65% of the "BioGeo" group answered that they would reserve it for none of the proposed purposes, compared to 6.67% of the "Others" group. It is worth noting that when both responses are combined, awareness is higher for the "Others" group. Likewise, the answer "for scientific, tourism and economic purposes" had 10% of responses in the "Others" group versus 13.91% in the "BioGeo" group. These results show, therefore, that the "Others" group has a more restrictive attitude towards site exploration, which could be related to the underestimation of the value of the scientific knowledge provided by the study of these areas. This perspective suggests a lack of familiarity with the fact that research in these environments need not result in environmental degradation, as long as appropriate conservation measures and sustainability protocols are implemented. As for the rest of the thematic areas, no significant relationship was found between attitude and behavior as a function of place of origin or age.

Table 4

Questions asked to assess attitude, behavior and awareness of the oceans and poles.

QUESTIONS					
Awareness and socio-environmental perception					
How important is the ocean to you? (Guest et al., 2015)					
Don't know (0)	Very little (1)	Little (2)	Moderate (3)	A lot (4)	Very much (5)
0 %	0,37 %	0 %	9,19 %	25,74 %	63,97 %
To what extent would you be interested in learning more about the ocean? (Guest et al., 2015)					
Don't know (0)	Very little (1)	Little (2)	Moderate (3)	A lot (4)	Very much (5)
0 %	0 %	2,57 %	14,34 %	31,62 %	51,10 %
Do you think the climate crisis is being exaggerated?					
Yes		No	I do not know		
8,82 %		85,66 %	5,15 %		
Point out the three ways in which you believe humans benefit most from the ocean (Guest et al., 2015)					
Food		Medicines	Climate regulation		Boat transportation
28,49 %		1,43 %	26,34 %		9,68 %
Power generation		Mineral extraction	Oxygen source		Recreation
6,99 %		2,15 %	21,68 %		3,23 %
To what extent is the ocean explored?					
Don't know (0)	Very little (1)	Little (2)	Moderate (3)	A lot (4)	Very much (5)
0 %	34,8 %	47,62 %	11 %	4,4 %	1,47 %
To what extent does the ocean influence the climate of the continents?					
Don't know (0)	Very little (1)	Little (2)	Moderate (3)	A lot (4)	Very much (5)
0 %	0,37 %	0,37 %	4,76 %	31,14 %	62,64 %
What year is the estimated extinction of polar bears? (modified from Hamilton 2008)					
I do not know	2030	2040	2050	2100	

54,41 %	8,82 %	10,66 %	17,28 %	9,19 %

Table 5
Questions asked to evaluate the attitude, behavior and awareness of the poles.

Studies	**The North Pole ice will be completely thawed** (Hamilton, 2008)			
	TRUE		FALSE	
All	53,87%		46,13%	
BioGeo	58,28%		41,72%	
Others	48,33%		51,67%	
Studies	**I would support Antarctica being reserved for:** (Modified from Hamilton, 2008)			
	I do not know	for scientific purposes only	for scientific, tourism and economic purposes	for any of these purposes
All	4,41%	78,68%	12,13%	4,41%
BioGeo	3,31%	80,13%	13,91%	2,65%
Others	5,83%	77,50%	10,00%	6,67%

Discussion and Conclusions

The results of this study highlight the need to improve oceanic and polar literacy in the Spanish-speaking population. As anticipated, students majoring in biology and geology expressed a higher level of ocean and polar literacy than the rest of the surveyed population (McKinley et al., 2025; Guest et al., 2015).

A particularly relevant and noteworthy finding is that, within this specialized group, geology students demonstrated superior oceanic knowledge. This underscores the critical importance of geology as a fundamental discipline for understanding the physical, chemical and geological processes that regulate these ecosystems. Given that geology is often invisible or marginalized in the compulsory education curriculum (García-Yelo et al., 2022), reinforcing its teaching in these early stages represents a transversal and effective strategy. This would not only directly improve ocean and polar literacy, but also the overall understanding of the current climate crisis (Metzger, 2024). In other studies, a relationship has been documented in which students with a higher level of ocean literacy tend to manifest a stronger and more positive appreciation of the marine environment (Guest et al., 2015).

In the specific context of polar literacy, a significant difference linked to geographical origin was identified: students from Latin America who did not study disciplines related to biology or geology showed a lower level of *Polar Knowledge* than those from Spain. This finding suggests that strategies to foster ocean and polar literacy should be adapted to the particularities of each region, with special emphasis on the general community that is less involved with topics in areas related to the natural and Earth sciences (UNESCO, 1977).

Contrary to what might be expected, no statistically significant differences in the level of oceanic and polar literacy were detected between those who have resided in coastal cities and

those who have not. This result is consistent with previous studies and suggests that geographic proximity, by itself, is not a determining factor in generating in-depth knowledge or effective awareness of these ecosystems (Fauville et al., 2019). However, in a study conducted in Nova Scotia, students had in their day-to-day lives greater interaction with the ocean, demonstrated higher levels of knowledge (Guest et al., 2015).

Generally, teachers identify that the main obstacles that hinder the process of teaching ocean culture are funding, the interest of educational institutions in including marine environmental education activities, and the support of other institutions (Camargo, 2023). Contrary to what might be expected, access to information technology (computer and internet) has been ruled out as an obstacle to teaching ocean literacy. Furthermore, it has been observed that such access does not significantly influence the level of knowledge possessed by students (Camargo, 2023).

Finally, despite the identified gaps, in several aspects of ocean and polar literacy, the surveyed population has shown interest and curiosity towards ocean and polar ecosystems. This result is highly encouraging as it evidences a solid motivational base upon which effective educational programs can be developed and implemented, fostering a comprehensive and critical understanding of the complex relationship between the oceans, the poles and contemporary global challenges.

Limitations and Future Prospects

It is important to note that the survey has certain limitations in relation to the size of the sample, so it cannot be considered representative of the Spanish-speaking university population. Additionally, we identified self-selection bias as an inherent limitation of sampling. This may imply that those participants who choose to respond to the survey have a greater interest in or knowledge of the topics covered, which could influence the results. That is, people who choose to respond to the survey may have different characteristics and literacy levels than those who choose not to respond.

This study shows that there are significant challenges and challenges to assessing and implementing effective ocean and polar literacy. Fully developing - and therefore truthfully estimating - the dimensions and components of literacy is complex, since it is not only based on knowledge about these media, but also on attitudes, beliefs and behaviors towards the sea and the poles, achieving attitudinal responses that are informed and respectful of them. Studying the relationship between a person's level of knowledge about these topics and his or her attitude towards them becomes a great challenge, since the two dimensions of literacy are not necessarily correlated.

Developing a single survey that works equally across linguistic and cultural differences in such a diverse population is complex. However, it is important to note that the results of this experience will serve as a basis for the development of a new version of the survey. To this end, some content will be (i) reviewed for clarity and alignment with the content, (ii) additional items will be added to the perception questions, (iii) questions to identify the respondent's profile will be improved, and (iv) linguistic expressions will be reviewed to avoid cultural bias.

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