frontiers | Frontiers in Marine Science

TYPE Brief Research Report
PUBLISHED 02 October 2025
DOI 10.3389/fmars.2025.1636803

OPEN ACCESS

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RECEIVED 28 May 2025
ACCEPTED 29 August 2025
PUBLISHED 02 October 2025

CITATION
Salazar J, Marambio M, Ballesteros A, Vendrell-Simón B and Gili J-M (2025) Reframing jellyfish perception from "enemies" to "helpers" through Ocean Literacy. *Front. Mar. Sci.* 12:1636803. doi: 10.3389/fmars.2025.1636803

Reframing jellyfish perception from "enemies" to "helpers" through Ocean Literacy

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Despite covering three-quarters of Earth's surface and comprising 99% of its habitable space, the ocean remains underrepresented in formal education, contributing to widespread Ocean Literacy (OL) deficits. Jellyfish – among the earliest metazoans – inhabit all ocean basins and play vital ecological roles. Yet, they are often misrepresented and negatively perceived due to the impacts of jellyfish blooms – phenomena often linked to anthropogenic pressures – on human activities. These blooms not only have ecological consequences but also reflect a broader disconnect between society and the ocean, highlighting the need to promote awareness and foster sustainable behaviors. To help address this gap, a marine research group developed an initiative introducing OL concepts using jellyfish as a flagship species in the context of global change. In collaboration with educators, primary school teachers and students from Catalonia and Asturias (Spain), jellyfish-centered educational interventions were co-developed and tested, including teacher training, classroom implementation and open-access educational resources. Pre- and post- intervention assessments of students and teachers revealed significant improvements in marine knowledge and the development of sustainable behaviors. OL tests revealed similar misconceptions and knowledge gaps in both regions, which declined markedly after the interventions. The autonomous application of the resources by teachers without direct scientific facilitation also yielded significant learning gains. Further teacher interviews two years post-intervention showed that the initiative fostered long-term engagement. By reframing the increase in jellyfish blooms as a potential indicator of anthropogenic pressure rather than a threat, this approach contributes to cultivating ocean-aware, engaged communities committed to addressing global environmental challenges.

KEYWORDS

global change, environmental education, perception change, coastal management, scientific education, gelatinous zooplankton, Scyphozoa, SDG 14: Life below water

1 Introduction

Jellyfish (Cnidaria: Scyphozoa) are among the earliest known multicellular animals, with fossil records dating back at least 505 million years (Cartwright et al., 2007). Jellyfish inhabit all ocean basins with holoplanktonic or metagenic life cycles (Helm, 2018; Ballesteros et al., 2021) and play key ecological roles (Kramp, 1961; Young and Hagadorn, 2010; Doyle et al., 2014). Jellyfish can form large aggregations commonly known as "blooms." Anthropogenic factors may affect bloom recurrence by reducing natural predators through overfishing, increasing water temperature and altering circulation via climate change, enriching nutrient levels through eutrophication, modifying habitats that favor bloom species, and introducing non-native species that disrupt ecosystem balance (Purcell et al., 2007; Richardson et al., 2009; Brotz et al., 2012; Duarte et al., 2013).

These blooms can disrupt marine food webs and negatively affect fisheries, industry, human health, and tourism (Purcell, 2012). This phenomenon has become one of the most frequently covered topics in the media related to the sea, especially in coastal regions (Vandendriessche et al., 2016; Levy et al., 2024), fostering a widespread perception of jellyfish as harmful species (Costa et al., 2023).

Effectively managing the negative impacts of jellyfish blooms requires both scientific understanding and public awareness, which can promote sustainable behavior (Lucas et al., 2014; Marambio et al., 2021b; 2022). The focus on developing strategies to promote attitudes and behaviors conducive to the sustainable use of natural environments is growing (e.g. Bamberg and Möser, 2007; Salazar et al., 2024). However, such behavioral changes cannot be achieved through knowledge alone – they must be supported by broader structural conditions, including social, economic, and political factors that often shape individual and collective decision-making (Kollmuss and Agyeman, 2002).

The United Nations Decade of Ocean Science for Sustainable Development 2021–2030 addressed the need for a "rigorous Ocean Literacy (OL) program of activities aimed at increasing awareness and informed decision-making". In addition, it emphasized the relevance of economic and social considerations in fostering public support for effective ocean management – particularly in preventing environmental degradation that threatens ecosystem health, habitat integrity, and human well-being (Intergovernmental Oceanographic Commission of UNESCO, 2018).

In countries like Spain, despite having one of the longest coastlines in Europe, marine concepts remain largely absent from the national education curriculum, as established by the Spanish Organic Law on Education (LOMLOE, Ley Orgánica 3/2020). This omission contributes to low levels of OL among citizens (e.g., Kelly et al., 2021; Koulouri et al., 2022). OL efforts frequently depend on resources and initiatives originating from non-formal educational environments, marine research institutions and universities, the latter two of which often rely on scientists' voluntary engagement (Salazar et al., 2022, 2025). Spain's education system has shifted from a centralized to a decentralized model (Egido, 2005), with authority now shared between the central and regional governments (Ferrer, 2000). Primary education curricula are regulated by key national legislation, particularly the Spanish Organic Law on Education (LOMLOE, Ley Orgánica 3/2020) and the Royal Decree 157/2022 (Real Decreto 157/2022). These laws establish a common educational framework while allowing for regional adaptations. Catalonia applies the provisions of Catalonia Education Act (Ley 12/2009), and Asturias follows the guidelines set out in Teachers' Authority Act (Ley 3/2013). This structure grants schools and teachers flexibility in implementing the curriculum (Vendrell-Simón et al., 2024).

However, previous studies have shown that scientific knowledge about jellyfish and other cnidarians is still scarce in both formal and non-formal contexts (Salazar et al., 2019). Although successful regional outreach projects have targeted specific groups – such as first-aid providers and public health personnel (Edelist et al., 2025; Ministerio de Medio Ambiente y Medio Rural y Marino, 2021) – there is still a lack of integration across all regions and into broader national strategies. Consequently, individuals exposed to stinging animals may lack adequate knowledge to protect themselves or respond appropriately after a sting (Ballesteros et al., 2022a). Citizen science projects have engaged the public (Marambio et al., 2021b; Edelist et al., 2025; MedusApp, n.d), demonstrating the potential for sustained and valuable participation (Dobson et al., 2023). Recent reviews have also highlighted Mediterranean-wide jellyfish monitoring efforts and opportunities for better integration into institutional frameworks (Edelist et al., 2025).

To contribute to addressing these challenges, the Institut de Ciències del Mar (ICM-CSIC) launched the *La Mar de Medusas* project (the translation in English would be "A Sea of Jellyfish") during 2021-2022. This education and outreach (E&O) project aimed to reframe jellyfish not as "enemies" but as possible "indicators" of human impacts on marine ecosystems, fostering more sustainable attitudes (Salazar et al., 2021a; Marambio et al., 2023c).

The main objective of the project was to initiate a collaborative process between the scientific and educational sectors to assess OL levels in two Spanish regions and develop new educational methodologies and tools. These tools were designed to promote marine environmental knowledge, shift perceptions of pelagic gelatinous organisms from "enemies" to "helpers," and highlight their role as indicators of anthropogenic pressure. The project aimed to encourage age-appropriate behavioral shifts, such as increased care for marine life, curiosity about ocean health, and reflection on human-nature interaction. Integrating ocean-related challenges into the classroom has been increasingly recognized as a key strategy in fostering environmental awareness among students (Pazoto et al., 2022).

The project incorporated key ecological concepts such as marine biodiversity, global change, and "fishing down marine food webs" (Pauly et al., 1998). The program integrated OL principles and Sustainable Development Goals (SDGs) of the 2030 Agenda (Soergel et al., 2021), especially OL principle 5 (*the ocean supports a great diversity of life and ecosystems*), and 6 (*the ocean and humans are inextricably interconnected*) (Cava et al., 2005), as well as SDG 13 (*Climate action*) and 14 (*Life below water*). It also highlighted the role of women in marine science, aligning

with ICM-CSIC's commitment to gender equality (Garcés et al., 2022) and inspired by examples of female leadership in jellyfish research (e.g., Purcell, 2018).

To reach broader audiences, the initiative developed open-access educational and outreach materials, workshop resources, and disseminated content via social media.

Accordingly, the aims of this study are as follows:

1. To present the collaborative process of the *La Mar de Medusas* project and its contribution to OL and SDGs.
2. To provide new data on jellyfish-related marine knowledge among primary school students and teachers in Asturias and Catalonia.
3. To identify effective strategies by marine research centers and universities to promote OL and sustainable behaviors.

2 Materials and methods

2.1 Study area and educational context

The initiative was developed during 2021–2022 by marine researchers from the ICM-CSIC. A total of 20 class groups from two regions, comprising students and teachers from the last two years of primary education (ages 10-12) were involved. These regions included Barcelona and nearby Sant Cugat del Vallès, influenced by the Mediterranean Sea, and various villages and towns in Asturias, influenced by the Cantabrian Sea (Atlantic Ocean) (Figure 1A). Ten class groups were selected per region: five schools in Catalonia (two groups each) and ten schools in Asturias (one group each).

The project had the support of regional educational authorities in both regions. In Catalonia, it was officially recognized as formal training by the Department of Education and promoted through official channels, with assistance from the educational foundation "Fundació Bofill" for school selection and initial contact. In Asturias, an outreach expert facilitated collaboration with the regional Science and Education Departments, whose staff provided ongoing support to teachers and students. The program also obtained official accreditation as a certified teacher training program in Asturias.

2.2 OL methodologies and educational resources based on jellyfish as "flagship" species

The teacher training program consisted of three main phases:

1. **Phase 1: Teacher Training**: A 20-hour theoretical and practical program comprising five remote sessions (two hours each) plus independent work covering mainly OL, ecology, conservation, first-aid and citizen science engagement. Practical exercises were included, and teachers provided feedback via questionnaires. The goal was to empower teachers with the knowledge and confidence to integrate marine science into their lessons.
2. **Phase 2: Class Group Implementation**: Teachers applied the concepts learned with their students, with optional support from scientists. They had flexibility and sufficient time to adapt their strategies to their educational contexts and communities. This phase culminated in a virtual session involving students.
3. **Phase 3: Resource Sharing and Legacy:** Participants shared methodologies and experiences within the program community, fostering a sense of belonging and achievement. A key outcome was the contribution to open-access repositories of educational resources like the ICM's Network of Marine Schools (Salazar et al., 2021b), enabling broader use beyond the initial participants.

To formalize collaboration, a "commitment letter" was signed by scientists and teachers, outlining mutual responsibilities. Throughout the process, continuous dialogue with the participants helped identify their interests, knowledge gaps, and misunderstandings, which guided the design of the educational resources. Teachers also submitted Project Reports to document their experiences (see Supplementary Figure 1; Figures 1C, E). This aimed to consolidate the outcomes and extend the project's long-term impact.

Given the common limitation of scarce resources and personnel for OL in marine research institutions, educational materials were designed for autonomous use by teachers and students. These included a Teacher's Guide (Marambio et al., 2021a), a board game (Marambio et al., 2023a) and an Identification and First-Aid Guideline (Marambio et al., 2021c) (Figure 1D). Additionally, a workshop for public awareness was held, featuring updated outreach materials (Figures 1F, H) and a life-size version of the board game for interactive activities (Figure 1G). The project also maintained active social media accounts on Facebook, Twitter and Instagram, regularly posting OL content (Figure 1B).

2.3 Evaluation tools and impact assessment

To assess marine environmental knowledge related to jellyfish, marine researchers and educators developed an OL test. The same questionnaire was administered to both teachers and students (see Supplementary Figure 4). Teachers distributed the test to students and submitted the results as part of the training participation requirements.

To analyze the differences between participants from the two regions, qualitative analyses and t-tests were performed using R software (R Core Team, 2023). Normality of the data distribution was assessed using the Shapiro-Wilk test prior to conducting t-tests.

The program's impact was also evaluated through teacher surveys after each training session and follow-up interviews two years later to assess the long-term use and effects of the educational program and materials (see Supplementary Figure 2).

To test the effectiveness of the educational resources when used independently (without scientist involvement), a pre- and post-test

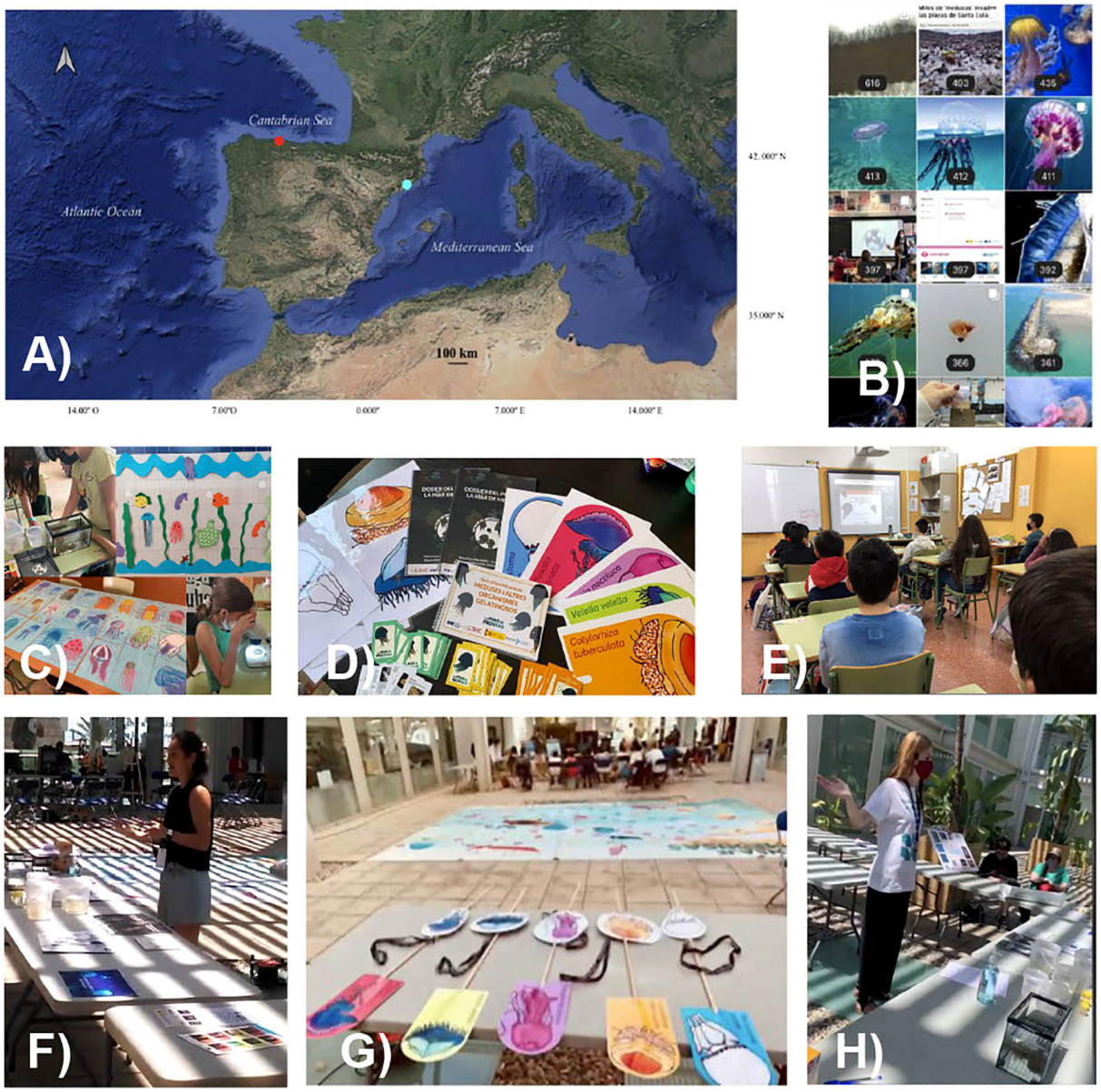

FIGURE 1
(A) Map of the study areas, highlighting the regions of Catalonia (blue dot) and Asturias (red dot). B-H) Overview of the E&O activities developed in *La Mar de Medusas*: dissemination through social media platforms **(B)**; experimental and artistic educational experiences in the classroom **(C)**; educational materials for autonomous use, including a teacher's guide, a board game and an identification and first-aid guideline **(D)**; in-class training sessions **(E)**; public awareness workshops sharing updated outreach materials **(F)**, a life-size version of the board game **(G)**; and exposure to living jellyfish **(H)**.

design was implemented with 48 students from an additional school in Catalonia. The same OL questionnaire in Supplementary Figure 4 was applied before and after using the resources. Teacher feedback was collected, and statistical analyses (paired t-test) were conducted with the average results of the students' scores on the true/false test to measure OL improvements. To verify the normality assumption required for t-tests, the Shapiro-Wilk test was applied. Since the same group was tested twice, homogeneity of variances was not required.

Furthermore, a questionnaire was distributed to two educational experts to evaluate the developed resources and identify factors facilitating or limiting their future use by teachers (see Supplementary Figure 3).

3 Results

3.1 OL methodologies and educational resources using jellyfish as flagship species

The teacher training was well attended, with participants actively engaging in the sessions, discussions, and ideas

exchanges. Teachers submitted project reports, participated in the final session with students, and completed feedback forms. This revealed their preferred methodologies and a perceptual shift toward greater awareness of ocean-related issues.

Reported satisfaction scores averaged above 4.3 out of 5. The final session, which focused on sustainability, received the highest appreciation.

Teachers expressed enthusiasm for learning directly from scientists and highlighted several suggested classroom proposals, including role-playing different marine sectors, promoting gender equality, and using a sustainable attitudes calendar. Ten teachers particularly valued *Slido*, an interactive platform used during training for real-time polls and indicated intentions to adopt it in future lessons.

Educational materials (Figure 1D) were reported to be valuable in promoting OL and sustainable attitudes both by teachers participating in the experience with and without scientific facilitation. However, both especially appreciated and valued any involvement of scientists, which they identified as one of the most important facilitating factors for integrating ocean-related concepts into their lessons. Despite a preference for in-person learning, virtual training and remote support were also positively received. Teachers in Asturias emphasized their prior lack of knowledge about jellyfish and valued the opportunity to explore this unfamiliar topic.

As part of the local expert evaluation, educational experts recommended strengthening the collaboration between scientists and teachers and praised the educational materials for their depth and quality (David Vilalta and Sandra Memminger, *personal communications*). One expert suggested involving experienced teacher trainers to better tailor the materials for classroom use, ensuring that students not only become jellyfish experts but also develop a broader scientific understanding and literacy. She also emphasized the importance of key concepts such as why jellyfish have remained unchanged over time and how ecosystems and food webs are affected by multiple stressors. The goal should also include fostering sustainable behavior. The board game was seen as a valuable training complement and was especially interesting for family engagement. Although it seems that can effectively engage primary students, due to its complexity, it may be better suited for secondary education when there is limited scientific guidance or teacher support (Sandra Memminger, *personal communication*).

The resulting collaborative process with teachers is outlined in Figure 2. The process includes five key steps: 1) Discovery, 2) Re-thinking, 3) Implementation (with optional external support), 4) Reflection, and 5) Reporting.

The *La Mar de Medusas* social media accounts reached over 39000 people (17000 on Twitter, 13500 on Instagram, and 8500 on Facebook), during one year of regular posting, according to Google Analytics (Google, n.d), and audience analytics provided by each platform. Most followers were from Spain, with international engagement from countries including France, Italy, Germany, Sweden, Norway, Algeria, the United States, Mexico, El Salvador, Colombia, Ecuador, Peru, Chile, and Argentina. Most followers were women, with the dominant age group being 25–34, followed by 35–44, 45–54, and 18–24. Few followers were aged 13–17 or 65 +.

3.2 Characterization of marine scientific knowledge related to jellyfish

A total of 23 teachers participated in the training, with 19 completing the background knowledge test (two from Asturias and two from Catalonia did not respond). In Catalonia, there were six female and two male teachers (aged 25–54), while in Asturias there were 11 female and four male participants (aged 29–62). The average age was similar: 38 years in Catalonia and 40.5 in Asturias. Some participants coordinated science departments, and two from Asturias and one from Catalonia were school directors. All teachers held university-level degrees, in accordance with the national requirements for public school educators in Spain.

Most Catalan teachers lived in coastal cities, though not necessarily directly by the sea. In Asturias, two teachers lived more than 50 km from the sea, while others lived closer, with some enjoying daily coastal views. Their frequency of visits to marine ecosystems varied, from once a year to nearly daily. Six teachers from Asturias reported near-daily contact with the sea. Only two teachers in Asturias had previously explored underwater ecosystems, compared to five in Catalonia.

Both groups generally agreed that jellyfish receive more media coverage than scientific dissemination. Most teachers showed limited knowledge of jellyfish, with some misconceptions (e.g., believing that jellyfish have a head or produce electric shocks). While some mentioned tentacles, none referred to the oral arms. One teacher even confused jellyfish with cetaceans. Interestingly, some Asturian teachers reported that jellyfish sightings were rare in their region.

The test results (Figure 3A) showed a normal distribution for both groups (Shapiro-Wilk: Catalonia $W = 0.885$, $p = 0.293$; Asturias $W = 0.873$, $p = 0.240$). No significant regional differences were found (t-test: $p = 0.797$).

From 192 student tests, several misconceptions emerged, such as referring to "spores" and unsafe handling practices. Common initial reactions to jellyfish included fear and improper responses, such as picking them up by the umbrella under the assumption it was safe.

Post-training responses included statements like "I would alert people from the beach not to bathe or do it with care" or "I would admire them". After stings, the common answer from students was to apply ice and seeking help from adults or first-aid centers. In the true/false section (Figure 3B), students identified jellyfish as animals from the phylum Cnidaria, although some still believed that plankton were always microscopic. They struggled to connect jellyfish proliferation when their natural predators, such as sea turtles and certain fish, decline. Interestingly, most of the students disagreed with the statement that we would live better without jellyfish. Common jellyfish species, their colors and traits were better recognized and more realistic in post-test drawings (Figure 3B). Earlier references to "head" or "flagella" were replaced by terms such as "umbrella," "tentacles," and "oral arms." Also, some pictures with only "tentacles" were changed to both "oral arms" and "tentacles."

The additional true/false evaluation conducted with 48 students from the Catalan school using the educational resources independently (i.e., without direct scientist involvement) revealed that the data were

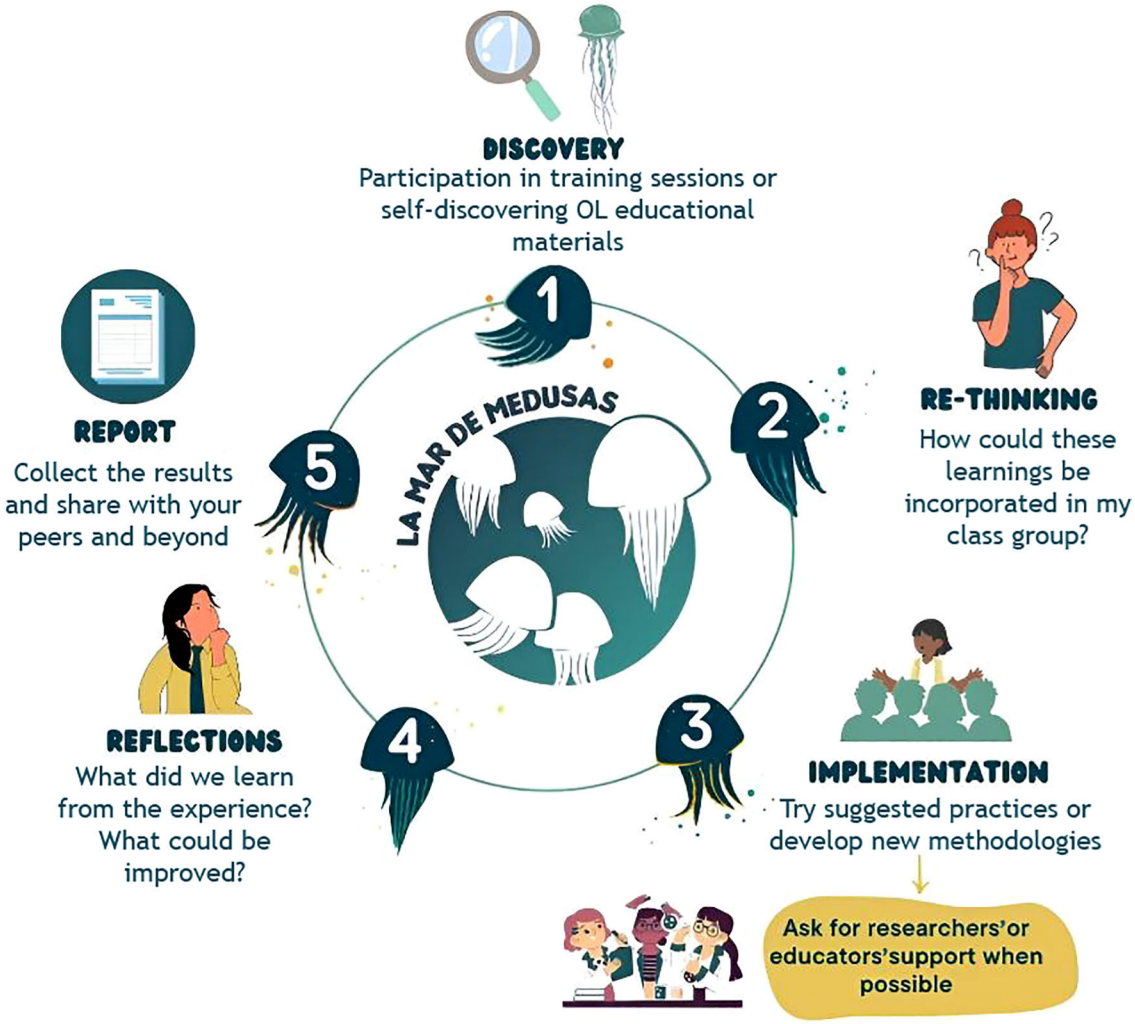

FIGURE 2
Process for optimizing the integration of OL concepts into schools, supported by marine researchers and educators (when possible), based on the experience of the *La Mar de Medusas* project.

normally distributed (Shapiro-Wilk: pre-test W = 0.891, p = 0.326; post-test W = 0.917, p = 0.485). A paired test showed significant improvement (p = 0.036) (Figure 3D). Open-ended responses (see Supplementary Table 1 (pre-) and 2 (post-)) revealed knowledge gaps, such as the mechanism of jellyfish stings, with the pre-test responses often referencing "electric shocks" or "spores." Post-test answers showed a shift from focusing solely on stings to broader ecological insights (e.g., "they are cnidarians," "they eat plankton," "they live in the sea").

4 Discussion and conclusions

The educational program aimed to advance global OL by connecting students and teachers to the ocean, using jellyfish as a flagship species. It emphasized OL principles 5 and 6, reframing jellyfish from feared creatures to vital components of marine ecosystems and possible indicators of anthropogenic impacts. The project encouraged reflection on human–ocean interconnections and promoted sustainable behavior.

The results confirmed its effectiveness, showing meaningful and lasting learning outcomes through active engagement. The initiative fostered new educational strategies, including artistic, playful, and digital tools (Figure 1C).

No significant differences and low levels of OL were observed between the regions of Catalonia and Asturias, highlighting the need for a national OL agenda. This aligns with the results of Koulouri et al. (2022) with Mediterranean middle school students and Mogias et al. (2019) in primary schools. Age or lifestyle may influence perceptions and knowledge of jellyfish (Torri et al., 2020); therefore, further studies in varied contexts are recommended to better inform E&O strategies.

Common gaps in knowledge and misunderstandings related to jellyfish in both studied regions were identified, including jellyfish delivering electric shocks or releasing spores, indicating a low understanding of biodiversity and stinging mechanisms. Post-training,

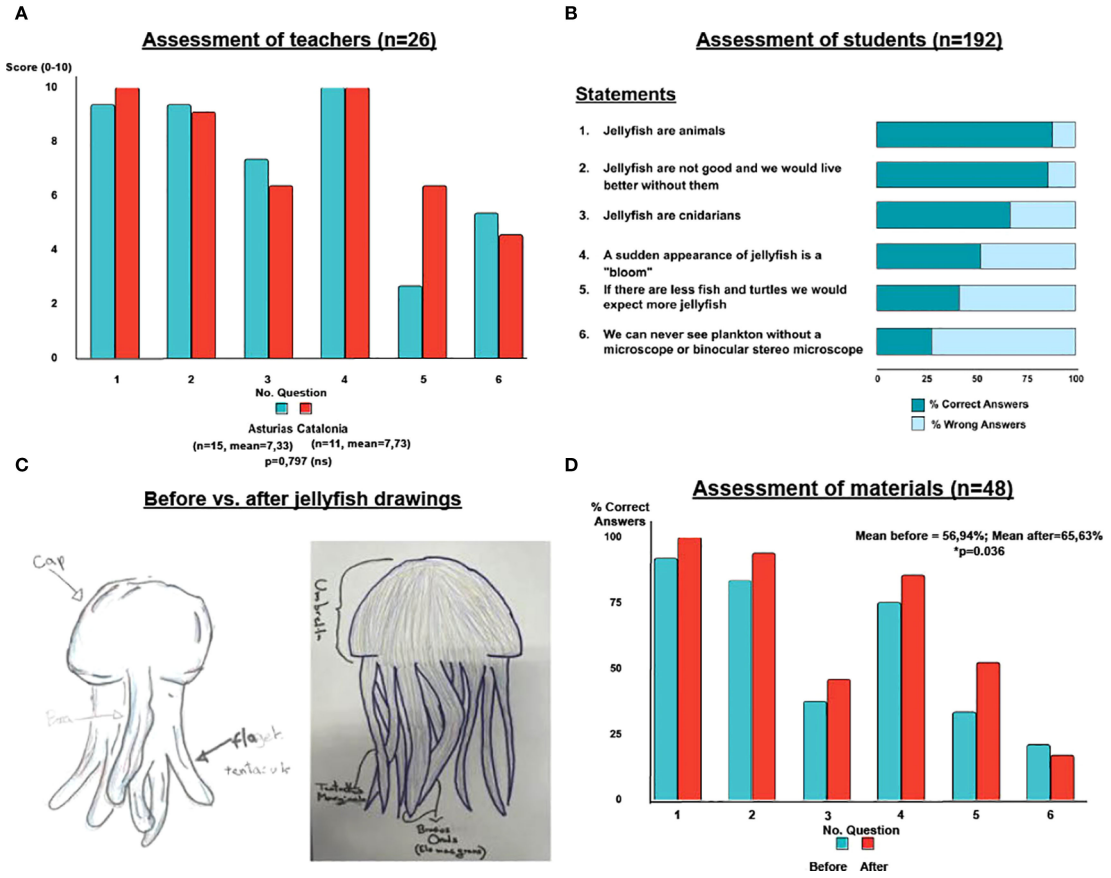

FIGURE 3
(A) Results of the knowledge questions answered by the 192 students before participating in the project. Note that correct answers are *true* for questions 1, 3 and 4 and *false* for questions 2, 5, and 6. **(B)** Examples of students'jellyfish drawings before (left) and after (right) the project. Common pre-project drawings included parts like "head" or "flagella", while post-project drawings included terms such as "umbrella", "tentacles" and "oral arms" (specifying that these are the bigger ones). **(C)** Results of the knowledge questions answered by 26 teachers before participating in the project. **(D)** Comparison of students' knowledge results before and after using the educational materials in the classroom.

participants demonstrated improved knowledge, referencing their classification (phylum Cnidaria), trophic role ("they eat plankton"), and habitats ("they live in the sea," "they live in open waters," etc.).

The appreciative words used to describe jellyfish in the post-tests suggest an emotional connection, which is essential for pro-environmental behavioral change (Kollmuss and Agyeman, 2002). This is aligned with trained beach visitors on the German Baltic coastline, who stated that they felt less bothered by jellyfish after being informed about them (Baumann and Schernewski, 2012), reinforcing the overall potential of jellyfish-focused OL interventions. Their educational potential has also been demonstrated in early childhood settings, where interactions with jellyfish inspired sustainable attitudes and a "sense of wonder" among kindergarten children (Jørgensen, 2016), highlighting their applicability across a broad age range. This is especially significant when learning is connected to local jellyfish and their sightings, connecting scientific knowledge to their local realities, strengthening students' comprehension and interest in their marine natural surroundings, and promoting sustainable behavior (Vendrell-Simón et al., 2025). However, fostering sustainability requires cultivating and assessing long-term awareness and commitment (Perrault and Clark, 2018), which is beyond the scope of this study.

Given the global distribution of jellyfish, studying them offers a gateway to discussing broader and often less tangible or accessible marine issues. In addition, considering the paramount role that culture and heritage play in the development of sustainable behavior, it would be particularly interesting to further explore the development of marine local culture projects with students (Gómez et al., 2025).

The widespread lack of knowledge about jellyfish sting first aid, found among both teachers and students, is concerning and highlights the urgent need for accurate public health information – as pointed out by previous studies (Suriyan et al., 2019; Ballesteros et al., 2022a, 2022b, 2023).

The methodological process followed (Figure 2) is adaptable to different educational and geographical contexts. To facilitate future applications, key enabling factors and the main learning opportunities are identified in Table 1. The findings of this study are aligned with Freitas et al. (2025), who highlighted the involvement of experts in the field, link to regional realities, involvement of educators, a wide variety of learning experiences, and adaptation to teachers' timelines as crucial points in developing OL programs in primary schools.

Digital technologies have proven effective in supporting family-based learning (Fauville et al., 2015 and Gomila et al., 2018). Suriyan et al. (2019) in a comprehensive study of Thai divers, reported that the internet was their primary source of information about jellyfish. In this case study, training sessions were conducted online using video call platforms and digital tools such as *Slido*. Some groups applied their new knowledge by developing video games, educational apps, and citizen science initiatives such as *Observadores del Mar* (Marambio et al., 2023b). There is a clear demand for accessible scientific training and user-friendly digital platforms, as shown by the popularity of apps such as Jellywatch, iMedjelly and MedusApp (Ghermandi et al., 2015; Edelist et al., 2025). The need for translating materials into more languages was detected as one of the limiting factors for being involved in citizen science as well as better training (Terenzini et al., 2023).

Some participants from Asturias reported being less familiar with jellyfish sightings. This is somewhat surprising, considering that Galicia and Asturias have 1,498 km and 401 km of coastline respectively, while Catalonia has only 699 km (MITECO, 2005). This finding aligns with recent scientific reports (Dobson et al., 2023), but should be interpreted with caution. Beyond regional differences in jellyfish occurrence, this may also reflect disparities in public awareness and outreach, leading to fewer reported sightings. In this regard, the present study found that teachers in Asturias particularly appreciated the new opportunities to learn about jellyfish. On the other hand, Catalonia has a long-standing tradition of E&O initiatives focused on jellyfish, including public messaging of the importance of reporting sightings. These discrepancies underscore the need to continue strengthening citizen science efforts from local to global levels, improve OL and expand public awareness campaigns, particularly in coastal communities. They also highlight the importance of integrating citizen-generated data into environmental policy and management strategies.

The role of trained teachers should not be underestimated. Three participants reported having encouraged others to integrate OL into their teaching, acting as knowledge multipliers. Education experts recommended closer collaboration between scientists and teachers, in line with findings by Salazar et al. (2019); Vendrell-Simón et al. (2024), and Freitas et al. (2025).

Overall, this study highlights how the close relationship between human activities and jellyfish blooms makes jellyfish particularly valuable flagship species for OL initiatives, as they effectively connect scientific knowledge with local realities. Increased marine knowledge is essential for interpreting environmental signals, such as jellyfish blooms, which also indicate changes in the ocean and underscore the need to reflect on anthropogenic changes in the ocean and the need to develop sustainable behaviors. In this regard, jellyfish sightings act as immediate and relatable phenomena that offer learning opportunities to reflect on human impact on the ocean, aligned with recommendations made by Pazoto et al. (2022). These results are also consistent with previous educational programs

TABLE 1 Main E&O opportunities and findings using jellyfish as flagship species.

Findings from E&O experiences in marine research centers using jellyfish as flagship species to promote OL and support the achievement of the SDGs
Main learning opportunities based on common knowledge gaps and misconceptions
Marine biodiversity, evolution, diversity of natural forms, structures adaptations and life cycles (OL5)
Global change, stressors, the key role of SDGs 13 and 14 in addressing sustainability challenges
Strengthen personal and emotional connection with (local) nature
Understanding the ocean's influence on people and people's influence on the ocean; ocean health and planetary health, global awareness (OL6)
Due to the wide range of habitats of jellyfish in the ocean, they facilitate the introduction of many other different topics, disciplines and other OL principles and SDGs
Observation of videos with jellyfish and their propulsion movements may often be used for meditation and their shapes and colors inspire lots of artistic expressions, among other different methodologies that could be developed with them (e.g. digital competences)
Key facilitators
Scientific support and direct involvement, whenever possible
Support by experts on scientific education for teachers
Engaging materials: theoretical framework combined with practical suggestions in different formats, ensuring highest inclusivity
Commitment agreements among stakeholders
Formal credit recognition for teacher training
Flexibility to accommodate both non-instructional hours (for teacher training) and to instructional hours (for students training)
Regional education experts providing support to scientists throughout the process
Development of workshops and social media accounts to reach wider audiences
Digital technologies including websites and digital citizen platforms adapted to different users

The table includes the main learning opportunities based on common knowledge gaps and misconceptions related to jellyfish and marine ecosystems, and key facilitators to get the most out of the experience.

addressing OL that helped understand and respond to anthropogenic signals (Gershwin, 2013). It would also be interesting to conduct similar studies like this one in other Spanish regions, countries influenced by different sea basins, and in inland areas to gain a broader perspective.

Ultimately, jellyfish-focused interventions can become a powerful educational opportunity. They help to introduce important OL concepts, encourage reflection on global change, human impacts, and the urgency of developing sustainable behavior. Thus, jellyfish shift from being feared marine creatures to valuable allies in marine education and for achieving the goals of OL and SDGs.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval was not required for the study involving human samples in accordance with the local legislation and institutional requirements because the study only involved educational activities with anonymized surveys, and did not include sensitive data or interventions requiring other approval. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

JS: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. MM: Conceptualization, Methodology, Writing – review & editing. AB: Writing – review & editing. BV-S: Writing – review & editing. J-MG: Writing – review & editing, Supervision.

Funding

The author(s) declare financial support was received for the research and/or publication of this article. This work was performed under the La Mar de Medusas project, which was funded by the Spanish Foundation for Science and Technology (FECYT) (Ref. FCT-2019-15322). In addition, the research was supported by the European project RESBIOS, which received funding from the European Union's Horizon 2020 Research and Innovation Program under Grant Agreement No. 872146. Furthermore, the authors affiliated to the Institut de Ciències del Mar had the institutional support of the "Severo Ochoa Centre of Excellence" accreditation (CEX2019-000928-S). We acknowledge support of the publication fee by the CSIC Open Access Publication Support Initiative (PROA) through its Unit of Information Resources for Research (URICI).

Acknowledgments

The authors would like to thank the reviewers and the editor for their constructive comments, which substantially improved the manuscript. We also thank the teachers and educators who participated in the different phases of the *La Mar de Medusas* project, the framework project for this study, for their cooperation and positive disposition. Our thanks also go to the Department of Education in Catalonia for recognizing the training program and granting credits to teachers, and to the Department of Education in Asturias for their involvement throughout the process. Special thanks to Amador Menéndez for his dedication to outreach and education and for his invaluable assistance, particularly in Asturias. We also express our gratitude to Fundació Bofill for their commitment to reversing school segregation in Catalonia and for facilitating our connections with schools in the region. Additional thanks to David Vilalta and Sandra Memminger from CESIRE for her invaluable suggestions for improvement and educational experts' insights provided. Finally, we extend our thanks to everyone who participated in the various OL activities conducted throughout the project and/or contributed to the dissemination of scientific knowledge, helping to spread awareness about jellyfish and the conservation of marine ecosystems.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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