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Article

Integrating Ocean Literacy into Secondary Education through Gamification: The Case of Marine Dobble

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Abstract

The accelerated loss of biodiversity and the limited integration of ocean literacy into school curricula highlight the urgent need for innovative approaches in Environmental Education for Sustainability (EES). This study presents the design and implementation of Marine Dobble, a gamified educational tool inspired by the popular card game Dobble, adapted with illustrations of marine species from the Andalusian coast (Spain). The aim was to foster knowledge, awareness, and commitment toward marine biodiversity conservation among secondary school students. The intervention was conducted in five 1st-year ESO classes (n = 110, ages 12–13) in Cádiz, Spain, through a one-hour workshop facilitated by an environmental educator. A qualitative exploratory design was employed, using observation chronicles to record students' participation, reactions, and learning evidence. The activity combined fast-paced gameplay with five reflective "pauses" addressing key concepts: marine habitats, species adaptations, scientific curiosities, environmental problems, and personal commitment. Results show high levels of motivation, participation, and engagement, with notable emotional and cognitive responses to less-known contents, such as the ecological role of microalgae and the existence of marine plants. Students progressively improved their use of scientific terms and formulated concrete actions for ocean conservation, including reducing plastic waste and promoting sustainable consumption. Differences among groups highlighted the importance of teacher involvement and classroom climate. This study concludes that gamification, when contextualized and combined with reflective dialogue, is an effective strategy to integrate ocean literacy into secondary education. Marine Dobble proves to be a replicable that fosters meaningful learning, environmental awareness, and pro-sustainability attitudes in young learners.

Keywords: ocean literacy; environmental education; gamification; biodiversity; marine conservation

1. Introduction

The progressive environmental degradation, the accelerated loss of biodiversity, and the advance of climate change have placed humanity in a critical situation that demands urgent responses from all social sectors, including education. For decades, numerous experts and international organizations have emphasized the need to foster citizens capable of understanding the magnitude of this planetary emergency and acting accordingly [1]. Within this framework, environmental education has emerged as a fundamental driver for promoting behavioral change and cultivating attitudes aligned with sustainability. Over recent decades, the concept of Environmental Education for Sustainability (EES) has evolved toward more integrative approaches that transcend the fragmented treatment of ecological problems [2]. These perspectives advocate for a systemic and critical vision of the interconnections between society and the environment [3]. Such approaches not only aim to understand environmental challenges but also to foster students' active involvement in addressing them, thereby promoting

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empowerment, environmental justice, and transformative action [4,5]. A key dimension of EES is the incorporation of ocean literacy, understood as the competence to recognize the influence of the ocean on human life and, conversely, the impact of human activities on ocean health, and to act accordingly [6,7]. This perspective acknowledges the essential role of the ocean as a climate regulator, a generator of biodiversity, a source of resources, and a guarantor of planetary habitability [8]. Although ocean literacy has gained increasing visibility in scientific and educational initiatives, it remains largely absent from school curricula, particularly at the secondary level. Recent studies show that neither the new curricular framework nor current textbooks in Spain explicitly incorporate the principles of ocean literacy, thus limiting its presence in classrooms [9]. This underscores the urgency of designing and implementing innovative educational proposals that integrate the ocean–land system into school learning, promoting understanding, systemic thinking, and students' environmental commitment from a situated perspective. The 2030 Agenda and Spain's Action Plan for Environmental Education for Sustainability [10] explicitly emphasize the need to strengthen environmental literacy across the education system, embedding sustainability competences transversally [10,11]. Within this framework, teaching strategies grounded in active methodologies such as gamification and project-based learning are increasingly recognized as effective approaches to transforming science education [12]. This article presents a teaching experience developed within the program *El mar que nos une, aprende conociéndolo*, promoted by CEIMAR and the Provincial Council of Cádiz. The initiative integrates the principles of ocean literacy into a playful and participatory resource: Marine Dobble, an educational game inspired by the popular card game Dobble, recontextualized with illustrations of marine fauna and flora from the Andalusian coast, particularly the province of Cádiz. This local focus seeks to strengthen students' connection with their immediate environment, fostering recognition and appreciation of species that form part of their natural heritage. The activity was implemented with 1º de Educación Secundaria Obligatoria (ESO) students, in line with the basic learning outcomes of the official curriculum. It was structured as a sequence combining game dynamics with reflective pauses facilitated by an environmental educator. During these pauses, students were engaged in questions concerning habitats, adaptations, threats, and conservation actions, along with initial and final assessment activities to evaluate the workshop's impact on knowledge and attitudes toward marine biodiversity. The proposal is aligned with Sustainable Development Goal 14: Life Below Water [13] and contributes to environmental literacy through an active, playful, and contextualized approach. Furthermore, it resonates with an emerging trend in science education that highlights the value of games as pedagogical tools for fostering meaningful learning, pro-environmental attitudes, and emotional connections with nature [2,8] . In sum, this experience responds to the challenge of integrating ocean literacy into classrooms through an innovative, situated, and transformative proposal that combines science, emotion, action, and commitment to ocean stewardship.

1.1. Objectives

This study aims at the following objectives:

1. **To design and implement** a gamified educational resource, Marine Dobble, adapted to local marine species, as an innovative strategy within Environmental Education for Sustainability and for the integration of ocean literacy into the classroom.
2. **To foster knowledge, curiosity, and environmental awareness** among 1º ESO students regarding marine biodiversity, its habitats, adaptations, and the challenges associated with global change.
3. **To explore the potential of gamification** as an active methodology to promote motivation, participation, and the development of pro-environmental attitudes among students.
4. **To qualitatively analyze students' responses** to the proposal, considering indicators such as participation, use of scientific vocabulary, emotional reactions to new content and suggested actions for ocean conservation.

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5. **To assess the replicability and transferability of the experience** to other formal and non-formal educational contexts, as a contribution to the 2030 Agenda and the achievement of the Sustainable Development Goals, particularly SDG 14: Life Below Water.

2. Theoretical Framework

2.1. Theoretical Principles: Environmental Education for Sustainability and Ocean Literacy.

The contemporary ecological crisis, characterized by rapid loss of biodiversity, climate change, marine pollution, and the overexploitation of natural resources, poses significant challenges to humanity. This situation has been widely documented in the scientific literature [14,15] and recognized by international organizations such as the United Nations, which, through the 2030 Agenda, emphasize the urgent need for a transformation towards sustainable development models. In this context, education plays an fundamental role as a driver of social change. One of the most relevant conceptual frameworks for understanding the severity of the current planetary situation is that of planetary boundaries, proposed by Rockström et al. [14] and updated by Steffen et al. [16]. This model identifies nine fundamental processes that regulate the stability of the Earth system and establishes threshold values that should not be exceeded to ensure a safe operating space for humanity (Figure 1). Among these boundaries, biodiversity loss is one of the most critically transgressed. According to this framework, the current extinction rate is between 100 and 1,000 times higher than the natural background rate, representing a critical threat to ecosystem services that sustain life on Earth [16].

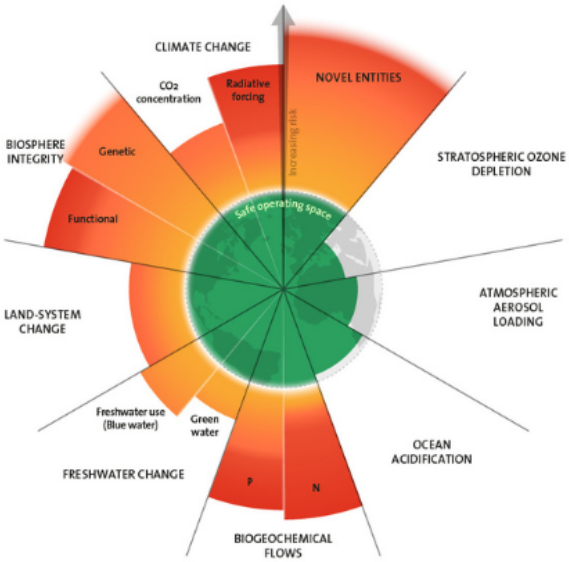

Figure 1. Figure 1. Current state of the planetary boundaries. Visual representation of the status of the nine processes regulating the stability of the Earth system. Green areas represent the safe operating space for humanity. Yellow, orange, and red zones indicate increasing levels of risk, from uncertainty to a high probability of irreversible changes. Of the nine boundaries assessed, six have already been transgressed: climate change, biosphere integrity, nitrogen and phosphorus cycles, freshwater use, land-system change, and pollution by novel entities. This transgression places humanity in a situation of heightened systemic risk. *Source:* Richardson et al. [17]. Earth system boundaries. Stockholm Resilience Centre. https://www.stockholmresilience.org/research/planetary-boundaries.html

The loss of marine biodiversity is particularly evident in the degradation of coastal habitats, the decline of key species populations, plastic pollution, and the impact of climate change on ocean ecosystems [18,19]. This process directly affects human well-being by reducing the resilience of natural systems and compromising food security, fishery resources, and climate regulation. In response to this situation, Environmental Education for Sustainability (EES) is conceived as a comprehensive formative process aimed at equipping individuals with the competencies, knowledge, attitudes, and

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values necessary to understand the complexity of environmental problems and actively engage in their resolution [4]. This approach goes beyond the mere transmission of information and fosters critical thinking, transformative action, and commitment to environmental justice [5]. In the school context, EES involves integrating contextualized educational experiences into the curriculum that connect learning with the immediate environment of students and incorporate active methodologies such as inquiry, modeling, project-based learning, or gamification [20]. These strategies not only enable knowledge acquisition but also promote the development of competencies for individual and collective action. In the current context, EES must transcend the transmission of knowledge and instead focus on preparing individuals capable of transforming their environment. For this purpose, the development of specific competencies is essential to help individuals understand the interconnections among natural, social, and economic systems, critically reflect on current development models, and actively participate in building more sustainable societies [13,21]. These competencies include, among others, systems thinking, anticipation, collaboration, complex problem solving, and informed and ethical decision-making [22,23]. They represent crucial capacities to act responsibly and transformatively in the face of global challenges such as biodiversity loss, climate change, and social inequalities, in line with the Sustainable Development Goals (SDGs) of the 2030 Agenda. One of the emerging approaches within EES is ocean literacy, defined as " understanding the influence of the ocean on us and our influence on the ocean" [6]. This concept involves not only acquiring scientific knowledge about the ocean system but also developing attitudes and values that promote its conservation. Ocean literacy is structured around seven fundamental principles [7]:

1. The Earth has one big ocean with many features.
2. The ocean and the life within it shape the Earth.
3. The ocean influences climate and weather.
4. The ocean makes the Earth habitable.
5. The ocean supports a great diversity of life and ecosystems.
6. The ocean and humans are inextricably interconnected.
7. The ocean is largely unexplored.

Working with these principles in schools contributes to the development of a blue scientific literacy that enables students to understand global phenomena such as climate change, ocean circulation, and marine biodiversity from an interconnected perspective [8]. In addition, it fosters empathy and a sense of responsibility toward the marine environment. Despite its relevance, ocean literacy is still not explicitly integrated into Spanish official curricula, nor into secondary school textbooks [9]. This absence highlights the need to design educational proposals that approach it through innovative and contextualized perspectives. Several studies have shown that addressing socio-environmental issues through experiential and situated approaches fosters deeper and more transformative learning [13,21]. In this regard, experiences such as environmental escape boxes have demonstrated their potential to connect curricular content with real-world challenges such as plastic pollution or biodiversity loss [24,25]. These methodologies, by promoting collaboration, critical thinking, and problem-solving, strengthen the bond between students and their environment, developing active environmental awareness and a commitment to sustainable action. The curriculum of Compulsory Secondary Education regulated by the LOMLOE [26] does not explicitly mention ocean literacy, but it includes core knowledge and key competencies that allow for its integration. In subjects such as Biology and Geology, Scientific Culture, or Environmental Sciences, the curriculum addresses content on ecosystems, biodiversity, sustainability, climate change, and the human–nature relationship.

2.2. *Gamification as an Active Methodology in Environmental Education Workshops*

In recent years, gamification has become consolidated as an active methodological strategy within innovative teaching–learning approaches. Its application in education seeks to incorporate game-like dynamics, mechanics, and elements (such as challenge, reward, narrative, or chance) into non-playful contexts, with the aim of increasing intrinsic motivation, engagement, and student participation [27,28].

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Far from being a simple technique to "make a class fun," well-designed gamification can foster the acquisition of knowledge, skills, and attitudes by generating meaningful experiences that involve students emotionally, cognitively, and socially [29]. In the field of environmental education, gamification is particularly relevant as a tool to address complex topics—such as biodiversity loss, climate change, or marine conservation—through experiential, emotional, and participatory approaches. As Fernández-Río and Méndez-Giménez [12] highlight, introducing game dynamics in the teaching of environmental issues promotes students' personal involvement and stimulates critical thinking, contributing to a deeper understanding of the relationships between humans and their environment. In this sense, environmental education workshops are ideal spaces for implementing gamified strategies, since they enable active learning through direct experimentation and shared reflection. Within the framework of the program *"El mar que nos une, aprende conociéndolo"* [The Sea that Unites Us: Learning through Knowing It], developed by CEIMAR and the Diputación de Cádiz, a gamified educational experience was implemented based on an adaptation of the game Dobble, entitled Marine Dobble. This teaching resource retains the original mechanics of the game—identifying the common symbol between two cards as quickly as possible—but has been recontextualized with illustrations of marine species from the Andalusian and Colombian coasts, selected for their ecological and cultural value. The game includes both emblematic and lesser-known species and represents relationships such as migration, shared habitats, or invasive presence, thus linking local and global biodiversity from an ecosocial perspective. The contextualization of the game is a key element for ensuring meaningful learning, since, as Ausubel [30] and Novak [31] argue, learning only occurs when new information can be related to students' prior knowledge and life experience. In this regard, adapting the game content to the local environment not only enhances concept comprehension but also strengthens affective bonds with nature and encourages attitudes of respect and care toward marine ecosystems. This emotional and cultural connection to the content, enhanced by the playful dimension of the resource, reinforces the sustainability competencies promoted by environmental education, such as active participation, systems thinking, and responsible decision-making [11,22]. Furthermore, the didactic proposal is structured into five pedagogical phases integrated into the course of the game, which address key aspects such as marine habitats, species adaptations, scientific curiosities, environmental problems, and personal commitment to the ocean. These pauses, designed as collective reflection moments during the game, make it possible to expand and contextualize the content, thereby strengthening the connection between gameplay and the objectives of environmental awareness and consciousness. In addition, recent studies have highlighted the potential of gamification in environmental education through proposals such as the escape box, designed to address complex socio-environmental issues like marine plastic pollution from integrative perspectives. These experiences are framed within Transformative Environmental Education [24,32] , the One Health approach [33], and the principles of Ocean Literacy [7,34]. Their implementation has shown a strong impact on students' motivation, participation, and critical understanding of the connections among marine pollution, animal health, and human health [18,25,35]. Along these lines, recent research reinforces the idea that gamification is an effective pathway to foster environmental literacy and ocean literacy. For example, Aragón and Brenes-Cuevas [36] demonstrated the potential of an escape box designed to explore marine plastic pollution, confirming a positive impact on students' motivation, involvement, and critical awareness regarding socio-environmental issues. Such proposals, together with resources like Marine Dobble, provide evidence that playful methodologies, when accompanied by reflection and contextualization, can act as catalysts for environmental action and commitment to sustainability.

3. Methodology

3.1. Context and Participants

This study is based on a marine environmental education workshop designed under a qualitative, exploratory approach, focusing on the use of gamification as a strategy for teaching content related to biodiversity and ocean conservation. The workshop, entitled Marine Dobble, was implemented in

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five 1º de la ESO classes in public schools in the province of Cádiz (Spain), with a total participation of 110 students between 12 and 13 years old. Each workshop lasted one hour and was conducted by an environmental educator with the support of a didactic guide structured into five thematic phases. No standardized evaluation instruments were applied, as the intervention was not intended to collect quantitative data. Instead, a qualitative observation tool, in the form of a field log, was used to record general impressions of the workshop's development, the students' reactions, their level of engagement, and possible evidence of learning.

3.2. Design of the Educational Experience

The teaching resource used was an adaptation of the commercial game *Dobble*, renamed *Marine Dobble*, in which each card represents eight marine species, and between any pair of cards there is always one match. Students played in groups of four, identifying the species that was repeated between their card and the one in the center, and saying its name out loud. The game proceeded in fast-paced rounds, fostering high levels of participation and visual attention.

Every 6-7 minutes, the game was interrupted to introduce a "didactic pause," during which images were projected, and open-ended questions were posed to the group. These five pauses formed a progressive didactic sequence, aligned with the objectives of Environmental Education for Sustainability and the principles of Ocean Literacy. The phases were organized so that students could establish connections between the species in the game and key ecological concepts: habitat, adaptation, biodiversity, threat, and commitment.

In addition, at the beginning and end of the workshop, open-ended questions were posed to the group, such as: "What marine animals do you know?" or "What do you think you can do to take care of the ocean?" These served as general indicators of student prior knowledge and of the types of learning acquired, as observed through their responses.

The following section presents the structure of the five phases of the workshop, including a synthesis of the contents addressed in each phase and the associated didactic intentions.

Table 1. Phases of the Marine Dobble Workshop, Addressed Contents, and Didactic Intentions

Workshop Phase	Topics Worked	Didactic Intentions
Pause 1: Marine Habitats	Diversity of marine habitats and species distribution (seafloor, beaches, open waters).	Recognize the variety of marine ecosystems and their ecological importance.
Pause 2: Surprising Adaptations	Physiological and behavioral adaptations of species (camouflage, ink, filtration).	Appreciate the adaptive richness of marine organisms and their connection with the environment.
Pause 3: Did You Know…?	Scientific curiosities: distinctions between algae and plants, remarkable species, living fossils.	Foster wonder, scientific thinking, and interest in biodiversity.
Pause 4: Ocean Challenges	Environmental impacts: pollution, warming, threatened species, and plastics.	To understand the relationship between human activities and environmental degradation.
Pause 5: Commitment to the Ocean	Individual and collective commitment to ocean conservation from land.	To promote awareness and responsible action in addressing ocean challenges.

3.3. Specific Competencies and Core Knowledge Addressed According to the LOMLOE

The Marine Dobble workshop directly contributes to the development of competencies and core knowledge established by the LOMLOE for 1º de la ESO, particularly in the areas of Biology and

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Geology, as well as in Civic and Ethical Values Education. Through a participatory and gamified dynamic, students analyze environmental phenomena, recognize ecological relationships, and propose responsible actions, thereby developing key competencies for citizenship committed to sustainability. Among the specific competencies addressed, CE3 (Awareness of the impact of human activity) is especially relevant. This competency is mainly developed during Pause 4, where students collectively reflect on ocean pollution, plastics, and coral bleaching. Students connect their daily habits with global environmental consequences, building a critical understanding of the link between society and nature. Likewise, CE5 (Communicating reasoned proposals and responsible attitudes) is promoted, particularly at the end of the workshop, when students are asked what individual actions they can adopt to protect the ocean. This moment allows them to express ideas related to responsible consumption, plastic reduction, or environmental awareness-raising among peers. With regard to core knowledge, SB D.4 (Water pollution: causes, consequences, and solutions) is especially relevant, as the workshop highlights how human waste affects emblematic marine species such as the loggerhead turtle. Through gameplay and didactic pauses, students gain meaningful understanding of the ecological effects of pollution and the importance of preventing it. In addition, SB E.8 (Valuing biodiversity and the need for its conservation) is worked on transversally across all phases of the workshop by showcasing a wide variety of local species (from both the Andalusian and Colombian coasts) and highlighting their uniqueness, adaptations, and ecological roles. This approach fosters respect, curiosity, and commitment toward marine life and ecosystems. Overall, the workshop articulates the development of cognitive, attitudinal, and ethical competencies in coherence with the principles of the LOMLOE, and within a framework of critical, active, and transformative environmental education.

4. Results and Discussion

4.1. Observation Instrument

To evaluate the pedagogical impact of the Marine Dobble workshop, an observation guide was specifically designed to accompany its implementation in the classroom. This guide, in the form of a field log, allowed for the qualitative recording of the workshop's development at four key moments: the beginning of the session (activation of prior knowledge), the gameplay dynamics, the didactic pauses between rounds, and the closing questions. No individual or quantitative data were collected, as the aim was to identify group-level patterns of participation, understanding, wonder, and environmental commitment. The analyzed observations correspond to five 1º de la ESO groups from different public schools in the province of Cádiz, with a total of approximately 110 students.

4.2. Start of the Workshop: Activation of Prior Ideas and Predisposition

The workshop began with open questions such as *'What marine animals do you know?', 'Do you know if there are many different types of life in the ocean?'* and *"What things do you think harm marine animals?"* In all five groups, a clear activation of prior knowledge was observed, although with varying levels of precision and depth. In general, the students responded enthusiastically and in four of the five groups, multiple marine species were cited. In three groups, several students used specific terms such as 'mollusks', 'cephalopods', or 'invasive algae'. The Cádiz school group (Group 2) demonstrated an exceptional level of participation and prior knowledge. They correctly identified species such as Posidonia oceanica and the ocean sunfish, differentiated algae from microalgae before receiving explanations, and displayed a highly consolidated scientific vocabulary. In contrast, one group showed lower initial concentration, possibly related to the absence of teacher support during the workshop, which made it more difficult to collect representative responses. However, even in this case, there was occasional participation from particularly interested students.

4.3. Game: Motivation, Interaction, and Connection with Content

Game dynamics were rapidly understood across all groups, generating a consistent atmosphere of playful competition combined with cooperative interactions (Figure 2). Motivation was uniformly

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high, but performance diverged when identifying less familiar organisms such as the basking shark, the ocean sunfish, or certain algae. In three groups, initial reliance on generic descriptors ("that one," "the shell," "the strange fish") evolved into the accurate use of species names during the session, evidencing a progressive appropriation of scientific terminology.

Figure 2. Students participating in the Marine Dobble activity, an educational game featuring local marine species, as part of the ocean literacy workshop.

One group made a particularly significant observation: before starting to play, they decided to take a few minutes to carefully analyze the cards, anticipating visual patterns and species types. This uncommon metacognitive behavior reflects a strategic approach and a deeper engagement with the material.

4.4. Didactic Pauses: Wonder, Understanding, and Dialogue

The five pedagogical pauses interspersed throughout the game allowed for the progressive introduction of key content. Each pause generated different levels of participation, curiosity, and reflection depending on the group. The observed results for each pause are described below:

Pause 1: Marine Habitats

In all groups, habitats such as beaches, seafloors, and open waters were recognized. Three groups successfully associated specific species with habitat types, and spontaneous comments arose about "marine neighborhoods." Understanding was particularly notable in Group 2 and the San Fernando group, where students showed interest in the movements of species such as dolphins and loggerhead turtles.

Pause 2: Surprising Adaptations

Pause 2 consistently elicited high levels of wonder across groups, particularly in response to the camouflage ability of the octopus and the size of the ocean sunfish (Figure 3). In several groups, the introduction of the term "chromatophore" triggered follow-up questions about mechanisms of color change, indicating that novel scientific vocabulary can function as an effective learning trigger during gameplay.

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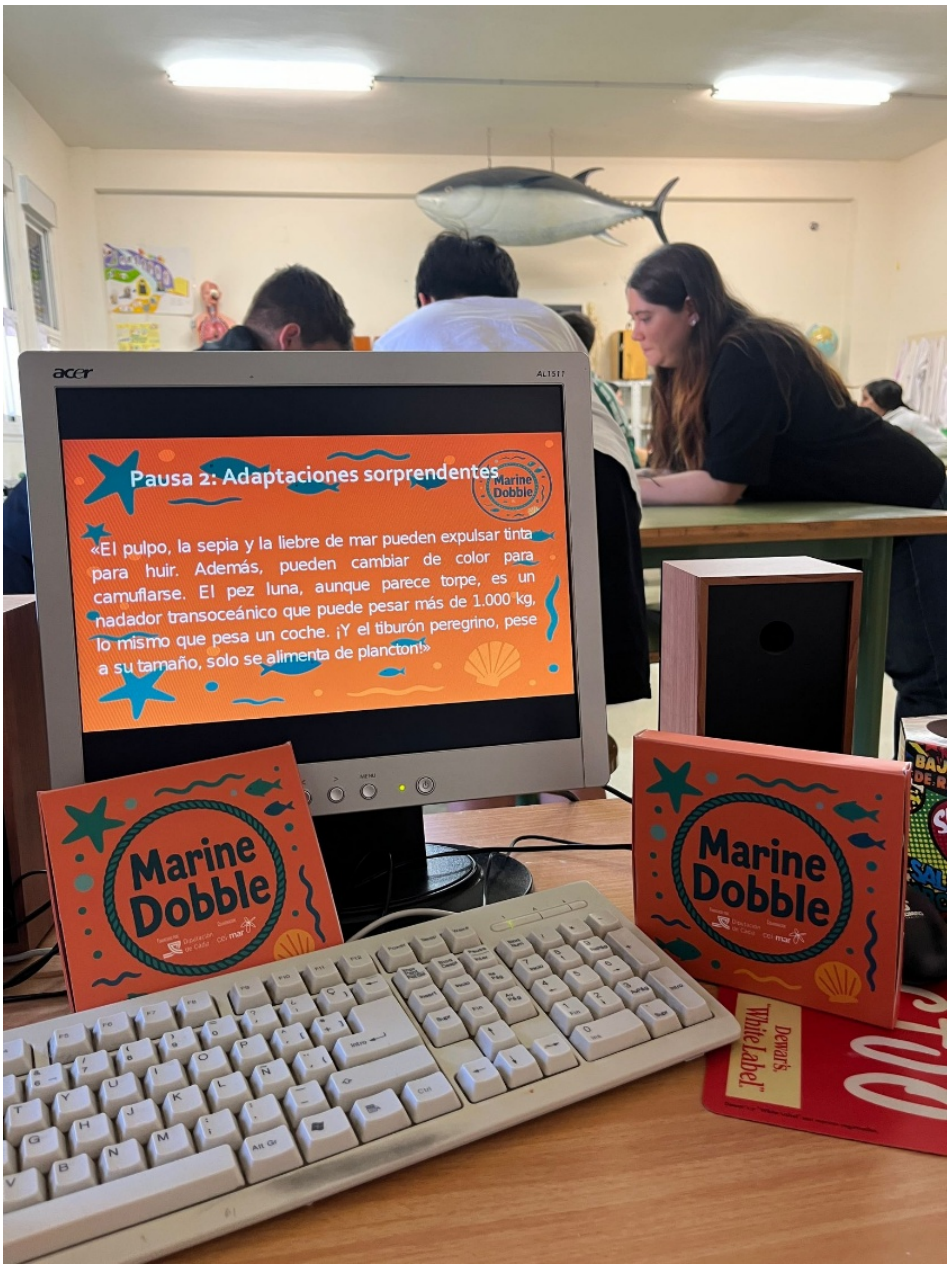

Figure 3. Photo pause 2 in middle of the workshop.

Pause 3: Did You Know…?

This was one of the most powerful moments of the workshop in terms of meaningful learning and scientific conceptualization. In four of the five groups, students expressed surprise at the fact that marine plants produce flowers and fruits, and even more so that microalgae generate a significant portion of the oxygen we breathe. This information elicited emotional reactions—"Really?", "I didn't know that!", "So algae are really important"—and was often reinterpreted as a discovery. In at least two groups, the difference between algae, plants, and microorganisms was discussed, allowing biological classification concepts to be addressed through students' curiosity.

Pause 4: Ocean Problems

Here, a clear progression toward critical awareness was observed. Issues such as pollution, coral bleaching, and plastic impacts were mentioned. In the San Fernando group, oil spills were highlighted, while in two other groups, direct references were made to marine litter and harmful everyday behaviors. Several students expressed empathy toward threatened marine animals and

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asked how they could help. In one group, the information about turtles mistaking plastic bags for jellyfish generated a moment of reflective silence.

Pause 5: Commitment to the Ocean

In this final phase, at least three of the five groups expressed personal proposals for caring for the ocean, including actions such as reducing plastic use, avoiding littering, saving water, or buying sustainable seafood. Some students stated they would share what they had learned with family or friends. Although one group did not have time to complete this part of the workshop, attitudes of respect and affection toward specific species, such as dolphins—described as "beautiful" or "worthy of protection"—were recorded.

The closing questions allowed for the collection of spontaneous learning outcomes and an overall assessment of the workshop's impact. Among the most frequently mentioned unfamiliar species were the ocean sunfish, sea hare, nautilus, and microalgae. Many students expressed surprise at the existence of "plants that live under the sea and produce flowers" and at "how important algae are for oxygen." These discoveries were experienced as moments of wonder that reinforced the emotional bond with marine biodiversity. In relation to proposed actions, ideas emerged concerning consumption reduction, water conservation, beach cleanups, and dissemination of the knowledge acquired. In some cases, students went beyond expectations—for example, one asked whether they could take the game home to continue learning. In general, the groups left the workshop with greater environmental awareness, new knowledge, and a positive emotional memory of the experience. The results of the five sessions show that the Marine Dobble workshop is an effective tool for combining meaningful learning, emotion, and participation in environmental education contexts. The game's structure, based on thematic pauses, allowed scientific content and environmental values to be articulated within a playful and progressive framework. The use of a contextualized gamified resource generated interest even in groups with attention difficulties and fostered critical thinking in groups with greater autonomy and conceptual background. In particular, Pause 3 was a turning point, as it allowed students to reinterpret the value of the ocean as a generator of life, oxygen, and plant biodiversity—dimensions often overlooked in formal education. The fact that in nearly all groups this content elicited surprise or excitement reinforces the need to approach marine biology through more experiential and relatable perspectives. Furthermore, differences among groups highlighted the importance of educational context and teacher involvement. In groups where teachers were present, greater concentration, respect for speaking turns, and better time management were observed. This suggests that, to maximize the workshop's impact, it is advisable to integrate it within a broader didactic sequence that includes continuity and follow-up.

As shown in Figure 4, Groups 2 and 4 exhibited consistently high profiles in all four dimensions, with particularly strong performance in scientific terminology and sustained initial participation. Group 1 achieved intermediate scores, notably higher in the dimension related to microalgae and marine plants. In contrast, Groups 3 and 5 obtained lower scores in conceptual vocabulary and final action proposals.

Two trends among groups stand out: (a) the content related to microalgae and marine plants consistently reached higher values across all groups, and (b) the initial levels of participation were uniformly strong. These patterns suggest that while the workshop reliably activated engagement, the depth of conceptual learning depended on contextual factors such as prior knowledge, classroom climate, and teacher support.

Figure 5 presents the aggregated mean values across the four observed dimensions, classified into four qualitative levels: very high ($\geq$ 4.5), high ($\geq$ 3.5 and $<$ 4.5), medium ($\geq$ 2.5 and $<$ 3.5), and low ($<$ 2.5). All dimensions reached the "high" level, indicating consistent engagement and understanding across groups. Within this overall pattern, the dimension related to microalgae and marine plants achieved the highest values, highlighting its central role as a driver of both cognitive learning and emotional engagement. In contrast, the dimension of final action proposals, while still in the "high" range, showed comparatively lower averages, suggesting that the translation of knowledge into concrete commitments may depend more strongly on group context and available time.

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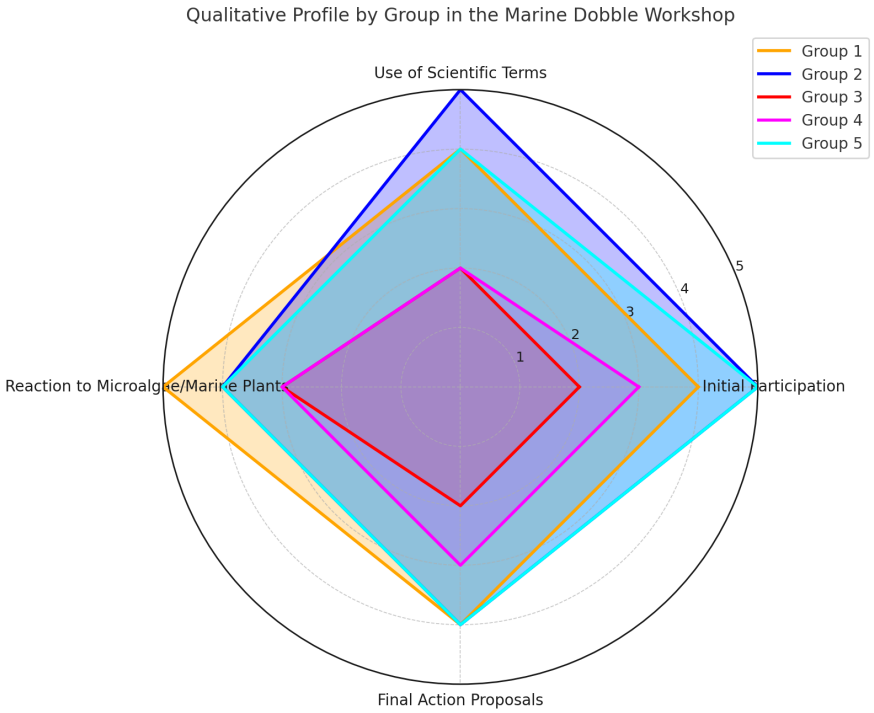

Figure 4. Qualitative profile of the five groups participating in the Marine Dobble workshop across four key dimensions: initial participation, use of scientific terms, reaction to microalgae and marine plants, and final action proposals. Each line represents a group's performance on a 1–5 scale, illustrating both common trends and contrasts in engagement and learning.

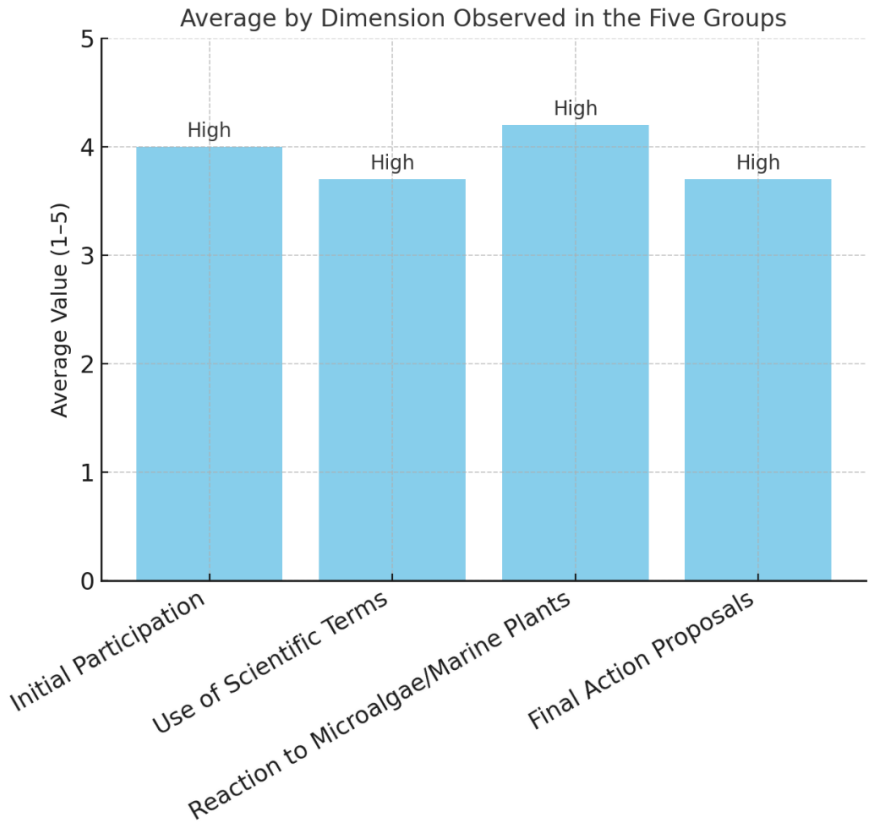

Figure 5. Average scores across the four observed dimensions in the five participating groups of the Marine Dobble workshop (scale 1–5). All categories—initial participation, use of scientific terms, reaction to microalgae and marine plants, and final action proposals—reached a "high" level on average, evidencing consistent engagement and conceptual understanding.

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Together, the results point to two central findings. First, curiosity-driven content—particularly the ecological role of microalgae and the existence of flowering marine plants—consistently triggered both cognitive gains and emotional engagement across groups. This reinforces the value of adopting active and contextualized methodologies in environmental education, echoing the perspectives of Tilbury [13] and Wals [21], who argue that learning for sustainability must be experiential, participatory, and action-oriented. In this sense, the gamification strategy applied through Marine Dobble acted as a catalyst for engagement, enabling not only knowledge acquisition but also an affective connection with marine biodiversity, in line with the observations of Mogollón et al. [11] regarding the development of sustainability competencies.

Second, contextual conditions, especially the presence of the teacher and the classroom climate, proved decisive in shaping the transition from initial participation to the formulation of concrete action proposals. These differences underscore that even well-structured gamified interventions require alignment with classroom dynamics to maximize impact. Moreover, the strong responses generated by content such as the oxygen production of microalgae or the existence of flowering marine plants illustrate the effectiveness of combining curiosity and surprise as drivers of meaningful learning, as proposed by Novak [31]. In general, the integration of gamification, contextualization, and reflective dialogue emerges here as a promising pedagogical pathway to promote critical and transformative ocean literacy.

5. Conclusions and Future Perspectives

The results of the five workshops carried out with 1º de la ESO students in schools across the province of Cádiz suggest that Marine Dobble is an effective and engaging didactic strategy for addressing marine biodiversity, environmental impacts, and sustainability from a playful and participatory perspective.

The contextualized gamification design fostered both emotional and cognitive engagement, even in groups with dispersed attention or lower initial motivation. The activity enabled the activation of prior knowledge, the incorporation of new concepts, and the connection of scientific content with students' everyday experiences. The didactic pauses played a pivotal role in conceptual progression, with particularly meaningful reactions emerging around the discovery that some marine plants produce flowers and that microalgae are a key source of atmospheric oxygen. These moments of wonder reinforced students' connection to the marine environment and deepened their understanding of the ocean as a vital planetary system.

The closing phase provided evidence of attitudinal transformation: students proposed concrete actions such as reducing waste, protecting species, and sharing knowledge with peers and family, signaling an initial step toward environmentally responsible citizenship. At the same time, the findings reveal the importance of contextual factors—such as teacher involvement, classroom climate, and prior experience—which influenced the depth of interaction and the consolidation of learning. This variability highlights the need to embed workshops like Marine Dobble within broader and sustained didactic sequences, thereby ensuring continuity, reinforcement, and greater long-term impact on students' environmental awareness and commitment.

6. Limitations of the Study

As with any educational process implemented in real contexts, the Marine Dobble workshop presents limitations that must be considered when interpreting the results and projecting its application to other settings.

First, the study followed a qualitative and exploratory approach based on group-level observations, without collecting individual data or applying quantitative measures of learning. This restricts the possibility of generalizing the findings or making precise comparisons across groups. In addition, as the observations relied on field notes and the evaluator's judgment, some nuances may have been lost or subjectively interpreted despite the use of a structured guide.

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Second, the one-hour duration of each workshop limited the full development of all phases and, in some cases, prevented the collection of final responses or the exploration of action proposals in depth.

Third, the influence of educational context and teacher involvement proved decisive. Groups without teacher accompaniment showed greater difficulties in maintaining attention and regulating participation, underscoring the importance of implementing such activities in coordination with teaching staff.

Despite these limitations, the experience provides valuable implications for educational practice. The results confirm the pedagogical value of introducing marine biodiversity through playful and contextualized strategies capable of fostering curiosity, wonder, and environmental awareness, even among students with little prior familiarity. Moreover, the findings suggest that gamified resources can contribute to the development of transversal competencies—such as critical thinking, ecological empathy, and sustainability commitment—particularly when combined with teacher mediation and collective reflection.

Looking ahead, future implementations could benefit from (a) complementary materials—such as worksheets, videos, and pre/post activities—that allow teachers to embed the workshop within broader didactic sequences, and (b) adapted versions for different educational levels, from primary to upper secondary and non-formal education. Furthermore, advancing the evaluation through mixed-methods approaches would enable a more precise documentation of learning progression and an assessment of medium-term impacts on students' attitudes toward marine conservation.

Overall, Marine Dobble emerges as an innovative and replicable tool with potential for integration into educational programs on ocean literacy and sustainability. These conclusions align with recent studies that highlight the importance of playful and reflective approaches in environmental education, where formats such as educational games and escape rooms have proven effective in fostering not only knowledge acquisition but also civic action in response to global challenges such as climate change and marine pollution [18,32,35].

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