Marine Pollution Bulletin 192 (2023) 114963

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Marine litter education: From awareness to action

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ARTICLE INFO

Keywords:
Marine litter
Education for sustainable development
Students
Knowledge
Perceptions
Integrated intervention

ABSTRACT

Marine litter is a global problem. Education has been acclaimed as a potential tool to tackle this issue, yet, integrative, student-centered, and over weeks studies to raise awareness on the theme that compares pre- with post-intervention results are limited in the literature. Furthermore, almost no studies rely on the basis of previous experience on the theme and local reality. This paper presents the design, implementation, and evaluation of an educational intervention to raise awareness and educate students (1st cycle to high-school) about marine litter. Different learning skills were fostered through theoretical, laboratorial, and hands-on activities and students participated in a beach clean-up to summarize the classroom's learnings *in loco*. Pre- and post-questionnaire results indicate that students' knowledge, perceptions, and behavioral intentions changed. Identification of marine litter estimated degradation times and observation of microplastics in local sand samples were activities highly appreciated by youngsters. This intervention positively impacted schoolchildren's literacy, contributing to advancing education in marine litter and can be further adapted to other educational areas.

1. Introduction

Litter has been acclaimed as one of the most pervasive and fastest-growing anthropogenic change in coasts and seas, being already used as an indicator of the Anthropocene (Rangel-Buitrago et al., 2022). According to United Nations Environment Programme, marine litter is defined as any persistent, manufactured, or processed solid material that enters the marine and coastal environment (UNEP, 2009). Several biological (Kiessling et al., 2015; Kühn et al., 2015), social (Potts and Hastings, 2011; Ragusa et al., 2021), and economic (McIlgorm et al., 2022; Mouat et al., 2010) implications have been attributed to this growing issue. Recently, microplastic fragments have been found in human placentas (Ragusa et al., 2021) and marine litter and climate change were shown to be inextricably connected (Lincoln et al., 2022). It has also been documented that with no meaningful actions, the quantity of plastic waste entering aquatic ecosystems can nearly triple by 2040 (UNEP, 2021). Predictions are alarming, reinforcing the urgency of action.

The management scheme for addressing marine litter is divided into preventive, mitigating, removing, and behavior-changing measures. Removal and mitigation measures have a short and medium-term impact, whereas prevention and behavior change actions have a long-term impact (Rangel-Buitrago et al., 2020). Behavior-changing actions are cross-cutting and support the development of the remaining measures, thus being considered essential in curbing the marine litter problem at its root. Education campaigns and awareness-raising activities are examples of measures that can be used to influence behaviors, thus engaging people in marine debris reduction (Chen, 2015).

Education's role in sustainable development received renewed attention with the 2030 Agenda for Sustainable Development. The

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https://doi.org/10.1016/j.marpolbul.2023.114963
Received 17 March 2023; Received in revised form 12 April 2023; Accepted 15 April 2023
Available online 16 May 2023

document adopted in 2015 has 17 Sustainable Development Goals (SDGs) and 169 associated targets. Ensuring an inclusive and quality education for all (SDG4) and conserving the ocean (SDG14) are foreseen in this Agenda. Parallel, it is expected the acquisition of knowledge and skills through education (target 4.7) and a significant reduction of marine pollution by 2025 (target 14.1) (United Nations, 2015). Developing competencies that empower people to reflect on their actions is one of the aims of education for sustainable development. The promotion of critical thinking is likewise among the goals of this education. It is a holistic, competence-based, and transformational education that privileges learning over teaching, in a learner-centered teaching approach (Rieckmann, 2018). A 'new type of thinking is essential if mankind is to survive and move to higher levels' was said more than 75 years ago by Albert Einstein and remains as up-to-date as it was in the last century (Einstein, 1946).

A typical target group of such awareness-raising and educational actions are children (Hedefalk et al., 2014). As there are barriers to adult education (e.g., time and funding), numerous educational programs rely on youngsters due to their recognized role as agents of social and community change (Duvall and Zint, 2007; Torres-Harding et al., 2017). Although various authors had previously explored marine litter educational interventions and outreach programs with youngsters, they continue to be a group where actions are needed. Hartley et al. (2015) evaluated the effectiveness of activities on 176 British schoolchildren, Torres et al. (2019) on 120 primary to high school scholars, Locritani et al. (2019) on 87 high school students, and Kusumawati et al. (2020) on 150 senior high school students. Most of the above-referred studies worked with the participants for a limited period (e.g., a 45–50 min intervention) and used little diversified strategies to deepen the subject, not always instilling critical thinking and a reflective spirit. The study presented here relied on the creation, implementation, and assessment of a novel integrated educational intervention, which was continuous over weeks and employed different strategies and activities to explore the theme. The program was designed to cover distinct marine litter topics as well as stimulate pro-environmental attitudes and behaviors. Also, it employed active learning methodologies as they tend to have positive impacts (O'Flaherty and Liddy, 2017). The traditional teaching practices where the teacher passes knowledge through lectures were replaced by innovative techniques, where the tutor acts as a guide and provides opportunities for learning and critical thinking development (Chong et al., 2008; Heaysman and Tubin, 2019). Overall, the intervention presented here aimed to promote 21st-century skills (i.e., critical thinking, collaboration, communication, and creativity) through different abilities (e.g., interpret information and draw conclusions, make decisions or solve problems, train flexibility and decision making, share information with others) to enhance young awareness and stimulate co-responsibility for marine litter (Amran et al., 2019; Battelle for Kids, 2019). Recent studies support such choices: 'findings suggest that pro-environmental behavior change cannot be expected from participation in environmental [citizen science projects] CSPs alone; it requires the incorporation of auxiliary educational activities' (Wichmann et al., 2022, p. 105035).

The research question of this study was 'how effective is an integrated theoretical, laboratorial, and hands-on educational program designed for young people in changing perceptions and raising awareness and literacy about marine litter?'. The study evaluated whether the proposed intervention could foster youngsters' marine litter perceptions and critical thinking through a diversified set of actions instead of the overexploited traditional educational strategies. It was hypothesized that participation in the intervention would positively change knowledge, perceptions, and literate on marine litter theme the young population, stimulating critical thinking and pro-environmental intentions. A pretest-posttest design was used to verify the hypothesis, following Hartley et al. (2015), Locritani et al. (2019), and Kusumawati et al. (2020) approach. The effect of age and gender was also investigated. The study was conducted in Funchal municipality - Madeira Island (Portugal, NE Atlantic) - a small island vulnerable to marine pollution (Cardoso and Caldeira, 2021). To ensure the designed educational program was targeted to the island's marine litter reality, instead of being another generic awareness intervention, it was created after a deep understanding of the local situation on the basis of previous works. A survey to the population was conducted in earlier research, identifying what inhabitants know and not about marine litter and on which topics greater awareness is needed (Bettencourt et al., 2023b). Also, marine litter was monitored over two years on the South coast of Madeira Island to perceive which items were frequently found and which behaviors possibly lead to their accumulation (Bettencourt et al., 2023a).

2. Material & methods

2.1. Participants

The study was conducted in Funchal municipality, framed in a broader work on awareness of marine litter. Public municipal schools from different cycles, selected for convenience due to proximity, were contacted to participate in the educational interventions. A total of 269 students between 7 and 17 years old (mean age 12 $\pm$ 3 years old) from 3rd (7–10 years old), 5th (10–12 years old), 8th (13–16 years old), and 10th (14–18 years old) grades from five schools (14 classes), accepted to participate in this study. An official request to the Regional Secretary of Education for the implementation of the intervention and application of the questionnaires in the schools was made and approved. Parents/guardians provided written informed consent for students to participate in the study and complete the questionnaires.

2.2. Intervention

Students' intervention comprised three mandatory sessions, usually in consecutive weeks (one per week), and one optional outdoor session (when the environmental and logistic necessary conditions and authorizations were met). Each session took 90 min and was developed during school hours. Only the 1st cycle sessions were shorter - 60 min - to guarantee students' attention. As described next, multiple techniques and approaches were used with minor adjustments considering the school year and the conditions of the classrooms.

The first session started with brainstorming. Students were asked to indicate which words they associate with marine litter. In classes where most students had a mobile phone, an online platform was used to collect words and construct word clouds. In the remaining, the collection of ideas was carried out orally. The ideas gathered served as a motto for defining the marine litter concept. In groups, students then played a game using a magnetic board to select the most common compositions of marine litter. With the game, students realized plastic belongs to the most predominant items, so the pros and cons of its use were presented and discussed. Following a common thread, students were asked how objects often end up in the ocean. Marine litter pathways and sources were examined using a scheme, short videos, and real images collected on their island. The concept of oceanic gyres was presented and pictures of litter floating on the water's surface were shown. The pictures were used to explain that floating litter represents a small part of the total litter, leading students to realize that the problem is much bigger than shown in those images. This was used to introduce the impacts of marine litter. Scholars were asked to indicate which consequences they mostly associated with marine litter. Results were discussed collectively and each impact was explained using images and videos. For the environmental consequences, animal models were distributed to students, as well as marine litter items (such as straws, disposable masks, six-pack rings, etc.), so that students could mimic the effects of debris. In groups, students presented to the class the impacts the items 'caused' on the fauna, promoting critical thinking and the development of communication and collaboration skills.

The second session started with a recap of the previous session,

identifying what participants retained. This session mainly consisted of team activities and collaborative games. Groups of 4–5 students were formed and asked to link the estimated degradation times (reference values from National Oceanic and Atmospheric Administration and Woods Hole Sea Grant) to different marine litter items. This activity proceeded with the presentation of some numbers to raise awareness: how much litter is estimated to exist in the ocean and enters yearly the sea. National and regional newspaper titles were shown so that participants recognize marine litter as a current threat in the place where they live. A small case study about litter found buried on a Portuguese beach after 40 years with still legible labels was analyzed by students for them better comprehend extensive litter degradation times. Then, it was explained how OSPAR marine litter samplings are performed. Each group received items collected on island beaches (e.g., part of iron, fishing wires, glasses, sneakers, umbrellas, straws, and electric cables). The task was to perceive how such items ended up on the beach and what their impacts could be. Each group presented the main conclusions to the entire class. Aware of the amount of litter found, students were afterward asked to propose individual and collective measures to tackle marine litter. Ideas were discussed and the session ended with the presentation of pro-environmental actions everyone can do, activities that must be stopped, and examples of initiatives that are being developed and implemented by collective entities. The session fostered various students' skills (Table 1).

The third session was laboratorial and took place in the schools' laboratories (whenever possible). Sand was brought to the activity and students were asked to pick up with tweezers the litter they found and discuss its composition. Separation by size was then carried out using sieves. The students prepared a solution saturated with sodium chloride and filtered the supernatant by suction. After, they observed the filter with the retained microplastics using a stereoscopic magnifier and realized the presence and the small size of microplastics in sand samples.

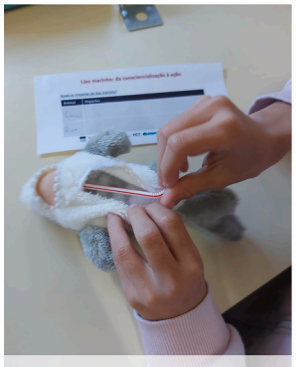
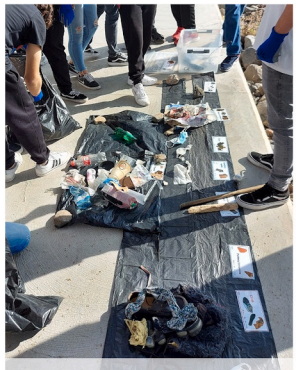
A fourth session – a beach clean-up activity – occurred for seven classes (115 students). This activity was optional due to transportation and leaving school constraints. In this session, students and teachers visited beaches and conducted a marine litter sampling following the OSPAR methodology (OSPAR Commission, 2010). All the litter collected was weighed and sorted into categories. Results were discussed collectively, leading students to realize that marine litter is a cause of concern on their island and to identify possible sources/pathways of some of the found items. Table 1 discriminates the objectives, activities, materials, and skills of each session.

2.3. Tools

A questionnaire to evaluate changes that occurred during the educational interventions was prepared and pre-tested with a small group of students ($n = 39$) in the academic year preceding the study. Some questionnaire adjustments were made: shortening it, simplifying some words, adjusting it to be jargon-free, and adding a visual scale to the questions with 1 to 5 Likert options (Appendix A). The final version of the questionnaire was subdivided into different sections. The questions were adapted from the study of Hartley (2013) and new ones were added. Questions and response options were in Portuguese and took approximately 5–8 min to be filled.

Students' parents/guardians provided written consent for their participation in the questionnaires. Nevertheless, participants also gave consent to participate in the study in the first question. For those who consented, the questionnaire started. The same questionnaire was distributed before the 1st session (pre-questionnaire) and at the end of the 3rd session (post-questionnaire) to evaluate the changes that have occurred. Confidentiality of answers was ensured. From the 269 students involved in this study, 256 completed the pre-questionnaire ($n_{female} = 112$, 43.75 %; $n_{male} = 137$, 53.52 %; $n_{other} = 7$, 2.73 %) and 243 the post-questionnaire ($n_{female} = 117$, 48.15 %; $n_{male} = 121$, 49.79 %; $n_{other} = 5$, 2.06 %). The difference in the number of students and

Table 1
Overview of the marine litter educational intervention developed over four sessions. Sessions 1 to 3 occurred in the school's facilities and the fourth session was on the beach.

Marine litter educational intervention	 Session 1	 Session 2	 Session 3	 Session 4
Objectives	Understand the marine litter concept, its composition, sources/pathways, and main impacts	Realize the amount and degradation rates of marine litter | Analyse litter found on region beaches | Propose actions to curb marine litter rise	Separate and observe microplastics | Perceive microplastics' ubiquitous distribution	Comprehend marine litter monitoring protocol | Discuss how items could reach the beach
Activities	Ideas collection (e.g., brainstorming) | Team games | Short videos | Simulation games | Presentation and discussion of ideas	Team games | Case study analysis | Presentation and discussion of ideas | Proposal of measures to solve a problem	Laboratory activity | Critical reflection on learning experience and results | Engagement with the problem under study	Practical activity | Critical reflection on results | Engagement with the problem under study
Materials	Magnetic board | Animal models | Marine litter items	Magnetic board | Marine litter items	Sand | Laboratory material | Sodium chloride	Measurement tape | Gloves | Bags | Scale
Skills	Critical thinking | Collaboration | Communication	Critical thinking | Collaboration | Communication | Creativity	Collaboration | Communication	Collaboration | Communication

questionnaires is due to scholars who were absent, did not want to answer, and null questionnaires.

The questionnaire included the following sections: Section 1 asked for two words related to marine litter. That was the first question to avoid biased answers, as the following words used in the questionnaire could influence the answers. Word clouds were constructed using the WordCloud Generator by MonkeyLearn Inc. to analyze the frequency of terms related to marine litter. The following questions were multiple or single-choice options. In Section 2, there were four questions: first, respondents had to choose the three commonest marine litter compositions, then select the degradation time of cigarette butt, disposable diaper, plastic bottle, aluminum can, and plastic bag, and afterward decide how are called the plastic particles with size less than 5 mm. Finally, seven statements about perceptions of marine litter were presented and participants had to choose between totally disagree (1) to totally agree (5). Section 3 listed pathways/sources for respondents to indicate their contribution to litter accumulation (1 - don't contribute anything to 5 - contribute a lot) and Section 4 marine litter impacts for punctuating between no impact (1) to high impact (5). In Section 5, respondents had to say how probable it was for them to practice certain actions (1 - never to 5 - always). In section 6, age, grade, gender, and municipality were collected and comments and observations were registered in section 7 (Appendix I in the Supplementary Material).

The questionnaire was made available for students online through a QR code or link. Lime Survey software (version 2.06) was used to collect the answers. Printed copies were offered to participants who could not use their mobile phones or tablets to fill in the questions.

2.4. Statistical analysis

The data from the questionnaires were analyzed using the Python programming language (version 3.8), with auxiliary open-source libraries, such as the SciPy library.

Upon data importation, all Likert scale questions were considered on an ordinal scale, being the responses encoded as a value from 1 through 5 (Coolican, 2014). To statistically analyze these questions, the nonparametric Mann–Whitney *U* test was used to determine if there were statistically significant differences between pre- and post-intervention responses (MacFarland and Yates, 2016).

Regarding the estimated degradation times of the marine litter items questions, data were encoded in a binary fashion, with '1' denoting the correct answers and '0' indicating the incorrect answers. As a result, and with the objective of comparing the relative frequency of correct answers between pre- and post-intervention groups, the Pearson's Chi-square (χ^2) test with Yates's correction for continuity was used. It is important to note here that the assumptions of this test were verified, namely that the observations are independent of each other and that the expected frequencies are at least 5 in no less than 80 % of the cells in the contingency table (Coolican, 2014).

Due to a low number of respondents, the statistical analysis did not include respondents who answered 'other' in the gender question. When studying the effect of age on the different topics, participants were grouped into four equally-spaced age groups (7–9, 10–12, 13–15, and 16–18 years old). It is important to note that three respondents did not fill in their age in the post-questionnaire. As a result, these subjects were not considered when studying the effect of age.

Finally, each statistical test was conducted considering the significance level of 0.05 (α). Moreover, when applicable, *p*-values were adjusted according to the Bonferroni adjustment for multiple comparisons (Wuensch, 2011).

3. Results

3.1. Marine litter concept

Litter, pollution, plastic, sea, and marine animals were the words students most associated with marine litter before the educational strategies (Fig. 1a). After the interventions, the written words were mostly the same but with different frequencies: the words 'cigarettes' (1.56 % to 4.32 %) and 'metal' (0.39 % to 1.23 %) increased frequency; the words 'pollution' (16.99 % to 15.43 %) and 'animal' (5.47 % to 3.70 %) had reduced the number of times they were written (Fig. 1b).

3.2. General perceptions and knowledge about marine litter

In line with predictions, before the raising awareness sessions students recognized that plastic (97.66 %) and cigarette butts (60.55 %) belonged to the top of the most common compositions of marine litter. Glass (39.84 %) was pointed out as the third most common material found on sea and beaches. Post-intervention results show that participants correctly indicated plastic (97.53 %) and cigarette butts (90.95 %) as the topmost common items of marine litter but realized during the sessions that metal is also commonly found (14.06 % in pre-intervention and 68.72 % in post-intervention), instead of glass as initially pointed out. In the same trend, the percentage of correct answers about the marine litter estimated degradation times increased after the sessions (Table 2). The disposable diaper was the item whose correct answers registered the higher difference as most students (60.94 %) initially believed diapers take 50 or fewer years to degrade in the environment, having only 10.94 % predicted that this item could take between 400 and 500 years to degrade. After the intervention, 79.01 % of students correctly estimated the degradation time of a disposable diaper. A similar tendency of increase in the number of correct answers occurred for the remaining questionnaire items. A $\chi 2$ test of independence was used to confirm this analysis, examining the difference in frequencies between pre- and post-intervention across the number of correct

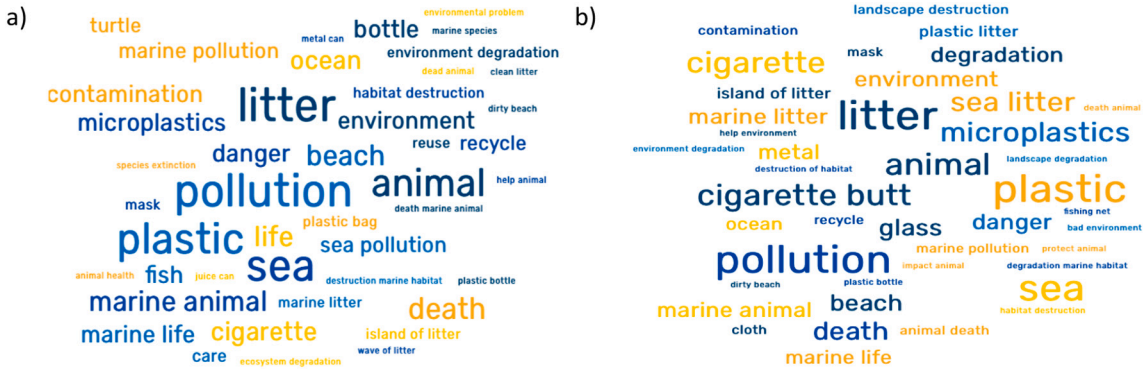


Fig. 1. Students' pre- (a) and post-intervention (b) keywords about marine litter.

Table 2
Percentage of students who correctly indicated the estimated degradation rate of different marine litter items in the pre- and post-intervention questionnaire. Differences that were registered in the correct estimated degradation rate between the pre- and the post-intervention (right more filled in green, more correct answers in the post-intervention) and χ^2 test. *$p < .001$.

Item	Estimated degradation rate	Pre-intervention	Post-intervention	Difference	χ^2
Cigarette butt	1-5 years	36.72%	77.78%	41.06%	83.946 *
Plastic bag	10-20 years	6.25%	51.85%	45.60%	125.107 *
Aluminum can	200 years	16.02%	49.38%	33.36%	61.992 *
Plastic bottle	450 years	36.33%	58.44%	22.11%	23.576 *
Disposable diaper	450 years	10.94%	79.01%	68.07%	231.612 *

answers (Appendix Table I in the Supplementary Material). As expected, all the statistical tests were significant, with the post-intervention students being more likely to indicate the estimated degradation times correctly.

Before the interventions, 84.34 % of students knew that plastic particles with a size less than 5 mm are called microplastics, a value that increased to 93.83 % after the three weeks of sessions; however, this difference was not statically significant ($p = .608$, as per the Mann–Whitney U test).

After the educational actions, students better realized that marine litter is a problem in their region and that their family and friends know what marine litter is and talk about it. As depicted in Fig. 2, these questions had their percentage of answers 'totally agree' significantly increased after the intervention; the remaining aspects, however, did not show evidence of a statistically significant difference between pre- and post-intervention (Appendix Table II in the Supplementary Material).

Interestingly, the age group of 7–9 years old (the youngest age group) showed a positive statistically significant difference after the intervention in the item 'most of my family and friends know what marine litter is and talk about it'. No other age groups, as well as gender, differ significantly among the items after the intervention (Appendix Tables III and IV in the Supplementary Material).

3.3. Sources/pathways of marine litter

The perception of the people's role in leaving garbage on the beach and the contribution of streams, irrigation channels, and rivers to litter accumulation in the sea positively changed after the intervention (Fig. 3). Similarly, after interventions, the influence of sewage discharges to the coast was stronger understood as a pathway of marine litter.

Nevertheless, the statistical tests (Appendix Table V in the Supplementary Material) suggest that garbage left on the beach is the only marine litter source showing a statistically significant difference between pre- and post-intervention. Still, in this item, the age group 13–15 years old and male students were the ones who showed a statistically significant difference after the intervention (Appendix Tables VI and VII in the Supplementary Material).

3.4. Marine litter impacts

Questionnaire answers show that the perception of marine litter consequences on marine life, human health, and appearance/aesthetic of beaches did not vary statistically significantly, as most students recognized their high impact both before and after the intervention (Fig. 4). Marine litter impact on tourism was noted by most of the pre-intervention participants as a medium-level consequence (52.34 %). After the educational actions, a statistically significant difference was detected, with some participants considering it as having a higher impact when compared to pre-intervention (23.05 % reported a 'high' impact on pre-intervention and 43.62 % in post-intervention). This behavior was also seen among students from the 7–9 years old age group and among female students. Recognition of marine litter consequences on shipping and fishing equally increased, with the difference being statistically significant. The statistical analysis of the marine litter impacts is detailed in Appendix Tables VIII, IX, and X in the Supplementary Material.

3.5. Behaviors intentions for reducing marine litter

Children and teenagers reported high intentions of performing litter-reducing actions, both before and after the educational interventions (Fig. 5). Use or say to parents to use their own bags when shopping, sort the garbage and recycle, and don't leave trash on the beach, mountains, floor, irrigation channels, and streams were the actions students reported a higher willingness to perform (median of five). The usage of reusable products, avoidance of plastic, and advertisement to the closest ones to the adoption of sustainable practices were the intentions that registered a lower intention of being achieved.

Despite that, the percentage of responses to those last two items showed statistically significant differences after the intervention (Appendix Table XI in the Supplementary Material), as students showed to be more prone to these sustainable practices. In the same direction, students between 7 and 9 years old showed statistically significant differences in the intention of using reusable products and students in the 13–15 age group in avoiding plastic use (Appendix Table XII in the Supplementary Material). Male students also showed a positive, statistically significant effect on avoiding plastic when pre- and post-intervention were compared (Appendix Table XIII in the Supplementary Material).

4. Discussion

'If people don't want litter in their homes why do they put it in the ocean, which is fishes' home?' was a question asked by a 3rd-grade child at the beginning of the authors' educational intervention. Considering that education's role is recognized in supporting behavior change (Hartley et al., 2018a), an integrated intervention to educate and raise awareness among students regarding marine litter was developed and evaluated to test the research question. The intervention was based on the earlier context of population awareness and on the characterization of the region's marine litter and covered different topics.

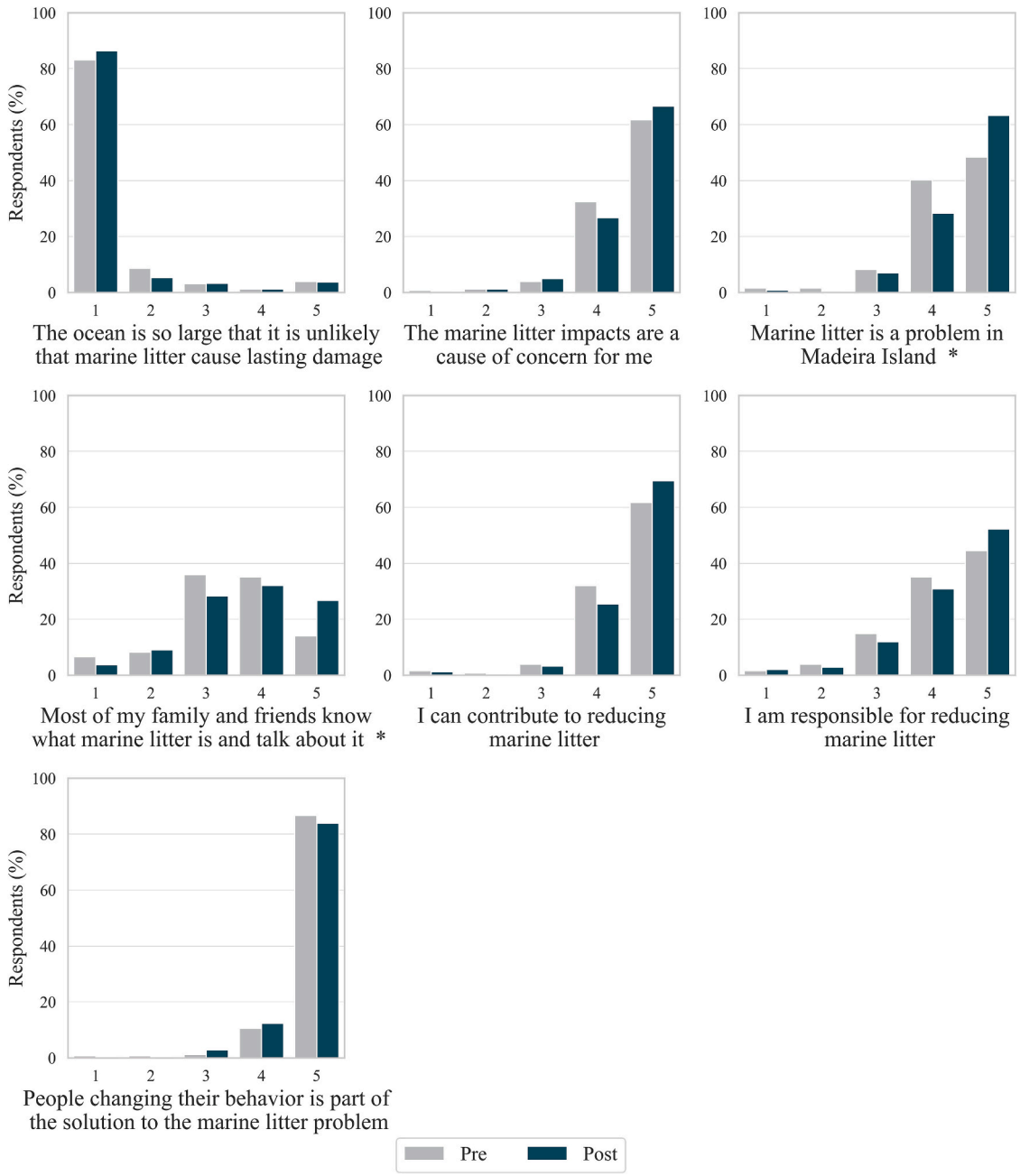


Fig. 2. Students' pre- and post-intervention percentages regarding the perceptions about marine litter (1–5 scale: totally disagree – totally agree). *$p < .05$.

Results indicate that the marine litter theme was not unknown to students as they demonstrated a pre-existing baseline knowledge and perception of the issue. Such was predictable, as schools closer to the coast tend to have higher knowledge scores (Mogias et al., 2019). Also, Portuguese schools have in their curricula a subject called 'Citizenship and Development' where environmental issues are frequently addressed (GTEC, 2017). A survey about marine litter to Madeira Autonomous Region inhabitants equally supports such pre-existing knowledge (Bettencourt et al., 2023b). Nevertheless, alterations in the way students perceive marine litter concept, theme, knowledge, sources/pathways, and impacts were registered after the intervention, corroborating the initial hypothesis.

Participants were somewhat aware of the marine litter concept, as shown by the words used to define the topic. After the intervention, the word 'cigarette butt' gained relevance compared to the pre-questionnaire. This was expected, as students learned that it is at the top of the list of the most common litter items (Araújo and Costa, 2019) and is a hazardous waste (Torkashvand et al., 2020). Furthermore, participants had the opportunity to see a bottle full of cigarette butts during the intervention (from a previous beach clean-up) and the ones who participated in the beach clean-up action collected and counted hundreds of them (Appendix B), realizing their ubiquitous presence in the environment.

Attending the educational intervention also deepened students' knowledge of the theme and altered some perceptions. A clarification of the usual litter items composition was accomplished: together with cigarette butts and plastic, participants realized metal shares the list of the most common compositions of marine litter (Araújo and Costa, 2019; Tekman et al., 2021), instead of glass as they initially thought. Similarly, a high percentage of students (84.34 %) already knew the name of plastic particles smaller than 5 mm even before participating in the hands-on microplastic sampling activity in week 3. The percentage

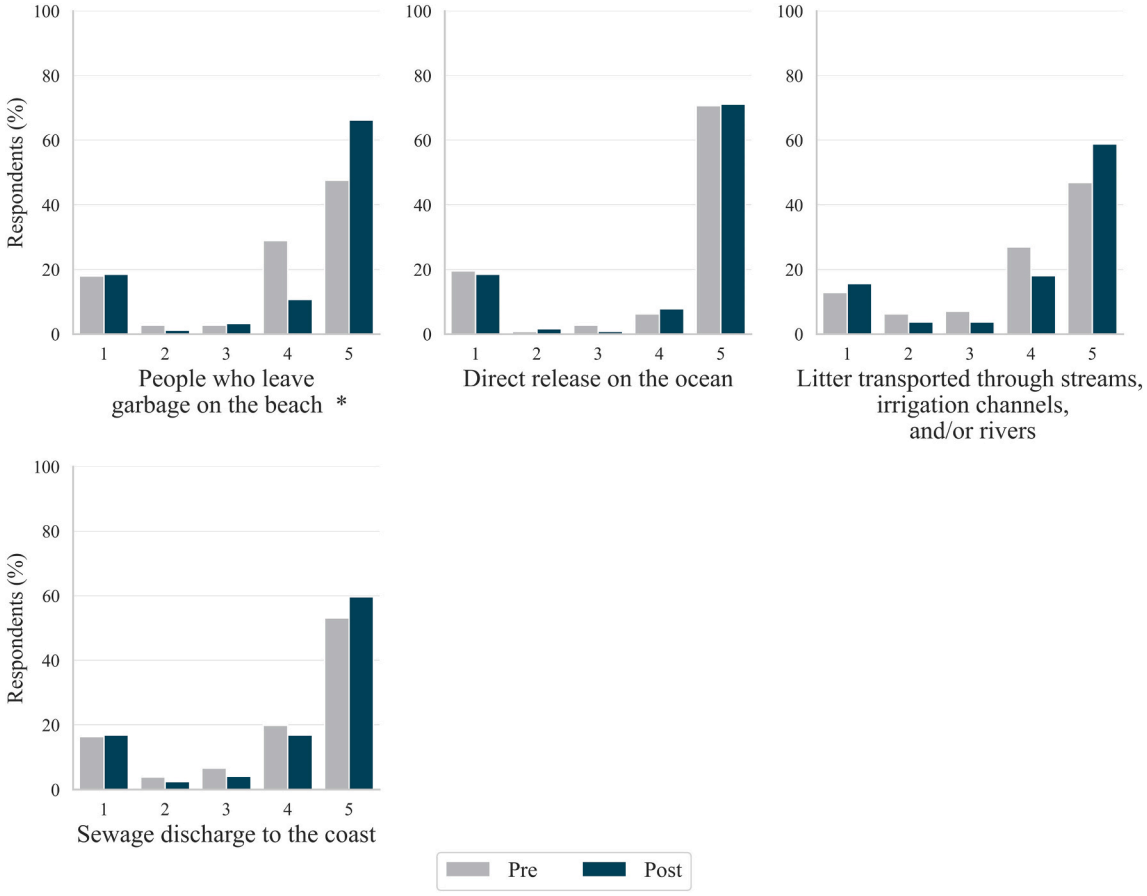


Fig. 3. Students' pre- and post-intervention percentage regarding the recognition of the sources/pathways of marine litter (1–5 scale: do not contribute at all – contribute a lot). *$p < .05$.

of students correctly naming these particles as microplastics increased from 84.38 % to 93.83 % after the three weeks intervention. With the boosted number of papers on microplastics over the last years (Barboza and Gimenez, 2015) and the report on microplastics in canned fish (Karami et al., 2018) and commercial sea salts (Iñiguez et al., 2017; Yang et al., 2015) it was expected a higher concern and knowledge of the term. Furthermore, the media plays an essential role in this topic: the Internet is the principal information source about microplastics and articles about this subject are among the most re-tweeted and commented (Garcia-Vazquez and Garcia-Ael, 2021). Indeed, it does not surprise the high number of correct answers even before the intervention. Nevertheless, and despite the question being formulated differently in other studies, the results of this differ from the ones of Deng et al. (2020) that concluded that only 26 % of the surveyed adults had already heard of microplastics and from Frias and Nash (2020) whose online survey showed only 19 % of respondents knew microplastics are smaller than 5 mm.

About the estimated degradation times of some marine litter items, the young were not so sure about them before participating in the actions. This is consistent with Hartley et al. (2015) study, where the authors stated that knowledge about degradation time changed substantially after their educational intervention. In this research, plastic bottles and aluminum cans were the objects that students were more aware of the degradation times. On the other hand, cigarette butts, plastic bags, and disposable diapers were the items that registered a greater variation (more than 40 %) in the proportion of correct degradation times after the intervention. Giving the example of a diaper used by a baby and explaining that the children, grandchildren, and great-grandchildren of that child will die and the diaper will remain in the ocean made the students realize the issue's magnitude. In fact, presenting concrete examples, with scales easily perceptible by scholars, proved to be a good strategy to raise awareness of the theme, having 79.01 % of students correctly estimated the degradation time of a disposable diaper versus the 10.94 % that did it initially. Moreover, degradation times were addressed in the second week and when reviewing the same topics at the beginning of the third week, several students referred that disposable diapers and plastics take a long time to disappear, so they should not end up in the ocean. The same was verified in the comments (e.g., 'I've found that certain types of garbage last longer than I thought', 'It was an experience that raised awareness, that I thought there was less plastic than there is, I can warn my friends and family to be more careful') left on the post-questionnaire, highlighting the importance participants attributed to this new knowledge acquired. These observations reinforce the necessity of rethinking labels with educational information to better encourage the sustainable use and deposition of products. People knowing the sources and pathways of marine litter and the time debris take to degrade in the marine environment can promote sustainable actions. Cigarette packs' anti-littering messages have already been proven to be efficient in raising awareness and knowledge about this issue, as well as refraining smokers from littering (Morgan et al., 2022). The use of visual communication for people's engagement (Pahl et al., 2017) and the inclusion of such a label that contains a sustainability scale that helps consumers with their decisions (Burrows et al., 2022) must be pursued to tackle marine pollution. In fact, poor knowledge and misperceptions concerning the sources and pathways can act as an obstacle in the marine litter fight. It was observed that students were not so aware that garbage left on the beach or transported through streams, irrigation channels, and rivers contributes to ocean pollution. The direct release of litter into the ocean was pointed out with high confidence by students as the main contributor to litter

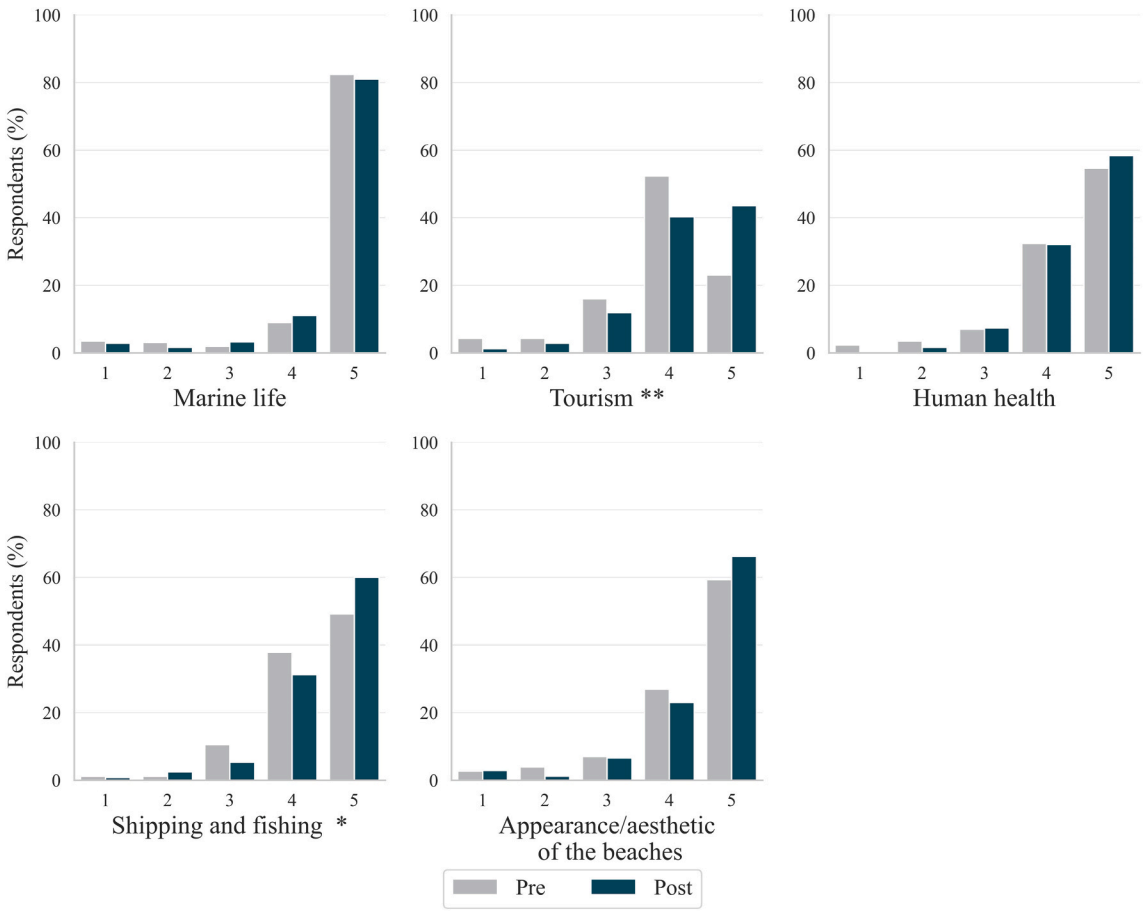


Fig. 4. Students' pre- and post-intervention percentages regarding the impacts of marine litter (1–5 scale: none – high). *$p < .05$ and **$p < .001$.

accumulation in the pre-intervention. Nevertheless, despite not being a consensual value, it is estimated that ocean-based sources contribute to about 20 % of the litter found in the ocean, being 80 % of marine debris from land sources (Allsopp et al., 2006). This misconception can have implications for daily household disposable practices. If people are unaware that disposing of litter in streams and irrigation channels contributes to marine litter, they will continue doing it. During the educational interventions, students realized the importance of water channels in transporting debris to the sea with wind and rain. Researchers showed pictures and took different marine litter items collected on Madeira Island beaches for students to examine, several possibly transported through streams (e.g., iron, car radio, gas cylinder, tires). Scholars were astonished that the garbage abandoned in the mountains and along the water courses could easily reach the ocean. It was explained to them that the orography of Madeira Island greatly contributes to that (Prada et al., 2005), supporting the importance of education campaigns in such region. The same reactions were obtained to several items that were probably left on beaches by bathers, with students admired by how people can be 'so dirty' (students' words). The youngsters believed that other sources and paths equally contributed to debris on the beaches: 'the wind may have taken', 'people littered to the floor', 'due to heavy rains', 'individuals unaware of their actions', 'fisher who went fishing and dropped', and 'the [rubbish] bin where they threw it could be full which caused the wind to drag it to the sea'. This practical exercise of providing actual marine litter items collected on beaches and asking students to hypothesize their sources and pathways contributed to enriching their knowledge about how debris reaches the sea and proved to be effective in raising awareness on the theme, validating the study hypothesis. Students who participated in the beach clean-up activity in the 4th session had the opportunity to see *in loco* objects that reached the beach via different ways (thus contributing to reinforcing that much of the garbage on the beach was not left there by bathers, as some students thought), complementing the classroom learning and discussions about sources but also impacts marine litter can have. The students' perceptions regarding marine litter present in Funchal beaches were surveyed orally during the clean-ups and at the end of the field activity (when the collected litter was weighed and characterized). Participants revealed predominantly surprise (with the amount, type of litter, and possible source/pathway), indignation (for seeing that the beaches in their region are polluted) but also motivation to carry out more beach cleaning actions, as they liked it and believe they are contributing to a cleaner and preserved ocean. Other authors have previously explored students' participation in marine litter scientific samplings with equally positive outcomes (Wichmann et al., 2022; Wyles et al., 2017).

When talking about consequences, a high impact of marine debris was indubitably attributed to marine life, a predicted answer considering the way children explain marine litter theme [as 'something that pollutes the ocean and endangers turtles and whales' - common students' words] and the sensational media headlines every time a species is found dead due to marine litter. Such observations are in line with previous studies (Kusumawati et al., 2020; Locritani et al., 2019). A surprising result was human health being punctuated as a high consequence of marine litter. In a 2015 research, human health was the second less perceived consequence of marine litter (Hartley et al., 2015). The widespread of recent investigations debating microplastics' effects and their presence in the human body (Ragusa et al., 2021; Vethaak and Legler, 2021; Yee et al., 2021) may have contributed to ascertaining the high health risks due to marine litter, thus supporting the answers obtained. Despite the difference between the pre- and post-questionnaires

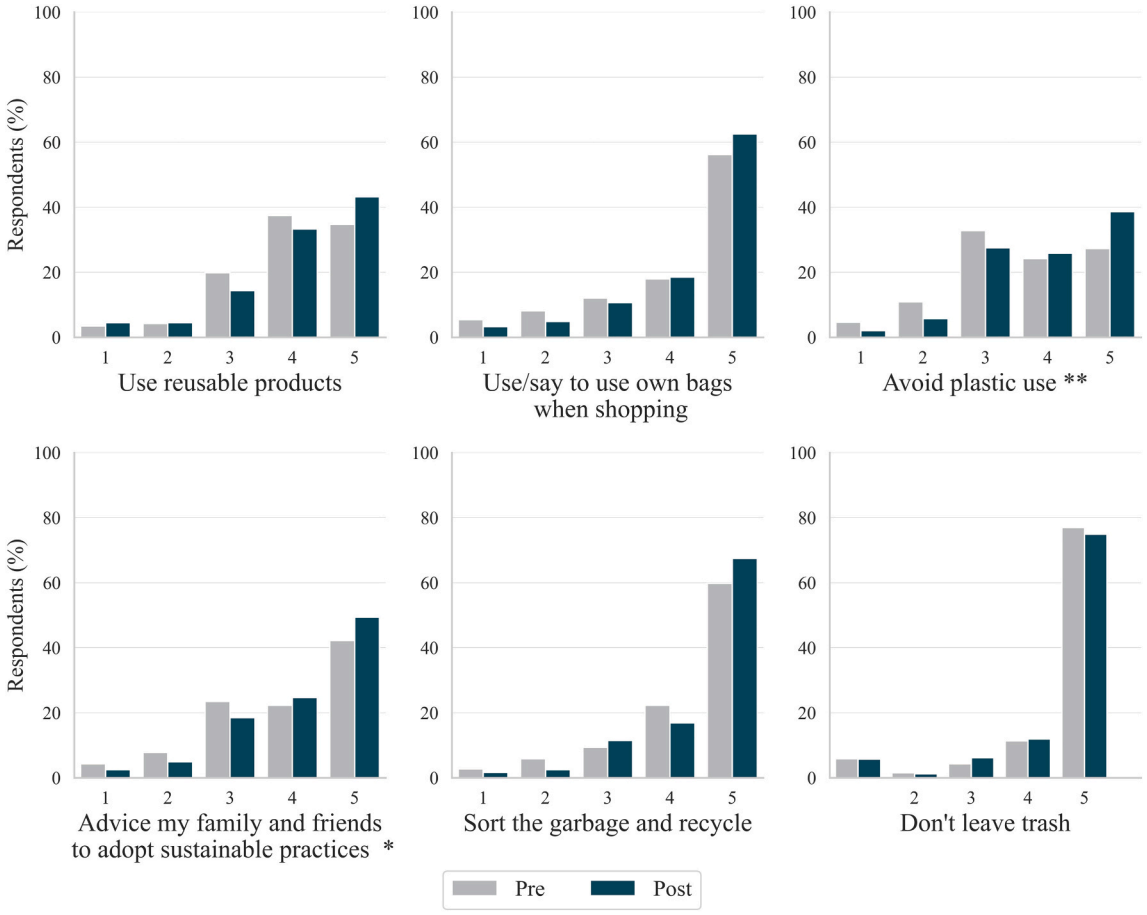


Fig. 5. Students' pre- and post-intervention percentages regarding the behavior intentions (1–5 scale: never – always). *$p < .05$ and **$p < .001$.

results being statistically significant, marine litter impacts on tourism were the least rated as 'high' by students after the intervention. This output was not expected as students live on an island whose economic sector strongly relies on tourism. Kusumawati et al. (2020) also did their study in an insular location (Sumatra) and observed that marine litter impacts on tourism were the second most perceived consequence by youths. In future interventions in Madeira, it will be necessary to reinforce the approach regarding the costs marine litter can bring to tourism so that students realize it can have a 'high' impact on tourism. Such impact can bring economic losses once levels of litter on the beach and the sea is the 3rd criterion visitors look for when choosing a coastal holiday destination (Werner et al., 2016).

Altogether, the different activities and the knowledge acquired regarding the composition of marine litter, degradation time, microplastics, sources, pathways, and impacts of marine debris led to changes in perceptions. Students realized marine litter is a problem in their region, particularly after observing objects collected on Madeira's beaches. They recognized that immediate action is needed, being themselves responsible agents for that. Both these perceptions achieved maximum punctuation after the intervention, an essential result as marine litter must first be recognized as a problem to then act accordingly. The perception that family and friends know what marine litter is and talk about it equally increased after the intervention. However, only the age group of 7–9 years old (the youngest age group) showed a statistically significant difference after the intervention on this topic, probably because the youngest students talked and shared more with their relatives about what they learned during the day. Yet, the perception that family and friends know what marine litter is and talk about it was the one that gathered a lower median, indicating more has to be done to increase the ocean literacy of the population, corroborating previous studies (Bettencourt et al., 2023b; Frias and Nash, 2020; Hartley et al., 2018b). The remaining student's answers in the perception category showed no statistically significant difference, indicating that it is due to the already high perception pre-test baseline levels.

Regarding behavior intentions, they did not change significantly after the intervention. Such was predictable since students reported high levels of behavior intentions before the educational actions, indicating they had already adopted some sustainable practices in their daily lives. Hartley's team observed the same, stating that 'children showed some level of problem awareness and sustainable behaviour prior to participating in the educational intervention' (Hartley et al., 2015, p. 214). However, for a truthful evaluation, a continuous assessment is needed. This is because even if intentions are formed, strong old habits or low perceived control can affect behavior performance (Klöckner, 2013). The use of reusable products and the avoidance of plastic were actions reported as less likely to be performed. Students' limited power over household purchase habits can justify these low intentions. Although parents' buying patterns are affected by children, their income level is a determining factor regarding shopping habits (Ishaque and Tufail, 2014; Sapkota and Kafle, 2020). Thus as some of these products are expensive, parents select others cheaper, being our observations in line with the literature: 'though consumers express their concern towards the environment; this does not necessarily translate into green purchases' (Yang, 2017, p. 160). Soares et al. (2021b) observed the same, being the lack of resources the first factor pointed out by respondents to justify the lack of pro-environmental behaviors. Therefore, the behaviors that do not depend on the families' economic conditions (e.g., using their own bags when shopping, sorting the garbage, and recycling) are the ones that registered a greater predisposition to be performed. Additionally, the fact that the population studied is aged between 7 and 18 years old

means that they do not have certain disposable behaviors as older ones have (e.g., 36 % of the inquiries of Webler and Jakubowski (2022) reported to have disposed cigarette butts improperly on the ground or through a car window).

Even though gender and age did not statistically significantly affect all responses, it was possible to observe that the youngest and the male were the groups with more recorded changes. Regarding gender, given that there were only differences in three of the items analyzed and that the Portuguese classes are gender-mixed, future interventions may continue to be applied in such mixed classes. However, in terms of age, it was observed that greater positive changes in knowledge, perception, and behavior intentions occurred in age groups 7–9 and 13–15 years old. This suggests that the intervention may have positively affected their behavioral intentions. The mentioned age groups correspond to 3rd and 8th grade students, which indicates that these basic education levels are the ones in which the intervention was most effective in increasing marine literacy. Such observation is in accordance with Soares et al. (2021a) inquiry, where interventions with basic education students were perceived as most relevant when compared to high school levels. Still, to cover more students and years of schooling, it is essential to capacitate and literate teachers as they are agents capable of stimulating pro-environmental practices. Some of them do not feel sufficiently skillful and confident to embrace marine litter in their teaching, therefore needing training on the theme (Ahmad-Kamil et al., 2022; Hartley et al., 2018a).

Overall, the educational intervention described in this study is of valuable worth, with formal education and personal experiences recognized as the main sources of ocean learning (Cudaback, 2006). The combination of theoretical, laboratorial, and hands-on activities, adequately planned and evaluated, differentiates this study from others and confirms the initial research hypotheses. Instead of a standard awareness-raising strategy, the educational intervention was adjusted to the local reality of an oceanic island. Data obtained through a previous population survey (which showed that degradation rates are sometimes underestimated by the population, that marine litter impacts are not fully known, and that individual responsibility is not entirely recognized by citizens, among others - Bettencourt et al., 2023b) and a two-year marine litter monitoring (which showed items in Funchal beaches are mainly from land-based sources where there is a high predominance of cigarette butts and plastic items, and where streams act as a potential litter pathway, among others - (Bettencourt et al., 2023a) provided important insights to direct interventions to the local reality, focusing on important key points for marine litter mitigation. Also, the activities were designed to appeal to students, as laboratorial and hands-on activities complemented the theoretical ones. Indeed, different strategies and tools were used to engage participants with the theme while fostering essential skills to lead them to act conscientiously. Furthermore, in addition to marine litter, the plan proposed in Table 1 can be adapted to other topics and educational areas.

A study's limitation is the relatively small sample, which may not correspond to the entire demographic variation in students' knowledge and perceptions, and the impossibility of continuous monitoring of behavioral intentions over several months due to students' classrooms or school changes along the academic years. Future work should surpass this limitation, ensuring that it is possible to apply the post-questionnaire to the same students a few months later to understand whether the positive changes perpetuate over time. External factors (e.g., participation in a beach clean-up action under the scope of another project, scout activity) may have interfered with post-questionnaire results, however, they are out of researchers' control. Moreover, as the educational interventions were developed on an island, a place where it is predicted that inhabitants have a deeper concern with the ocean, it will be good to test the program's effectiveness in non-coastal locations. Nevertheless, the conduction of the study on a small island was important as a pilot test, as it can be adopted by other similar regions (Tyedmers et al., 2020).

5. Conclusion

Ocean pollution, particularly marine litter, needs to be curbed holistically. This study combined differentiated theoretical, laboratorial, and hands-on activities to engage students from 7 to 18 years old with the marine litter theme so that they can act as informed and literate individuals. The intervention design benefited from previously acquired information, namely inhabitants' perceptions, knowledge, responsibilities, and behavior intentions on marine litter and data regarding items found on beach litter monitoring actions. Such previous evaluation contributed to designing a customized intervention for Madeira students, differentiating it from existing studies that do not assess the baseline situation before planning the strategies. The outputs of this new approach were assessed using pre- and post-questionnaires. It was found that participants already had a baseline knowledge of the issue and high intentions of adopting marine litter reduction behaviors. Yet, the intervention awakened students to the actuality and urgency of the theme while fostering their critical thinking, collaboration, communication, and creativity skills. Moreover, students' knowledge, awareness, perceptions, and behavioral intentions were boosted, confirming the study hypothesis. The continuous sessions showed positive results, with statistical differences before and after the intervention. The beach clean-up action recapped the classroom's learnings and gave students a better idea of the amount and type of litter on the Funchal's beaches and the possible sources and pathways for that same debris. The integrative and innovative intervention proposed here can be extended to other target audiences and regions, improving current and future sustainability education interventions not only on marine litter but also on different environmental topics. With that, literacy can be boosted in different areas, contributing to knowledge in the area and the achievement of the SDGs of Agenda 2030.

CRediT authorship contribution statement

Sara Bettencourt: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Diogo Nuno Freitas:** Formal analysis, Writing – original draft, Writing – review & editing. **Carlos Lucas:** Investigation, Writing – review & editing. **Sónia Costa:** Validation, Writing – review & editing, Supervision. **Sandra Caeiro:** Validation, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Acknowledgments

The authors thank all schools, students, and teachers who participated in the study.

Funding

This work was supported by the Fundação para a Ciência e Tecnologia, I.P., Portugal [grant SFRH/BD/147085/2019 to Sara Bettencourt and grant 2021.07966.BD to Diogo Freitas]. CENSE [UID/AMB/04085/2019], MARE [UIDB/04292/2020], and ARNET [LA/P/0069/2020] are also financed by Fundação para a Ciência e Tecnologia, I.P., Portugal. Fundo Azul do Ministério do Mar funded through the project ALIMAR – Ação Lixo Marinho! (FA_06_2017_081).

Appendix A. Student filling the questionnaire with the visual 5-Likert scale on an electronic device

Appendix B. Students counting the cigarette butts collected in the beach clean-up action

Appendix C. Supplementary Material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.marpolbul.2023.114963.

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