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Turning the tide on trash: Empowering European educators and school students to tackle marine litter

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Highlights

- This research examined two educational activities for European audiences.
- An online training course for educators and a video competition for students.
- After the activities, understanding and willingness to address the problem increased.
- Educators felt more able and confident to include marine litter in their teaching.
- Students felt more concerned, aware of causes and impacts, and took more action.

Turning the tide on trash: Empowering European educators and school students to tackle marine litter

Marine litter is a global environmental problem, and working with educators and school students has much potential to facilitate greater public understanding of the solutions and to enable action. This research examined two new educational activities designed to empower European educators and school students to engage with the topic of marine litter, particularly focusing on behavior and on known determinants of behavior rather than knowledge alone. In Study 1, 120 educators participated in an online training course on marine litter, and completed a pre- and post-course questionnaire to assess change. After participating in the course, educators felt significantly more skillful and confident to incorporate marine litter education into their future teaching. In Study 2, 341 school students (7-18 years old) participated in an educational video competition on marine litter, and completed a pre-post questionnaire to assess change. Following the educational activity, students were more concerned about marine litter, had a better understanding of the issue, causes and impacts, and reported performing more waste-reduction behaviors. This research brings together educational and behavioral literatures and demonstrates how educational activities can be documented and evaluated systematically in the quest of tackling marine litter.

Keywords: Marine litter, Environmental education; Educators; Children; Education for Sustainable Development

1. Introduction

Litter is prevalent in marine and coastal environments globally and is increasingly attracting academic, policy and media attention due to its considerable negative ecological and socio-economic impacts [1, 2, 3]. Many sectors of society contribute to marine litter, from industry to fishing and tourism, and tackling the problem must involve concerted efforts across nations, disciplines and with all stakeholders. Human behavior is a major factor contributing to marine litter, and behavioral change all along the supply chain has the potential to reduce the problem [4, 5]. This paper focuses on the role of the education sector as an important agent of social change [6]. It investigates change in perceptions and behavioral indicators (behavioral intentions and self-reported behavior) following two educational activities and seeks to contribute to good educational practice regarding the issue of marine litter. In particular the focus is on known determinants of behavior such as concern, perceived control and confidence, rather than knowledge alone. In the next section, the relevant environmental, psychological and educational literatures are reviewed which provides the conceptual basis of the research. This is followed by the methodology and results for Study 1 and Study 2, and finally a discussion of the findings, contribution and limitations of the work.

2. Literature Review and Conceptual Basis of the Paper

Education is essential for the advancement of sustainable development (e.g., United Nations Decade of ESD - UNESCO, 2014 [6]). Indeed, in the last decade, there has been more emphasis towards developing ownership, empowerment and action in learners, in addition to solely increasing knowledge and awareness [7]. This research seeks to understand how teachers and students can be empowered to deal with marine litter (with empowerment indicating feelings of confidence, control, competence and readiness to act), which will

ultimately encourage more responsible behaviors. In terms of content, such transformative pedagogies involve participatory teaching and learning methods to promote change in behaviors, and life-skills such as critical thinking, imagining future scenarios and collaborative decision-making [8]. These methods are focused on harnessing intrinsic motivation and deep engagement with the issues. However, the need for more research, integration with behavioral science and environmental psychology approaches, monitoring and evaluation to assess the effectiveness of good practice has been identified as a key priority [6].

Environmental psychology provides a rich body of research on individuals' perceptions of different environmental challenges, such as climate change and energy use. Various theories and approaches describe and test a range of determinants of environmentally relevant behavior [9, 10, 11, 12, 13, 14]. Such determinants and factors include knowledge and awareness, concern, personality, perceived control (also often referred to as self-efficacy or feelings of confidence and competence to act), values, attitudes and worldviews, personal responsibility, moral norms and demographic variables (e.g., age, gender, education level) (for a review see [11]). These factors are likely to apply equally in the present context. For example, knowledge of and concern about litter, and perceived competence and confidence, are expected to correlate with both educators' willingness to incorporate marine litter education into their teaching on the one side, and school students' willingness to take action to reduce marine litter on the other side. Indeed, examining these factors among educators and students in this novel context can help identify barriers to, and opportunity for, guiding effective educational policy and practice.

2.1. Research on environmental and sustainability education

Research with *educators* suggests that they are keen to implement environmental and sustainability education but lack the confidence, skills and understanding to do so, particularly in an already overcrowded curriculum [15, 16, 17]. Therefore, educators may need better training and support, and materials that are ready for implementation in educational practice. Although teacher training on specific topics is available, it is not standard practice to evaluate the effects of such training courses systematically. Some feedback is typically requested after the activity, but this is often focused on what participants have learnt in terms of content (knowledge) and on how satisfied they were (e.g., [18, 19]), rather than on evaluating the factors reviewed above that are known to predict action (such as awareness, concern, perceived control or responsibility).

Research with *school students* suggests that young people are aware of environmental problems [20, 21], can behave in an ecologically responsible manner [22], and can shape the perceptions and behaviors of others [23, 24]. Several systematic reviews have been conducted on environmental education programs but none specifically on marine litter (see [25, 26, 27]). Overall, these reviews suggest that participation in environmental education activities can improve children's environmental knowledge and attitudes. However, again the majority of studies focus on assessing a change in knowledge or attitude after the activity, rather than assessing changes in behavioral determinants (as reviewed above) or behavioral indicators (e.g., behavioral intentions, self-reported behavior). Substantial research on human behavior recognizes that knowledge gain is not typically sufficient for (or a direct cause of) behavior change [28, 29, 30]. Therefore, evaluation should include factors beyond knowledge, as reviewed above such as concern, perceived control, responsibility, and self-reported behavior or behavioral intentions, which are known to be linked to actual behavior.

In summary, it is evident that there is a lack of research into environmental education on marine litter, with little to no assessment of the impact these have on the target audience. To our knowledge, only two published studies have employed an environmental education activity to raise school students' awareness and engagement in actions to help solve the problem. Hidalgo-Ruz and Thiel (2013) [31] used the opportunity of a citizen science project to engage students (aged 8-16 years) with the topic of microplastics in the marine environment. They worked with 983 students in Chile who sampled, sorted and counted small plastic pieces on local beaches, and entered their data into an interactive website. After the activity, students reported that they found the project interesting and fun, and that they would be likely to participate in other environmental activities in the future. Hartley, Thompson, and Pahl (2015) [32] implemented an environmental education activity with 176 British schoolchildren aged 7-18 years and assessed their level of concern, understanding and self-reported behavior regarding marine litter before and after engaging in the activity. After the educational activity, children were significantly more concerned about marine litter, had a better understanding of the causes and negative impacts, and reported improved behavior. However, more work is needed on engaging teachers, and on engagement methods that allow the children more freedom and creativity to explore the topic, such as creating their own materials rather than a predetermined program of education, in line with transformative pedagogy.

2.2 *The present research*

This research set out to (1) develop two educational activities designed to increase understanding and empower educators and school students to engage with the topic of marine litter and take action, and (2) assess the impact of each activity on learners' understanding, perceptions and behavior. Specifically, Study 1 employed and evaluated an online training

course for educators across Europe in 2015 in terms of the educators' level of understanding, confidence, perceived skills and competence, sense of responsibility and intentions to integrate marine litter education into their teaching, using a before-after design. It was predicted that after the course, educators would feel that they had a greater understanding and knowledge of the topic, feel significantly more competent, skillful and confident to teach about marine litter, and that they would have positive behavioral intentions following the course, for example offering more lessons and activities about the topic, and encouraging other educators.

Study 2 implemented and evaluated an environmental education activity in the form of a video competition with European schoolchildren in 2014 and examined perceptions and behavior regarding marine litter before and after participating in the activity. It was predicted that after participating in the educational activity, students would be significantly more concerned about marine litter, have a better understanding of the causes and negative impacts, and report engaging in more actions to help tackle the problem.

3. Methodology

3.1 Participants & Recruitment

In Study 1, a total of 120 educators (99 females, 21 males) aged 19-62 years (Mean age = 35.39, SD = 9.77) participated from 18 countries across Europe (Greece, Romania, UK, Ireland, Italy Portugal, Cyprus, Germany, Turkey, Spain, Denmark, France, Netherlands, Bulgaria, Croatia, Malta, Sweden and Switzerland). Participants included 26 individuals working in formal education (e.g., school teachers), 46 in non-formal education (e.g., NGO and museum staff, activists), 29 in both formal and non-formal education, and 19 who specified another field (e.g., university). The online training course was advertised through

educational networks, in newsletters and social media. Educators registered via an online platform, provided consent to participate in the study, and later received a debrief with more information.

In Study 2, a total of 341 school students (200 girls, 141 boys) aged 7-18 years ($M_{age} = 13.54$, $SD = 2.63$) participated from 12 countries across Europe (Portugal, France, UK, Netherlands, Cyprus, Germany, Italy, Slovenia, Ireland, Turkey, Romania, and Spain). School students were recruited for the video contest via educational networks, newsletters and social media, and also through directly contacting school boards and teachers. School teachers and other educators facilitated children's participation with support from the MARLISCO project (Marine Litter in European Seas: Social Awareness and Co-Responsibility). Schools provided consent to participate in the study, and confidentiality of responses was ensured.¹

3.2 *Education Materials*

Study 1 Educator resource pack and online training course. These were developed within the MARLISCO project by the Mediterranean Information Office for Environment, Culture and Sustainable Development (MIO-ECSDE)². The resource pack '*Know, Feel, Act! to Stop Marine Litter: Lesson plans and activities for middle level students*' [33] is designed for educators working with young people aged 10-15 years in formal or non-formal educational settings. It contains 17 learning activities that examine the characteristics, sources, effects and possible ways to tackle marine litter, addressing it from an

¹ The number of participants in both studies reflects the number of pre-post questionnaires that could be matched. In Study 1, 51 pre-questionnaires could not be matched with a post-questionnaire (70% completion rate). In Study 2, 825 pre-questionnaires could not be matched with a post-questionnaire (29% completion rate).

² MIO-ECSDE is an Athens-based Non-Governmental Organization (NGO) with a long standing experience in the design and production of educational material and the implementation of educational programs. Since 2002, MIO-ECSDE has facilitated an initiative on Education for Sustainable Development (ESD) called MEDIES (www.medies.net) that aims to support the Euro-Mediterranean formal and non-formal educational community to integrate in their teaching practices ESD themes and pedagogies.

environmental, societal, cultural and economic point of view. The online course trained educators in using the resource pack in their teaching, and aimed at increasing their skills and sense of confidence to do so, with a strong focus on pedagogy rather than marine litter facts. The course was spread over a two week period with no fixed online meetings, enabling participants to log in and proceed at any time convenient to them (the total workload was around 16 hours). During the course, effective ways of incorporating the pack were demonstrated, learning activities were simulated in an interactive fashion, and trainers and participants discussed how they could be adjusted to different teaching needs. Trainees were treated as experts and had opportunities to talk about the validity and appropriateness of the activities and potential obstacles to implementing them. In the current study, the educational pack was provided in English but it has now been translated and can be found online in 15 languages (<http://www.marlisco.eu/education.en.html>).

Study 2 Video Contest. The educational activity was developed within the MARLISCO project by the Coastal and Marine Union (EUCC)³ and encouraged school students to think about the sources, impacts and solutions to marine litter. Participating students were asked to prepare a two-minute video on the issue of marine litter, considering some key themes, including: *Why is marine litter a concern?; What can be done?; What has been done in our school/local community to deal with it?* (see [34])⁴. This aimed at fostering a sense of citizenship and ownership to give students an active voice in the problem and thus empower them to act. It was designed to be appropriate for learners of different ages,

³ Coastal and Marine Union (EUCC) is a stakeholder and network association with members in 40 countries, founded in 1989 with the aim of promoting a European approach to coastal conservation by bridging the gap between scientists, environmentalists, site managers, planners and policy makers. Since then it has grown into the largest network of coastal and marine practitioners and experts in Europe and neighboring areas.

⁴ Once the competition had closed, judging panels were set-up in each country to select the best national video and there was also public voting on the best videos via YouTube.

backgrounds, levels of knowledge and cultures and included hands-on experience and investigative learning.

3.3 Measures

Study 1 Questionnaire. Questions were informed by environmental psychology and education literature, forming a quantitative evaluation that participants completed before they began the training course (pre) and again after (post). It took approximately 5 minutes to answer these questions.

The pre-course questionnaire included ten questions designed to assess educators' concern, responsibility, perceived knowledge, perceived understanding, confidence, perceived skills and perceived competence in relation to teaching about marine litter (e.g., '*I feel a responsibility to educate young people about the topic of marine litter*'; '*I feel I have the skills to teach about marine litter*'; Appendix A). Educators were asked to indicate their (dis)agreement with these statements with response options from 1 to 7, with end anchor points labeled "*strongly disagree*" and "*strongly agree*". The post-course questionnaire included the same questions and an additional set of eight questions designed to assess educators' intentions to integrate marine litter education into their teaching (e.g., '*I plan to develop lessons or activities about marine litter*'; '*I will encourage other educators in my network to use the Education Pack on marine litter*'; Table 1). Educators indicated their intentions using response options from 1 to 7, with end anchor points labeled "*no, definitely not*" and "*yes, definitely*".

Study 2 Questionnaire. A short online tool was developed, based on Hartley et al. [32], to evaluate the educational activity. Students responded to questions about the problem and whether they were worried about marine litter, the negative impacts and possible causes, the proportion of marine litter that is plastic and its longevity, and they reported their own

behavior (Appendix B). Students answered all questions (except those about proportion and longevity of plastic) by choosing from four response options (*not at all, a little bit, quite a bit, a lot*). This smaller range of response options was used so that it was more appropriate for the younger sample. The questionnaire was completed online at school before students began the educational activity (pre) and again afterwards (post). The questionnaire was translated for all participating countries and took approximately 5-10 minutes.

3.4 Analysis

Study 1 analysis used paired samples t-tests with Bonferroni correction such that only comparisons with $p < 0.005$ are interpreted as significant. Effect size Cohen's d is reported, calculated by taking the difference between the two means and dividing by the pooled standard deviation (i.e., the root mean square of the two SDs). Here, 0.20 is considered a small effect, 0.50 is medium, 0.80 is large, and 1.20 is very large. Study 2 used Wilcoxon's matched-pairs signed ranks test because there was a smaller range of possible response options (*not at all, a little bit, quite a bit, a lot*). Bonferroni adjustment accounted for multiple comparisons in each response category. Effect size r is reported (Z divided by square root of N), where 0.1 is considered a small effect, 0.3 is medium and 0.5 is large. Due to unequal sample sizes it was not possible to assess results from different demographic groups (country, age, gender, or educator type) individually or to compare across these groups and maintain reliable or representative findings.

4. Results

Study 1 Pre- and post-comparison of perceptions.

After completing the course, educators reported that they knew and understood significantly more about marine litter, $t(119) = 11.06, p < 0.001, d = 1.18$ and $t(119) = 9.28, p < 0.001, d =$

1.05, respectively. Their confidence and perceived skills increased significantly, $t(119) = 9.06, p < 0.001, d = 1.13$ and $t(119) = 8.17, p < .001, d = 0.88$, respectively. Similarly, educators reported greater perceived competence in that they had significantly more ideas for teaching about marine litter, $t(119) = 11.36, p < 0.001, d = 1.37$, and that they could think of more ways to integrate the topic into their teaching, $t(119) = 6.66, p < 0.001, d = 0.83$. Moreover, after participating in the course, educators thought that young people would be more receptive to learning about marine litter, $t(119) = 5.60, p < 0.001, d = 0.63$ (Figure 1).

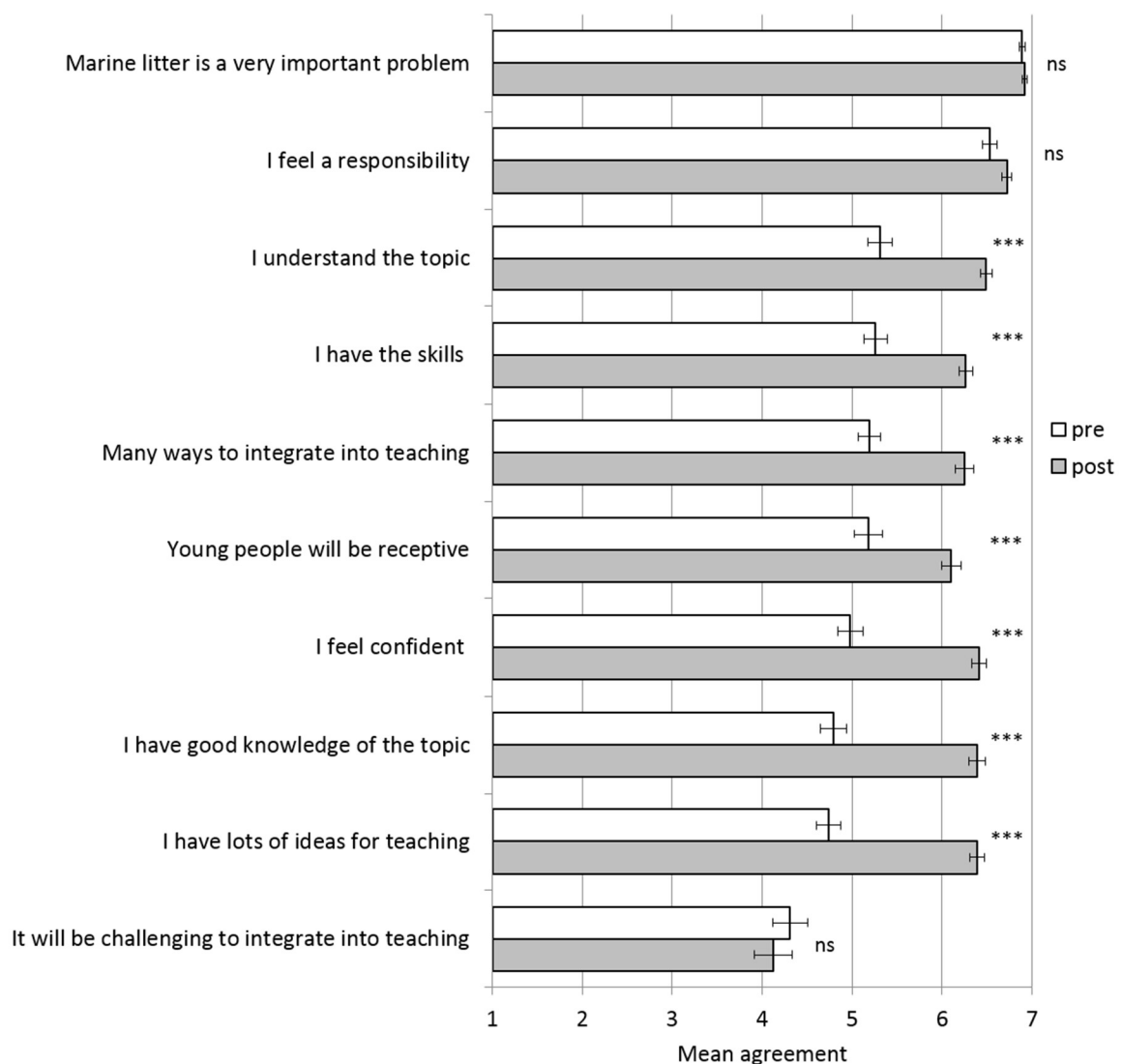


Fig. 1. Educators' pre- and post-course perceptions about marine litter education (1-7: *strongly disagree – strongly agree*). Note. Error bars represent standard error. *** $p < 0.001$

There was no significant change in perceived importance of the problem, which was already high before the course $t(119) = 0.77, p = 0.441, d = 0.10$, feeling responsible to educate young people about marine litter, $t(119) = 2.31, p = 0.023, d = 0.25$, or perceptions about how challenging it would be to integrate marine litter into teaching (which educators neither agreed nor disagreed with, on average), $t(119) = -1.05, p = 0.297, d = 0.09$ (Fig. 1).

Study 1 Post-course intentions to integrate marine litter education into teaching

After completing the course, educators showed positive behavioral intentions to integrate marine litter education into their future practice (Table 1).

Table 1. Descriptive statistics for educators' intentions to integrate marine litter education into their teaching after completing the online course (1-7: no, definitely not – yes, definitely).

	<i>Mean</i>	<i>SD</i>	<i>Median</i>
I am unlikely to have sufficient time to integrate marine litter education into my teaching	2.17	1.45	2.0
I am unlikely to increase the amount of marine litter education I provide	2.08	1.54	1.5
I am unlikely to use the Education Pack 'Know feel act! to stop marine litter' in my teaching	1.92	1.50	1.0
I plan to develop lessons or activities about marine litter	6.21	1.19	7.0
I will tell other educators about marine litter education	6.42	0.88	7.0
I will encourage other educators in my network to use the Education Pack on marine litter	6.42	1.02	7.0
I will encourage other educators in my network to consider including marine litter as a topic in their teaching	6.49	1.05	7.0
I intend to integrate marine litter education into my teaching	6.51	0.75	7.0

Study 2 Pre- and post-comparisons of perceptions and self-reported behavior

Students reported greater worry about the problems that marine litter might cause after participating in the project, $Z = 3.61$, $p < 0.001$, $r = 0.20$ (pre- $M = 3.38$, post- $M = 3.52$), but did not change their assessment that marine litter was a very important problem, $Z = 1.57$, $p = 0.117$, $r = 0.09$ (pre- $M = 3.76$, post- $M = 3.80$). Students increased their estimates on the proportion of plastics in marine litter from 65% to 73% on average, $Z = 7.57$, $p < 0.001$, $r = 0.41$. Their estimates of degradation times also increased from approximately 100 years to 200 years, $Z = 4.69$, $p < 0.001$, $r = 0.25$ (note: median scores are reported here because means are skewed by very high values).

Students increased their perceptions of negative impacts for what the beach looks like, human health, and people's enjoyment. Perceptions about impacts on fishermen and on sea animals did not change (Fig. 2 and Appendix C). Students' perceptions about dropping litter on the beach and streets as a cause of marine litter remained unchanged following the video contest. However, students' perceptions about the contribution of all other factors increased significantly (Fig. 3 and Appendix C). After participating in the video contest, students' self-reported waste reduction actions significantly increased (Fig. 4 and Appendix C). No change was reported for throwing litter on the ground, which was already very low.

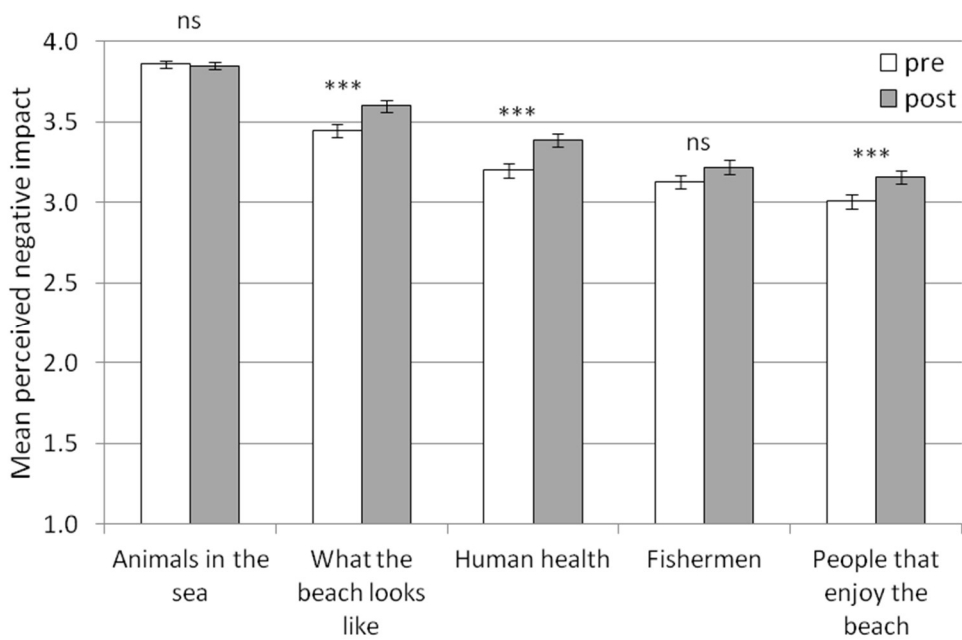


Fig. 2. School students' perceptions about the negative impacts of marine litter pre- and post-intervention (1-4: not at all – a lot). Note. Error bars represent standard error. *** $p < 0.001$

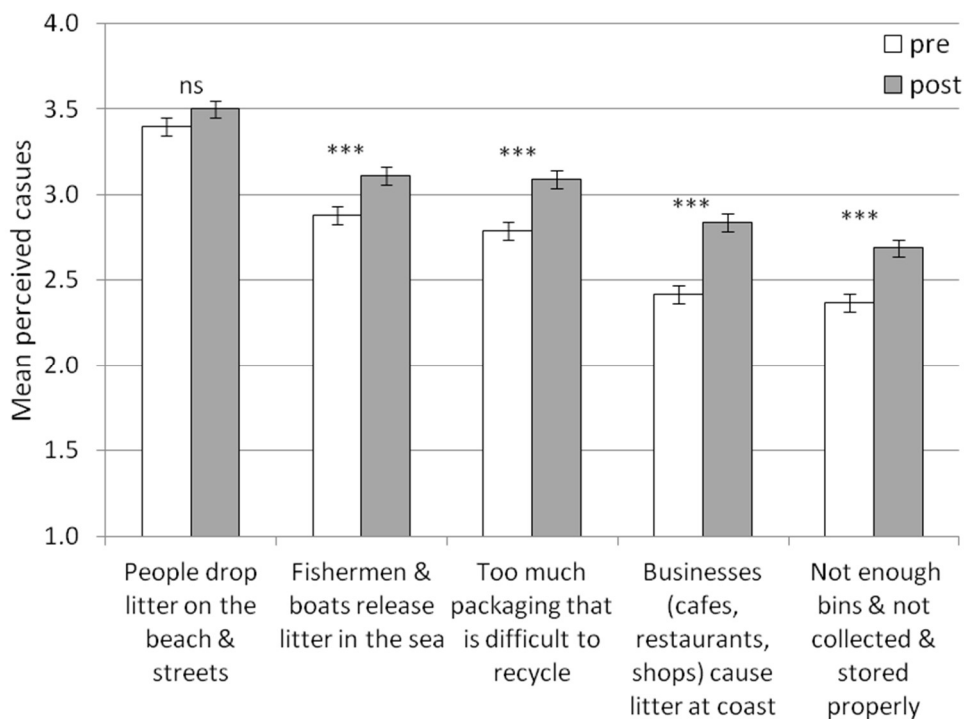


Fig. 3. School students' perceptions about the causes of marine litter pre- and post-intervention (1-4: not at all – a lot). Note. Error bars represent standard error. *** $p < 0.001$

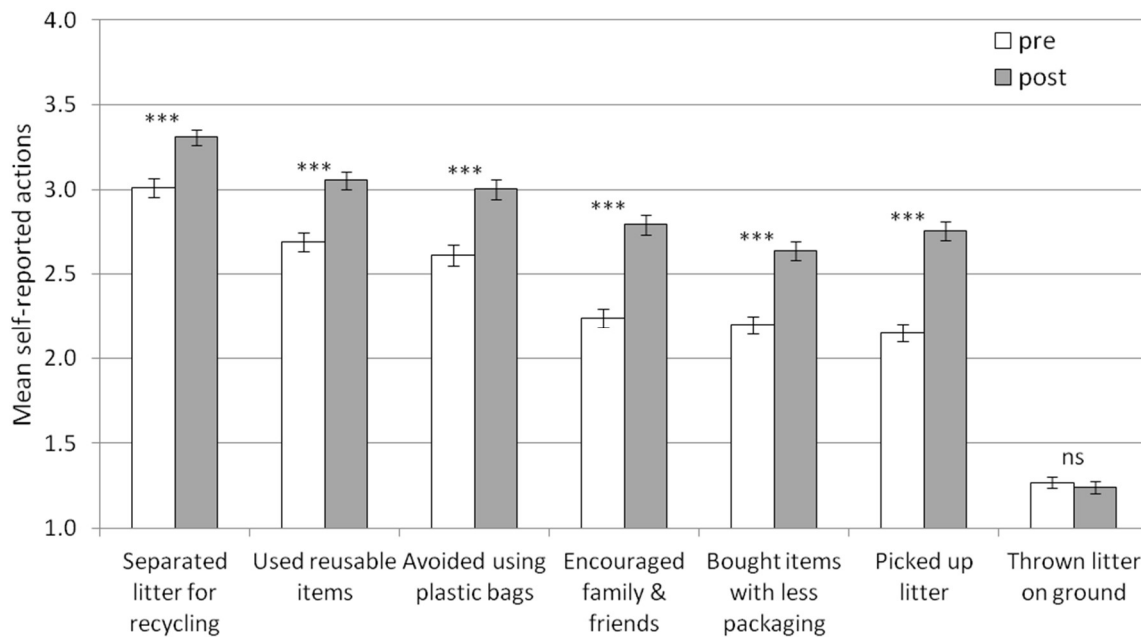


Fig. 4. School students' self-reported actions to reduce the potential causes of marine litter pre- and post-intervention (1-4: not at all – a lot). Note. Error bars represent standard error.

*** $p < 0.001$

5. Discussion

5.1. Main findings

This research tested two educational activities designed to raise understanding and empower both educators (Study 1) and school students (Study 2) to engage with the topic of marine litter and take action. Study 1 showed that participation in an online training course significantly bolstered educators' perceived understanding and knowledge on the topic, and their sense of confidence, competence and skills in marine litter education. Following the training they had high intentions of implementing the materials in their teaching. They also intended to encourage others in their network, which may lead to the training and resources to be distributed more widely. This is promising given previous research showing that educators

may be keen to implement environmental and sustainability education but lack the confidence, skills and understanding to do so [15, 16, 17].

Study 2 demonstrated that after participation in an environmental education project – in this case a European video competition about marine litter – school students were more concerned about the problem and perceived greater negative impacts and causes. Students also became more accurate at estimating the predominance and longevity of plastic so that their answers came to closely resemble figures commonly reported (cf. reviews [35, 36]). Moreover, they reported performing more waste reduction behaviors. These findings are novel for the context of marine litter but consistent with previous research that has found positive effects of environmental education activities on understanding, attitudes and behaviors [25, 26, 27]. Students also reported encouraging their family and friends to take action more, which is in line with studies showing that children shape the perceptions and behaviors of others [23, 24], indicating the potential of a wider social multiplication effect. Further work is needed to examine this relationship directly.

5.2. Contribution

This research represents the first assessment of educators' attitudes and behaviors related to marine litter before and after participation in a training course specifically designed to increase confidence, skills, and willingness to integrate the topic into their teaching practice. It integrates the theoretical insights and methodological approaches from the behavioral sciences into educational programs. Findings contribute to emerging evidence that educators are interested in implementing environmental education, but may benefit from greater confidence and skills to do so [15, 16, 17]. Sustainable development issues, such as marine litter, are complex with interconnected ecological, economic and social dimensions and require expertise in a broad range of knowledge domains as well as problem solving skills

[37]. The findings support the idea that educators need smart tools that support what they are already doing rather than providing an additional burden. By viewing educators as the experts, the course provided resources, techniques and ideas to facilitate teaching whilst at the same time increasing confidence and perceived skills. This form of training is particularly useful when face-to-face training sessions are not feasible. It allowed educators from across Europe to work together in an online community and share best practices, ideas and experiences – something which would not have been possible with face-to-face national training courses.

In addition, this paper extends Hartley et al.'s 2015 [32] recent study of British students' marine litter attitudes and behaviors and applies similar methods in a European-wide environmental education project. Students in the Study 2 reported slightly elevated problem awareness, concern and understanding of the impacts and causes of marine litter compared to the children that Hartley et al. (2015) surveyed [32]. Such differences may be due to a number of factors, such as greater opportunity for self-selection in the current sample (e.g., students volunteering rather than the activity being imposed and led by the teacher), or differences in sample demographics (e.g., students in the current study were on average over 3 years older than in Hartley et al.'s 2015 study). It is encouraging that positive effects are found following both, fairly standardized education activities such as that used in Hartley et al. (2015) and also much freer approaches that rely on self-guided research and learning such as in Study 2 here.

This research represents the first quantitative assessment of European students' attitudes and behaviors related to marine litter before and after participation in an educational project designed to raise awareness and inspire action in the younger generation. A potential extension to this work would be to integrate some open-ended questions which allow school

students to put forward their own perceptions (or misconceptions) about the causes and negative impacts of marine litter.

5.3. *Implications*

The findings have implications for marine policy by showing how to engage educators and students in the topic of marine litter, in order to raise awareness, confidence and action in learners through environmental education. The education sector represents an important agent of social change in society [6], and it is crucial that educational activities and training are evaluated better, especially taking into account known determinants of behavior in addition to knowledge per se. Several researchers have raised concern that there is a lack of good quality evaluation studies published in the environmental education literature [38, 39, 40, 41]. It is not clear whether this is because the majority of programs do not include evaluation in their projects, or because evaluations that are taking place are not published in the academic literature as perhaps they tend to make less of a contribution to theory [42, 43]. The evaluations in the current research provided a concise methodology to measure the short term effectiveness of a marine litter educational project and training course, but longer term studies are needed too.

5.4. *Limitations*

First, it is probable that the students and educators that participated in the environmental education project and training course were more conscious of environmental issues, and perhaps marine litter specifically, than the ‘average’ student or educator. Indeed, educators recruited for the training course were already aware of the problem of marine litter and interested in understanding how to integrate the topic into their teaching; they volunteered to take part. This may limit how generalizable the findings are to less engaged groups, but it is encouraging that each activity had a positive impact even among this interested sample. A

common challenge is reaching out to educators who are not already aware of or engaged in the topic. Educators have many commitments and are under numerous demands and restrictions within and outside the curriculum. Better incorporation of marine litter in the curriculum and formal teacher training process would give educators greater time, resources, confidence and skills to teach about this and other emerging environmental topics. In addition, greater promotion of and support for schemes through dedicated networks, such as Eco-Schools, would also help establish a norm for schools to consider environmental issues and take action. By engaging educators who are already interested in marine litter and/or who have received resources and undergone training, and by encouraging them to share their experience and skills with fellow educators, there is potential for a snowball or social multiplication effect – educators become the 'trainers', and the network of educators that are reached should continue to grow. Notably, the social psychology literature has shown that even a minority of people can have substantial influence on the majority [44].

Second, there are limitations to the self-report method. Participants may provide responses which are socially desirable, or which they believe are consistent with the goals of the study. Whilst this is a potential limitation, educators and students in this research completed questionnaires online which is likely to suffer less from social desirability than a face-to-face interview methods. In addition, this limitation presents less of a problem for studies which measure changes in responses using a before-after methodology, compared to more basic post-course evaluations where participants reflect on what they have learnt and how satisfied they were with the course.

Third, despite educators being exposed to the same information during the training course, and students participating in the same education project, participants could have sought out or been exposed to more information about marine litter, which was outside of the researcher's control and which could influence their post-intervention questionnaire

responses. However, any further learning that may have occurred outside the training and education activities could be viewed as an additional outcome. It would be beneficial for future research to include control groups, standardize the length of time between the pre- and post-questionnaire and conduct additional longer term follow-up questionnaires to improve the evaluation methods further.

6. Conclusion

Overall, the present research shows how complex environmental issues can be made accessible to educators and school students using online training and creative multimedia methods. Moreover, this work demonstrates not just the feasibility of such methods of engagement but also applied a systematic evaluation method and data. Both educators and school students demonstrated increased understanding and willingness to address the problem of marine litter following the educational activities.

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Appendix A: Study 1 questionnaire items: Educators' pre- and post-course perceptions (1-7: *strongly disagree - strongly agree*).

Concept	Item
Concern	I think marine litter is a very important problem
Responsibility	I feel a responsibility to educate young people about the topic of marine litter
Knowledge	I don't know very much about marine litter
Understanding	I understand the topic of marine litter well enough to include in my teaching
Skills	I feel I have the skills to teach about marine litter
Confidence	I feel confident to teach about marine litter
Competence in methods	I can think of lots of ways I can integrate marine litter in my teaching
Competence in creativity	I have lots of ideas for teaching about marine litter
Ease/difficulty	I think marine litter will be challenging to integrate into my teaching
Potential barrier	I don't think the young people I work with will be very receptive to learning about marine litter

Appendix B: Study 2 questionnaire items: School students' pre-post perceptions and behaviors regarding marine litter (1-4: *not at all – a lot*).

Concept	Item
Problem awareness	Do you think litter on the beach and in the sea is a problem?
Concern	Are you worried about the problems that litter on the beach and in the sea might cause?
Proportion of plastic	What percentage of litter on the beach and in the sea do you think is plastic? (<i>Students provided their answer in an open response box</i>)
Longevity of plastic	How long do you think it takes a plastic bottle to breakdown/decompose? (<i>Students provided a number and circled a unit of time: hours/days/weeks/months/years</i>).
Perceived impacts	Do you think litter on the beach and in the sea is bad for... a) Animals in the sea? b) People that enjoy the beach? c) Human Health? d) Fishermen? e) What the beach looks like?
Perceived causes	Why is there litter on the beach and in the sea? (How did it get there?): a) Because people drop litter on the beach and streets b) Because there are not enough bins and litter is not properly collected and stored c) Because businesses like cafes, restaurants, and shops cause litter at the coast d) Because fishermen and boats release litter in the sea e) Because lots of things we buy have too much packaging that is difficult to recycle'
Self-reported waste-reduction behaviors	Have you done the following things in the last week?: a) Picked up litter lying around b) Separated your litter for recycling c) Bought items with less packaging d) Avoided using plastic bags in the supermarket e) Used reusable items, not throw away ones f) Encouraged family and friends to do all or any of the things above g) Thrown litter on the ground

Students answered all questions (except those about proportion and longevity of plastic) by choosing from four response options (*not at all, a little bit, quite a bit, a lot*).

Appendix C: Children’s pre- and post-education attitudes and self-report behaviors about marine litter in Study 2. Means (and standard deviations), number of participants, Wilcoxon Z statistic, p values, and effect size r (Z divided by square root of N) are presented comparing pre- and post-intervention responses.

	<i>M (SD)</i> <i>pre-intervention</i>	<i>M (SD)</i> <i>post-intervention</i>	<i>N</i>	<i>Z</i>	<i>p</i>	<i>r</i>
Problem awareness	3.76 (0.48)	3.80 (0.43)	341	1.57	0.117	0.09
Concern	3.38 (0.72)	3.52 (0.65)	341	3.61	<0.001	0.20
<i>Impacts:</i>						
Animals in the sea	3.86 (0.38) _a	3.85 (0.43) _a	341	0.34	0.736	0.02
What the beach looks like	3.45 (0.74) _b	3.60 (0.64) _b	341	3.51	<0.001	0.19
Human health	3.20 (0.82) _c	3.39 (0.76) _c	341	3.89	<0.001	0.21
Fishermen	3.13 (0.80) _c	3.22 (0.85) _d	341	1.75	0.079	0.09
People that enjoy the beach	3.01 (0.82) _d	3.16 (0.78) _d	341	3.49	<0.001	0.19
<i>Causes:</i>						
Dropping litter	3.40 (0.69) _a	3.50 (0.64) _a	341	2.01	0.045	0.11
Fishermen and boats	2.88 (0.82) _b	3.11 (0.80) _b	341	4.28	<0.001	0.23
Too much product packaging	2.79 (0.98) _b	3.09 (0.96) _b	341	4.91	<0.001	0.27
Coastal businesses	2.42 (0.82) _c	2.84 (0.87) _c	341	4.90	<0.001	0.27
Not enough bins	2.37 (0.91) _c	2.69 (0.96) _d	341	5.14	<0.001	0.28
<i>Actions</i>						
Separated litter for recycling	3.01 (1.03) _a	3.31 (0.86) _a	341	5.10	<0.001	0.28
Used reusable items	2.69 (1.02) _b	3.05 (0.98) _b	341	5.45	<0.001	0.30
Avoided using plastic bags	2.61 (1.13) _b	3.00 (1.08) _b	341	5.13	<0.001	0.28
Encouraged family and friends	2.24 (1.02) _c	2.79 (1.12) _c	341	7.93	<0.001	0.43
Bought items with less packaging	2.20 (0.97) _c	2.64 (1.03) _d	341	6.25	<0.001	0.34
Picked up litter	2.15 (0.95) _c	2.75 (1.01) _d	341	8.68	<0.001	0.47
Thrown litter on the ground	1.27 (0.64) _d	1.24 (0.66) _e	341	0.80	0.425	0.04
Estimated % plastic	65.32 (18.44)	73.13 (15.27)	341	7.57	<0.001	0.41
Estimated degradation time (in years)	15534(121305)	27119 (162947)	341	4.69	<0.001	0.25

Note. Means are based on response options: 1= not at all, 2 = a little bit, 3 = quite a bit, 4 = a lot. Subscripts indicate results from Wilcoxon tests for item means that are significantly different at pre-intervention and item means that are significantly different at post-intervention within each category of questions, with significance criteria adjusted for multiple comparisons; impacts ($p < 0.01$), causes ($p < 0.01$), and actions ($p < 0.007$).