Chapter

How Marine Plastic Pollution Education Develops Secondary School Students' Sustainability Competences

Viktoria Smenes and Hilde Ervik

Abstract

Marine plastic pollution is a global environmental challenge. Providing marine plastic pollution education is essential for combating marine plastic pollution. Knowledge about biodiversity and an understanding of how biodiversity should be safeguarded should be included in education on marine plastic pollution. This study provides answers about the knowledge, understanding and attitude that Norwegian secondary school students (n = 50) have about how marine plastic pollution affects biodiversity and how biodiversity can be protected. The results from the questionnaires (pre-test and post-test) and group interviews showed that after having completed their education, over half (51.4%) of the respondents possessed adequate knowledge of and a good understanding of how biodiversity can be safeguarded and 29.7% showed a good understanding of why microplastics pose a threat to biodiversity. 35.1% provided good arguments as to why they believe their actions will make a difference. However, the results were less promising with respect to how the international community should cooperate on sustainable development. This study provides a foundation for what should be included in the education of secondary school students on marine plastic pollution, and how it should be provided.

Keywords: education for sustainable development (ESD), action competences, sustainability, biodiversity, macro and microplastics, field and laboratory work, marine littering

1. Introduction

Sustainable development refers to development that covers current requirements without compromising the requirements of future generations [1]. In Ref. [2], it is pointed out that the term sustainability is often incorrectly applied, especially when it is limited to environmental issues without taking into account the social and economic aspects. According to Ref. [2], a fragmented approach has contributed to a lack of agreement on how sustainability competencies should be defined and taught.

In order to solve sustainability challenges, create a sustainable future and promote social, economic and environmental sustainability, students must acquire knowledge, attitudes, skills and values from Education for Sustainable Development (ESD) [3, 4], and there is currently a crucial need for action [2] if we are going to be able to meet our ever-increasing sustainability challenges. Schools, with their mandates, play a critical role in promoting ESD, because the current climate and environmental crisis requires the way in which we educate future generations to be restructured [5]. Education must go beyond traditional academic disciplines and focus more on the development of competencies that will enable students to face complex global challenges [6, 7]. This will lay the foundations for a more sustainable future [5].

Sustainability competencies, as discussed in several studies [2, 6, 8, 9], include skills such as systems thinking, future thinking, critical reflection, cooperation and the ability to act responsibly. These skills are essential for understanding and addressing the complex challenges associated with sustainability dilemmas. In Ref. [2], it is emphasised that ESD is a key component in developing such competencies, and the overall perspective on sustainable competences is regarded as being key for equipping future generations to become active change agents.

Several studies have pointed out that education on sustainable development has a positive impact on students' attitudes and behaviour with respect to sustainability because it raises awareness about environmental challenges and also strengthens students' critical thinking about complex sustainability issues [10]. A Swedish longitudinal study shows that ESD increases students' competence to act, provides them with the skills to tackle sustainability challenges and helps them to take action in their everyday lives [11]. This serves to emphasise the fact that ESD has a long-term impact on students' ability to contribute to sustainable solutions. Ref. [12] describes a study conducted at three upper secondary schools in Norway which emphasises that school experiences that allow students to positively influence society, correlate with their competence to act and that this competence includes knowledge, self-confidence and a willingness to act. The findings also indicated that providing students with the opportunity to influence society can promote their development of sustainability action competence [12]. Ref. [3] explains that key issues with respect to sustainable development, for example, biodiversity and climate change, must be included in teaching and learning. Students should participate actively in order to be empowered and motivated to implement sustainable development measures, and learning and teaching methods are required in order to facilitate this [3].

Society is dependent on having a sustainable coexistence with the planet [2]. Every year, 19–23 million tonnes of plastic end up in the ocean, threatening biodiversity and amplifying climate change [13, 14]. About 88% of marine species are negatively affected by plastic [15], and plastic waste is broken down into microplastics which damage organisms and the environment [16]. Plastic pollutants exacerbate the stressors created by climate change and affect species and public health [17–19]. According to Ref. [19], several solutions are required, because the causes are diverse and complex. The solution categories outlined in Ref. [19] are circular economy, awareness/bans/less consumption, price-fixing/fees/subsidies, better raw materials/recycling and reuse and clean-up/better waste management. Measures must be implemented at several levels of society, and Ref. [20] shows that there is no stronger motivator than education for promoting measures designed to combat biodiversity loss. It is believed that education can help students understand the consequences of what marine plastic waste entails and the lessons learnt at school will influence students' knowledge,

understanding and attitudes about marine plastic pollution [20–22]. Knowledge must be developed along with skills, attitudes and values in order to effect behavioural changes [23], such as increased awareness, less consumption, recycling and cleaning up. Being involved and implementing measures will create the belief that making a difference works and will create hope for the future because involvement is positively related to hope [24, 25].

Marine plastic pollution is a complex sustainability dilemma, and the academic context included in teaching may vary [21]. Several studies have examined students' knowledge, skills, attitudes and values with respect to various sustainability dilemmas, including nature conservation [26–29]. However, more research is required about the knowledge, understanding and attitudes that students have about how marine plastic pollution affects biodiversity and how biodiversity can be safeguarded. In Ref. [21], it is emphasised that more research is required in order to ensure quality assurance practices with respect to teaching marine pollution. Teacher education should include more focus on marine littering in order to equip teachers with the knowledge and skills required for teaching this subject in a suitable way [21]. Ref. [21] states that teachers must have a good, thorough understanding of the problem and also be able to pass on such knowledge effectively to their students. It was also discovered that teachers' attitudes towards marine littering and how they teach such are important factors with respect to the benefits of teaching marine littering.

This study examined the sustainability competencies developed by Norwegian secondary school students when undertaking a modelled sustainability project, which was designed to enable students to understand how marine plastic pollution affects biodiversity. The findings provide a basis for how marine plastic pollution education can be carried out. We start below by explaining the conceptual background and literature underlying the study, followed by the methods, results, discussion and conclusions.

2. Conceptual background

The study was originally motivated by the first author's own desire to design a teaching programme for secondary school students, aimed at being able to contribute towards students' understanding of how to maintain biodiversity, based on the threat to nature imposed by marine plastic pollution. In preparation for designing this study, the first author participated in cleaning up marine waste, along with coastal renovators from Eider AS Mausund Feltstasjon[1], in order to gain an insight into the extent of marine plastic littering on the Froan archipelago in central Norway.

Schools play a key role; teachers are important change agents with respect to teaching about marine plastic pollution [21], and students will be made aware of how plastic waste needs to be handled by acquiring increased knowledge [30]. The teaching provided not only includes the incorporation of sustainability competencies but also embraces innovative and forward-thinking approaches that motivate and empower students to change their behaviour and provide them with the desire to take action that will ensure a better future [23, 30]. Studies conducted with groups of students similar to those in this case study have examined how teaching can increase

[1] www.eider.no

students' awareness and actions, focusing particularly on their knowledge, attitudes and skills with respect to plastic pollution. The results indicate the suitability of conducting practical work in lessons on plastic littering. Ref. [30] explains that practical teaching strategies improved students' understanding of plastic waste problems and handling, while Ref. [29] shows that participation in clean-up activities strengthened students' insight into the impact of plastic pollution on the environment. Several studies providing further insight have been conducted in the UAE, where, in Ref. [31], it was shown that students at the secondary school level possess knowledge and awareness about the impact of plastic pollution on the environment and health, as the findings indicated that the students regarded plastic waste as being harmful to the environment. Ref. [32] describes a study conducted in Denmark where students participated in the clean-up of marine waste through Citizen Science (57,000 students, 7–16 years). The study found that students were generally very concerned about plastic pollution, which they explained was due to their increased awareness about the subject. In Italy, a four-day Sea Cleaner programme was conducted that boosted students' attitudes towards and understanding of marine littering [28]. Another similar programme was undertaken in Spain, Italy, Cyprus and Portugal [33] in order to raise awareness about marine littering in the Mediterranean and the Atlantic Ocean. An Indonesian study showed that teaching had a positive but limited impact on students' awareness of marine littering [34].

In this case study, we wanted to investigate whether or not a modelled sustainability project, including field and laboratory work, changed Norwegian secondary school students' knowledge and understanding of how biodiversity is affected by marine plastic pollution. The aim was also to identify what academic expertise and practical activities should be integrated into lessons about marine plastic pollution. This led to the following research questions:

1. Does field and laboratory work in marine plastic pollution education affect secondary school students' knowledge and understanding about biodiversity?

2. What factors influence secondary school students' learning outcomes during practical work in their marine plastic pollution education?

3. Methods

3.1 Research context

During the autumn of 2021, 50 secondary school students in 10th grade (age 15) from a district school in Trøndelag, Norway, undertook a sustainability project on the subject of marine plastic pollution. During the education programme, the students studied the properties of plastic and learned about its impact on biodiversity during field and laboratory work. Field and laboratory work was carried out at Mausund and at the Mausund Field Station (Appendix B, **Table B1**). There, they saw and experienced real-life issues relating to marine plastic pollution. The Mausund Field Station is working towards achieving sustainable development in the ocean, and the area was well suited for the theme of the sustainability project because large quantities of marine waste are flushed ashore on the islands due to the ocean currents. Since 2017, the coastal renovators employed at the Mausund

Field Station have cleaned up marine plastic waste on the coast of central Norway. Mausund' s topography resembled the students' local environment, and it was therefore important to facilitate activities that the students experienced as being relevant and meaningful.

In August 2021, the research group went to the students' secondary school and informed them about the excursion area and what they would be doing there. The pre-test was conducted in order to identify the students' prior knowledge about the subject. After answering the pre-test, they attended an academic lecture on the history, build-up, characteristics of plastics in the ocean, biodiversity and why plastics and microplastics pose a threat to biodiversity, as well as economic, moral, biological and aesthetic arguments (Appendix B, **Table B2**). The students had the opportunity to discuss in plenary the pros and cons of plastic. The researchers led the discussion and gave the secondary school students answers and follow-up questions.

In October 2021, the selected 50 secondary school students were divided into two groups. One group of 25 secondary school students travelled to the excursion area and undertook the education programme on day 1. The second group of 25 secondary school students travelled to the excursion area and undertook the same education programme on day 2.

In the excursion area at the Mausund Field Station, the secondary school students were able to study plastic both in the field and at the field station. The student groups consisting of 25 students were divided into field and laboratory groups, with 12–13 students in each group. Three hours were allocated for fieldwork, and three hours for laboratory work, for each group (Appendix B, **Table B1**).

3.2 Research approach

This study is a descriptive case study and is a strategy that, in qualitative research, describes what is characteristic within a group in a real-world context and where the case is time-sensitive [35]. Descriptive studies are particularly useful for obtaining information relating to the current status of activities in order to provide answers to questions such as what, when, where and how [36]. Both quantitative and qualitative methods were used for answering the research questions. Data was collected in pre-test and post-test questionnaires and group interviews.

The quantitative questionnaire was designed to assess secondary school students' (i) knowledge about how and why one should take care of biodiversity, (ii) knowledge about microplastics, (iii) knowledge about sustainable development seen from a global perspective and (iv) whether or not student actions make a difference. In order to assess the secondary school students' learning outcomes after the laboratory work, the post-test also included (v) knowledge obtained from the laboratory work and (vi) motivation for biodiversity conservation. The questionnaire was designed on the basis of the interdisciplinary subject entitled "Sustainable Development"; the core element entitled "The Earth and Life on Earth" and the science competence goal for 10th grade entitled "Provide examples of and discuss current dilemmas relating to the exploitation of natural resources and the loss of biodiversity" [37]. The questionnaire consisted of open (O) and closed (C) questions (**Table 1**). When the informants were supposed to answer either yes or no, they were asked to justify their answers. Questions 1, 2, and 3 about biodiversity and microplastics were open, question 4 about microplastics was closed, and questions 5 and 9 about sustainable development and the belief that action makes a difference were open. In the post-test, question 6

about laboratory work was open, and questions 7 and 8 about knowledge and understanding after the laboratory work, and about motivation to preserve biodiversity, were closed.

The interview guidelines for the semi-structured interview (Appendix A, **Table A1**) were designed with introductory questions about what the laboratory work day had been like. The questions were formulated around practical work in the laboratory, sustainable development, biodiversity, plastics, the three tests students had conducted in the laboratory, and what the students believed could be done to prevent further marine plastic pollution. To validate the questions and ensure clear and unambiguous questioning, a pilot test was conducted where two colleagues at the same university answered and tested the questionnaire. The feedback resulted in minor changes being made to the wording.

3.3 Data collection instrument

Data was collected during the autumn of 2021 *via* an anonymous pre-test and post-test questionnaire designed on the University of Oslo (UiO)'s digital online form and two group interviews. The research project was conducted in accordance with the regulations on the processing of personal data [38]. The audio recordings from the interviews were deleted at the end of the project.

Of the 50 secondary school students who were asked to participate, 46 gave their consent and answered the pre-test (August 2021), and 37 secondary school students answered the post-test (October 2021). The post-test was carried out at the school on the day after the secondary school students had undertaken the field and laboratory work at Mausund. A group of volunteers from among the 50 secondary school students attended the group interviews immediately after the laboratory work. The group interviews with a total of nine secondary school students were conducted in October 2021. There was an even distribution between the genders, with five boys and four girls. Five secondary school students attended the group interview on day 1, and four secondary school students attended on day 2.

3.4 Data analysis

The data analysis had a qualitative and quantitative approach. The responses and rationale provided by the informants with respect to each questionnaire question were converted into numerical form (score), thus making it easier to summarise the data [36]. The scores were 1 = do not know, 2 = below average, 3 = average, 4 = above average, 5 = very well answered. How well the answers were explained and argued formed the basis for where they were categorised in scores 2–5. The results for each score were provided as a frequency (%) in order to compare whether or not there were changes in the pre-tests and post-tests. Excerpts from the secondary school students' responses to the pre-test and post-test questionnaires and direct quotes and excerpts from the transcribed interviews provide in-depth information with respect to the questionnaire's quantitative analysis.

4. Results

Table 1 lists questions 1-9 from the questionnaire, along with the corresponding results (5) for each score.

		Pre-test					Post-test				
Questions	**Score**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
1. Biodiversity is the diversity of living organisms. In what ways can we take care of biodiversity? (O)		78.0%	13.0%	8.7%	0%	0%	28%	8.1%	51.4%	5.4%	0%
2. Why should we take care of biodiversity? Explain your answer. (O)		60.9%	21.7%	15.2%	2.2%	0%	40.5%	29.7%	21.6%	8.1%	0%
3. Do you know what microplastics are? What are they and where do they come from? (O)		19.6%	21.7%	58.7%	0%	0%	13.5%	0%	35.1%	51.4%	0%
4. Do microplastics pose a threat to biodiversity? Explain your answer. C:		32.6%	32.6%	34.8%	0%	0%	24.3%	16.2%	29.7%	18.9%	10.8%
5. In order to create sustainable development, the international community must work together in three areas. Which ones? (O)		43.5%	30.4%	19.6%	6.5%	0%	56.8%	16.2%	13.5%	13.5%	0%
6. What do you remember best from the laboratory at the Field Station? (O)							18.9%	48.6%	24.4%	8.1%	0%
7. Have you learnt anything from what we did in the laboratory? C:							24.3%	21.6%	43.3%	10.8%	0%
8. Have you been motivated to preserve biodiversity after your laboratory activities? If so, how have you been motivated? C:							40.5%	21.6%	35.2%	2.7%	0%
9. To what extent do you think your/their actions make a difference? (O).		2.2%	19.69%	60.9%	17.4%	0%	8.1%	21.6	35.1%	35.1%	0%

Table 1.
Details about questions 1-9 in the questionnaire with information on whether or not they were open-ended (O) or closed (C) questions. Pre-test and post-test are divided according to the scores (1-5). The frequency for each score is provided as a %. Score 1: don't know, score 2: below averagely well answered, score 3: averagely well answered, score 4: above averagely well answered, score 5: very well answered.

Question 1 had the highest response rate for score 1 for the pre-test. For the post-test there was a marked increase in score 3 (averagely well answered) of 51.4% and score 4 (above averagely well answered) of 5.4%. In response to question 1 one informant wrote: Dispose of the plastic in the right place, pick up plastic that has gone astray and reduce unnecessary plastic production. Another wrote: we can be more aware, pick up more rubbish and try to make a change. During the group interview one informant gave the following answer:

> *When I dug in the soil there was a piece of rope, the sort that consists of tiny pieces of rope, and they had somehow dissolved inside the soil, so the clump of earth only consisted of pieces of rope like that with a bit of soil. And this made me see how much there actually is.*

During the same interview another informant said: "The plastic is not just what we see, but there's also a lot we do not see." A third informant added: "Microplastics. They are everywhere. We looked at a small clump under the microscope and there was a lot!" Another informant explained:

"That experiment which involved studying how much plastic there was in the soil was really surprising."

Question 2 score 1 had 60.9% for the pre-test and 40.5% for the post-test. This showed a change for score 3 (averagely well answered) from 15.2% for the pre-test to 21.6% for the post-test and for score 4 (above averagely well answered) a change from 2.2% for the pre-test to 8.1% for the post-test. A written response to the post-test was: and many animals ingest environmental toxins because the microplastics take it to them. When they ingest environmental toxins, their immune and hormone systems are compromised, and their fertility is reduced.

During the group interview, one of the informants gave the following answer:

> *There was so much plastic in the mink. Yes, I did not actually think there was going to be so much plastic in it since I did not think it ate anything that might resemble plastic or something that had so much plastic in it, so I did not think it [the mink] was going to have as much plastic in it as it did.*

Question 3, score 4 (above averagely well answered) had 0% for the pre-test and 51.4% for the post-test. One informant wrote: There are plastic pieces that are smaller than 5 mm. These come from larger pieces of plastic that have been in nature for a long time.

Question 4 had 0% for both scores 4 (above averagely well answered) and 5 (very well answered) for the pre-test, 18.9% for score 4 and 10.8% for score 5 for the post-test. One informant with a score of 5 wrote: Yes, it does. Microplastics are eaten by animals and then the environmental toxins pass into the animals. They also get a false feeling of being full up. Another informant wrote: There are major consequences for animals such as polar bears, e.g. having two genders as a result of the environmental toxins contained in microplastics.

Question 5, score 3 (averagely well answered) was 19.6% and score 4 (above averagely well answered) was 6.5% for the pre-test, and for the post-test, this was 13.5% for both scores 3 and 4. One informant indirectly responded to the question about how to create sustainable development when they observed microplastics in the stomach of the mink: "We need to do something to stop this."

Questions 6 and 7 provided information about knowledge and understanding obtained from the laboratory experiments at the field station. For question 6, the post-test result was 48.6% for score 2, 24.4% for score 3 and 8.1% for score 4. One of the informants wrote that there was a lot of plastic in both the soil samples and

the mink. For question 7, the post-test result was 21.6% for score 2, 43.3% for score 3 and 10.8% for score 4. One of the informants wrote about the knowledge and skills required for identifying different types of plastic.

For question 8, the post-test result was 21.6% for score 2, 35.2% for score 3 and 2.7% for score 4. One informant wrote: When I saw what the mink had in it and that we need to do something to stop this. During the interview one informant also responded as follows: "I was motivated because the teacher [supervisor from the research group] was enthusiastic."

For question 9, the pre-test result was 19.7% for score 2, 60.9% for score 3 and 17.4% for score 4, and for the post-test the result was 21.6% for score 2 and 35.1% for scores 3 and 4. During the interview the informants said something needs to be done. "We need to pollute less, plastic in nature needs to be cleaned up, less plastic needs to be produced, and this will make a difference."

It emerged from the interviews that secondary school students have heard about Plastic in the Ocean in the media, and they have been working on it at school. One of the informants said during the interview: "It's mainly at school. We wrote a text about it in 8th or 9th grade, and we learnt a lot about it then. And then we saw a lot of news broadcasts about it too." Another informant added: "Yes, there's a lot in the media, these subjects are also being addressed more at school than before and it's more relevant now." One of the informants replied: "Media and natural sciences. We're talking about it at home too, but not as much as we hear at school." Another informant added: "At the moment it's everywhere, there is an increasing amount of attention being paid to the environment around the world, so we hear a lot about it, at least young like us people do."

5. Discussion

The discussion is presented on the basis of the research questions.

5.1 Does field and laboratory work in marine plastic pollution education affect secondary school students' knowledge and understanding about biodiversity?

The consequences of marine plastic pollution can be difficult to understand, just like climate change, if they are only talked about. Climate change and marine plastic littering are two sides of the same issue [39]. The global challenges lead to the degradation of the environment and a loss of biodiversity because species face greater challenges in adapting to the environment. The binding global agreement on plastic pollution contains main areas for measures designed to reduce climate change, pollution and biodiversity loss [40]. One possible analogy for explaining people's relationship with marine plastic pollution and its hidden impact on biodiversity, is climate change. Global warming is well documented scientifically, and human behaviour is widely accepted as being a contributory factor [41, 42]. However, studies show that many people do not actively try to counteract global warming, something that may be associated with there being a psychological distance between theoretical understanding and noticeable changes [43]. In Refs. [44, 45], this is described as a form of paralysis, whereby people understand the problem intellectually but disassociate themselves from it emotionally (splitting), and in Ref. [46], indifference is explained as being an emotional response to a constant flood of overwhelming environmental news, which also makes it difficult for many people to see the direct link between human activities and global changes [47].

The results of this study show that the students acquired more knowledge and understanding about microplastics and their impact on biodiversity. The results of the

post-test with respect to question 1 showed 51.4% for score 3, compared to 8.7% for the pre-test. This is the knowledge and understanding that is most likely acquired during lessons because score 1 was 78.0% in the pre-test (**Table 1**). This was related specifically to how much microplastic they detected in the soil and in the stomach of the mink during the laboratory work carried out at the field station and what they experienced when they uncovered marine waste in the soil during their fieldwork. When they studied the stomach contents of the mink after dissecting it, the secondary school students acquired knowledge and understanding that showed that microplastics are absorbed into the food chain. One important piece of knowledge that they acquired was that microplastics contain environmental toxins that contribute towards disrupting hormonal balance and reproduction and that microplastics are a threat to biodiversity because they also create a false feeling of being full up. The results show that the secondary school students had an increased knowledge and understanding of questions 3 and 4. Here, the results were 51.4% for score 4 in the post-test compared to 0% in the pre-test for question 3, 18.9% for score 4 and 10.8% for score 5 compared to 0% for scores 4 and 5 in the pre-test for question 4 (**Table 1**). One explanation as to why they were more precise in their descriptions of these may be that they remembered a lot from the lecture that was first held at school and then at the field station about microplastics, environmental toxins and hormones.

The theme of microplastics ran like a connecting thread through the teaching programme at the field station [48]. For question 5, there was a change in score 4 from 6.5% for the pre-test to 13.5% for the post-test (**Table 1**). The three areas that require cooperation on sustainable development were addressed in the lectures but not specifically during the field and laboratory work. During the lecture at the school, the secondary school students gained an overview of the many factors that influence social and economic conditions that are required in order to solve environmental problems. Despite this, it is not always easy to repeat this if they do not have ownership of the content. It should be explicitly mentioned, for example, when secondary school students are out cleaning up marine plastic waste or are standing in the laboratory discussing the properties and uses of plastic. In order to acquire control of what is in nature, it is necessary to focus on the economic situation and the workers in order to do the job. For question 9, there was a change in score 4 from 17.4% in the pre-test to 35.1% in the post-test. The secondary school students show that they have an insight into what should be done. In the interviews, it emerged that secondary school students realise that we need to pollute less, that plastics in nature need to be cleaned up and that less plastic needs to be produced. Here, they are indirectly involved in key factors in ESD, such as how overall agreements, strategies and measures can contribute to solutions, without mentioning such explicitly. The secondary school students do not mention how we can reduce pollution or who is responsible for cleaning up plastics from nature. They point out that it needs to be done. Ref. [25] shows that education has the expectations and potential for focussing on hope when it comes to dealing with climate change. This should have a transfer value in education which could also apply to environmental challenges such as marine plastic pollution, where students should have the hope that commitment and actions will make a difference. Commitment is positively related to hope [24].

5.2 What factors influence secondary school students' learning outcomes during practical work in their marine plastic pollution education?

Secondary school students derive much of their knowledge from media and can repeat information about plastic pollution, but often without a deeper understanding or the ability to justify their claims [31]. The results obtained in the interviews in this

study support the fact that secondary school students receive information from the media. The results from the pre-test show that the majority of them have averagely good justifications (score 3) with respect to questions 3, 4, and 9 (58.7, 34.8 and 60.9%) (**Table 1**). Their approach to the complex picture presented by marine plastic pollution must be addressed in several contexts and worked on in several ways.

The secondary school students have acquired increased knowledge and understanding and there may have been many factors that influenced their learning process. It is therefore difficult to determine if it was solely the field and laboratory work that led to their increased learning outcomes. During their interview, one of the informants said that the teacher's [the research group's supervisor] commitment motivated learning, thus creating a greater understanding of the challenge of marine plastic littering. This is consistent with what has been underlined in [21], that is, the teacher's lessons about marine littering are an important factor with respect to the teaching benefits.

Other factors that could influence motivation for learning include teaching being conducted at the Mausund excursion area, which is a different arena than the students' school area. This may have affected students at an affective level because the field and laboratory work was carried out in a local environment [49], and the impressions that they acquired from their relevant experience contributed towards motivation for learning. Reference [50] refers to a connection between external motivation and concerned reactions, thus indicating a high affective level because looking after the environment entails an awareness of the importance of action in order to reduce specific environmental challenges.

The secondary school students' visit was guided by others who were not their usual teachers. The questions that the informants answered were directly related to the laboratory work. They also carried out fieldwork on cleaning up marine waste and identifying its origins on the same day, and this would also affect their overall impressions, commitment and motivation. The teaching was facilitated so that the students could be involved in authentic issues and solutions designed to promote knowledge development and a sense of responsibility [48], and when secondary school students are taught to face current real-world problems, it is more likely that they will be able to solve the problems that they will face in the future [51]. In [21], emphasis is placed on the teacher's role in teaching about marine plastic pollution, where practical ways of working are highlighted as being useful tools for providing students with specific examples and engaging activities.

Schools shall provide students with the skills required for looking after the environment and making sustainable choices. Despite the increase in focus on sustainability both in educational policy and in a research context, there are several teachers who feel uncertain about the academic content and the didactic approach to the subject of sustainability [52]. The background for this can be linked to the fact that sustainability subjects not only provide a theoretical introduction to the subject, but that teaching that introduces the subject in the classroom shall also provide students with sustainability awareness and the competence to act. This is a challenging but important mission in order to ensure that students have an all-around general natural sciences education. The link between ESD and natural science practice has great potential for the development of students' knowledge and skills both inside and outside the classroom [53]. A lot of what has been published about ESD includes the practitioners' gut feelings and political recommendations [10], and there are calls for what is being implemented and the learning outcomes that are emerging from such.

In Ref. [54], reference was made to the report entitled "Education for Life and Work" and the fact that competence transfer of skills and knowledge will be sought

after in the twenty-first century, and these should be competencies that students acquire experience of during their education. Ref. [20] refers to the importance of sustainability competencies, where practical work in particular can help students to develop these competencies, as well as equip them with the skills that they need in order to be able to handle complex issues.

6. Conclusion

This study was conducted with 10th-grade Norwegian secondary school students, and the new thing about this study is that it investigated how a modelled sustainability project could contribute to increased knowledge and understanding about how marine plastic pollution affects biodiversity. The secondary school students responded with words and terms that they had been taught in lectures. They referred to the subjects discussed during the lectures and laboratory exercises, and their fieldwork experiences, and this helped the secondary school students to formulate evidence-based arguments about questions on how microplastics affect biodiversity.

The post-test showed a result of 51.4% for score 3 (averagely well answered) and 5.4% for score 4 (above averagely well answered), compared with 8.7% and 0% for the pre-test on how to safeguard biodiversity. The results of the post-test on microplastics were 51.4% for score 4 (above averagely well answered) and 0% for the pre-test. When asked why microplastics pose a threat to biodiversity, the results were 18.9% for score 4 (above averagely well answered) and 10.8% for score 5 (very well answered), and 0% for scores 4 and 5 in the pre-test. These results can be explained by the fact that microplastics were a consistent topic at the field station and that the secondary school students were allowed to study the characteristics and structure of microplastics during two out of three parts of their laboratory work.

Concerned reactions, looking after the environment and the belief that action will make a difference and provide hope for the future may have helped to influence the affective level of the secondary school students and their motivation for learning. Secondary school students realised that we need to pollute less, that plastics in nature must be cleaned up and that less plastic must be produced. When asked if they thought that their actions make a difference, the result was 35.1% for score 4 (above averagely well answered) for the post-test. The findings may reflect secondary school students' personal experiences of the impact of marine plastic pollution in their local environment.

6.1 Future research directions

This study highlights the importance of marine plastic pollution education and opens several pathways for further research. Conducted with 10th-grade students, the teaching program demonstrated its potential for adaption across different academic levels, offering valuable insights for future educational strategies on this vital issue of biodiversity loss. Future research may examine, among other things, how this teaching programme affects students' knowledge and action competence over time, how commitment affects hopes for preserving biodiversity, and whether or not the same student group or other student groups will use these sustainability competencies later

on in life. This could include studies in sixth form college (e.g. with respect to subjects like biology and chemistry), or at a higher university level and in teacher education. Furthermore, it might also be interesting to explore how such a teaching programme could be integrated into interdisciplinary projects that include the three sustainability dimensions: economics, social conditions and the environment.

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Appendix A

Subject:	Question
Practical work in the laboratory	What was it like doing something practical in the laboratory? What are your science lessons usually like? Do you learn best from doing things in a practical way or from normal whiteboard teaching? Do you feel like you learn more from practical work? Do you feel more motivated by doing practical work? (Outer/inner) What are you motivated by?
Sustainable development	What did you know previously about marine plastic pollution? Where have you heard about it before? Media, school, friends, family, own observations of your local environment? Where do you think your knowledge on the subject comes from? Is it from natural science subjects? Have you acquired a new insight into the problems relating to plastics after spending a day here at Mausund? In what way?
Biodiversity	Can anyone explain what it means when we say that nature is biodiverse? *Total diversity is seen at three different levels: (genetic, species and ecosystems)* What are the arguments for preserving biodiversity? "Do you think it's important to preserve biodiversity, why?" What do you think is the most important reason for maintaining biodiversity? "After today have, you been motivated to preserve biodiversity?"
Plastics	Why do plastics (microplastics) pose a threat to biodiversity? What are microplastics? What did you know about microplastics before and what do you know now? Did you learn anything new?
Laboratory	During your laboratory activities (Items 1–3), what do you find most enjoyable? Did you experience anything that you did not expect in advance? Have you learnt anything that you would like to take with you into your everyday life, and if so, what?
Conclusion	What three things do you think are the most important things we have talked about?

Table A1.
Interview guide.

Appendix B

	The laboratory booklet contains information about
1	Why the area around the Mausund Field Station is eminently suitable for conducting fieldwork on the subject of marine plastic pollution.
2	Facts about plastic
	• decomposition time • effects on biodiversity • affinity of environmental toxins for microplastics • statistics on how many tonnes of plastic end up in the ocean each year • illustrative images
3	Posts at the Field Station with procedures for each laboratory experiment
	Post 1: Investigating soil samples for microplastics Post 2: Identification of plastics (six attempts) in order to identify different types of plastic according to specific criteria. Post 3: Dissection of mink. The stomach of the mink was to be opened in order to check whether it contained microplastics.
4	Field for notes to write hypotheses and results
5	Discussion questions for each laboratory experiment

Table B1.
Information in the laboratory booklet.

Lecture at school before excursion	**Lecture at the field station**
History of plastics	Build-up of plastics
Build-up of plastics	Properties of plastic
Properties of plastic	Plastics in the ocean
Plastics in the ocean	BD
BD*	Arguments on why we should look after BD
Arguments about why we should look after BD	Why plastics pose a threat to BD in the ocean
Why plastics pose a threat to BD in the ocean.	Microplastics
Microplastics	Why microplastics pose a threat to biodiversity
Why microplastics pose a threat to BD	
Economic, moral, biological, aesthetic arguments.	
Norway's plastics strategy	

**BD = Biodiversity.*

Table B2.
Academic content of the lectures.

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Author details

Viktoria Smenes[1] and Hilde Ervik[2*]

1 Vika Upper Secondary School, Oslo, Norway

2 The Norwegian University of Science and Technology (NTNU), Trondheim, Norway

*Address all correspondence to: hilde.ervik@ntnu.no

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