AN ABSTRACT OF THE THESIS OF

Marie Kowalski for the degree of Master of Science in Marine Resource Management presented on June 6, 2016.

Title: **Mitigating Microplastics: Development and Evaluation of a Middle School Curriculum**

Abstract approved:

____________________________________________________

Shawn Rowe

Microplastics, plastic marine debris less than 5 mm in size, is a threat to the health of our oceans. One important way to reduce microplastics in our oceans is to educate people about the issue, particularly future decision-makers. In this study, a middle school curriculum was developed using current scientific data and evaluated using formative and summative methods. The curriculum includes three lessons based on Ocean Literacy Principles, Next Generation Science Standards, and teaching best practices. The lessons engage students in sources and impacts of microplastics as well as possible solutions. The curriculum has been evaluated using Stufflebeam’s Context, Input, Process, Product (CIPP) model. The evaluation included pre and post surveys of students and teachers in Lincoln County School District, a rural, coastal school district in Oregon. The surveys assessed the extent to which attitudes and beliefs about microplastics changed as well as how understanding and knowledge of behaviors changed after participating in the microplastics curriculum. Student work was analyzed to understand any changes in knowledge. Students participating in the curriculum increased their knowledge, awareness, and sense of personal responsibility around the issue of microplastics.
Master of Science thesis of Marie Kowalski presented on June 6, 2016

APPROVED:

________________________________________
Major Professor, representing Marine Resource Management

________________________________________
Dean of the College of Earth, Ocean, and Atmospheric Sciences

________________________________________
Dean of the Graduate School

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Marie Kowalski, Author
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INTRODUCTION

Microplastics in the Ocean

“We would all be dead if we didn’t have plastic because of all the plastic doctors use!” (Student comment in researcher’s fieldnotes, December 11, 2015). As this student’s comment suggests, it is sometimes a challenge to imagine a world without plastic. Almost unavoidable in many of our everyday lives, plastic is used in food packaging, electronics, and clothing. Plastic is everywhere. Our use of plastics, however, has consequences beyond our daily lives. Plastic waste produced all over the world ends up in the ocean, where its impacts are largely unknown.

We depend on our ocean for food, recreation, beauty, and biodiversity. The health of our ocean is threatened by the presence of plastic waste and other debris. Marine debris is defined as “any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes” (NOAA, 2015). Marine debris is a global issue because it is ubiquitous in our ocean (Browne et al., 2011) and most marine debris is plastic (Ryan, 2009; Thiel et al., 2013).

Microplastics are plastic marine debris less than 5 mm in size (Law & Thompson, 2014) and are estimated to make up more than 90% of the plastic particles in the global ocean by count (Eriksen et al., 2014). The issue of microplastics is a growing concern, and understanding its sources, impacts, and solutions will be critical in addressing the issue effectively.

There are multiple sources of microplastics to the ocean, shown in Figure 1.1. When small plastic pieces less than 5 mm enter waterways, they travel to the ocean. This can occur when personal care products such as face wash (Figure 1.2) or toothpaste containing microbeads are rinsed down a drain, or clothes containing synthetic fibers are washed. Microplastics bypass water treatment plants because of their small size (Fendall & Sewell, 2009). Industry can also be a source of microplastics. Pre-
manufacture resin pellets, or “nurdles,” are sometimes spilled in transit or at factories, making their way into the ocean. Plastic debris larger than 5 mm in size, however, is thought to be a major source of microplastics (Browne, 2015). In the ocean, larger plastic debris items fragment into smaller pieces, producing microplastics.

![Diagram of microplastic sources and impacts](image)

**Solutions to prevent marine debris**
- Legislation (bans on plastic products)
- Education and awareness
- Individual consumption behaviors

**Solutions to manage existing marine debris**
- Cleanup activities

Figure 1.1. Main sources, impacts, and solutions to microplastics into the ocean

![Dried plastic microbeads from face wash](image)

Figure 1.2. Dried plastic microbeads from face wash with a centimeter ruler for scale
Once plastics are in the ocean, they can have a variety of impacts. While impacts of microplastics in the ocean are largely unknown and research is ongoing, microplastics have been shown to accumulate toxins (Mato et al., 2001), provide substrate for microbial communities (Harrison, Schratzberger, Sapp, & Osborn, 2014), and be ingested by various species of organisms (Cole et al., 2013; Van Cauwenberghe & Janssen, 2014; van Franeker et al., 2011).

The microplastics issue is challenging to address due to its global scale and multiple sources. Individual actions such as managing personal waste appropriately or purchasing plastic-free products are one solution. Although small in scale, these actions have the potential to become more impactful when the behaviors are a model for others or it starts a conversation in a community. Furthermore, students participating in environmental education programs have been shown to increase their parents’ knowledge about issues learned in school (Damerell, Howe, & Milner-Gulland, 2013).

A larger scale solution is policy and legislation. Legislation can be effective in preventing plastics from entering the ocean. Laws prohibiting the dumping of trash in the ocean by vessels have been in effect for over 20 years. The Marine Protection, Research, and Sanctuaries Act of 1972 (Ocean Dumping Act) requires a permit to dump within US federal waters. The Act to Prevent Pollution from Ships, MARPOL Annex V (1988), prohibits the disposal of garbage by ships. More recent bans on plastic products such as plastic bags may help prevent land-based waste from entering the ocean. A federal ban on personal care products containing plastic microbeads was passed in December 2015. The Microbead-Free Waters Act of 2015 phases out the manufacture and sale of personal care products with plastic microbeads by 2018.

Education is another solution to microplastics. Awareness of marine issues is associated with people feeling concern for the environment (Gelcich et al., 2014). Increasing awareness, communicating accurate knowledge about the issue, and educating people about possible solutions can potentially promote behaviors that lead to a reduction of plastics in the marine environment.
Although this study does not measure student and teacher behaviors explicitly, there is evidence that several factors exist that effectively inspire changes in behavior. Building self-efficacy, focusing on local issues, and taking the values and beliefs of the audience into consideration have been shown to strengthen the likelihood of action (Chawla & Flanders Cushing, 2007; Clayton & Myers, 2015; Stern, 2000). The belief that your actions make a difference in an environmental issue, or self-efficacy, is not enough to inspire a change in behavior without the belief that you have the capability and resources to be successful. Both these ideas are built into the microplastics curriculum presented here with the goal of inspiring change.

Classrooms across the country are effective places to educate students about microplastics and empower them to make responsible choices. This study focuses on the development and evaluation of a curriculum about the sources, impacts, and solutions for microplastics. The goal of the curriculum is to reduce microplastics in the ocean through education.

**Marine Debris Curriculum**

Curriculum about marine debris is widely available on the internet. In this study, curriculum is defined as a document that includes learning experiences and an ultimate goal. Curriculum under this definition may be a single lesson, a series of lessons, or a complete unit. These online curricula, which exist as electronic documents, stand alone and out of the context of a classroom.

Evaluating the effectiveness of a written curriculum out of context is different from evaluating the effectiveness of a taught curriculum in a classroom. For this reason, this study distinguishes between evaluating the merit of a curriculum and its worth. Merit, according to Guba and Lincoln (1981), is the intrinsic value of the work out of context and free of any implementation. The authors contrast merit with the concept of worth, which is the value of something in context. This is Posner’s (2004) operational curriculum, which includes the way in which the curriculum is taught and the topics it
emphasizes. In this study, existing marine debris curriculum documents were evaluated on their merit, while the microplastics curriculum developed by the researcher was evaluated on both its merit and worth in the context of middle school classrooms on the Oregon coast. The merit of the existing marine debris curricula was evaluated using a needs assessment which identified strengths, weaknesses, and gaps. The needs assessment also revealed gaps in the content covered in the existing curriculum. Microplastics was identified as such a gap during this assessment.

**Middle School Minds**

Lessons focused on large-scale, abstract environmental issues like microplastics are not appropriate for all ages. Although there are mixed ideas about when and how to engage children in environmental issues, an influential concept is Sobel’s ecophobia (1996). Sobel defines ecophobia as “a fear of ecological problems and the natural world” (p. 5). Ecophobia is the idea that by teaching young children about large-scale environmental problems with the hope of inspiring environmentally responsible citizens, we are in fact doing the opposite. The effect can be dissociation from the natural world and inaction. Sobel identifies three stages of development, and Table 1.1 describes appropriate environmental engagement at each stage.

Table 1.1. Sobel’s developmental stages and appropriate environmental engagement

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<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empathy</td>
<td>4-7</td>
<td>Encouraging empathy between children and animals in nature</td>
<td>Children first explore nature through play, introduce concepts through observations, etc.</td>
</tr>
<tr>
<td>Exploration</td>
<td>7-11</td>
<td>Exploring the local world</td>
<td>Following a stream to see where it goes</td>
</tr>
<tr>
<td>Social Action</td>
<td>12-15¹</td>
<td>Saving the world through individual and group actions</td>
<td>Recycling programs, influencing legislation, etc.</td>
</tr>
</tbody>
</table>

¹Age range targeted by this microplastics curriculum
The social action stage encompasses students in upper elementary and middle school. In this stage, students are able to begin addressing problems in their environment and be empowered to take ownership and responsibility for these actions. This stage was one justification for targeting middle school students with a curriculum about microplastics.

Another reason for targeting middle school students was to provide rigorous, scientific curriculum that is appropriate for students’ cognitive development. This was mainly assessed through the analysis of learning standards for grades four through twelve. Middle school (sixth through eighth grades) was determined to have the most appropriate standards for the microplastics curriculum. Next Generation Science Standards (NGSS), Common Core State Standards, Ocean Literacy Principles, and Oregon Environmental Literacy Plan standards were used to make this determination. The scope and purpose of each set of standards is described in Table 1.2.

Table 1.2. Learning standards used to develop the microplastics curriculum

<table>
<thead>
<tr>
<th>Standard</th>
<th>Scope</th>
<th>Date Written</th>
<th>Subject</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGSS</td>
<td>National</td>
<td>2013</td>
<td>Science</td>
<td>Designed to reflect interconnected, practical nature of science</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Emphasizes higher-order thinking and problem-solving</td>
</tr>
<tr>
<td>Common Core</td>
<td>National</td>
<td>2010</td>
<td>English Language Arts and Math</td>
<td>Based on higher-order thinking and application of knowledge</td>
</tr>
<tr>
<td>Ocean Literacy Principles</td>
<td>National</td>
<td>2004</td>
<td>Ocean Science</td>
<td>Framework focused on developing ocean literacy through knowledge of the ocean,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>communicating of this knowledge, and using the knowledge to make responsible decisions</td>
</tr>
<tr>
<td>Oregon Environmental Literacy Plan</td>
<td>State</td>
<td>2009</td>
<td>Environmental Science</td>
<td>Emphasizes understanding the natural world, sense of community and civic responsibility, and planning for a sustainable future in Oregon</td>
</tr>
</tbody>
</table>
Study Purpose

For this curriculum to meet its goal of reducing microplastics in the ocean, it must be effective. While reducing microplastics was not directly measured in this evaluation, there were measures of effectiveness that could possibly lead to broader impacts. The measures of effectiveness used in this curriculum evaluation included student and teacher understanding, awareness, attitudes, beliefs, behaviors, and student knowledge. Changes in these metrics could possibly lead to similar changes among school or family communities, including spreading awareness, knowledge, and potentially changing behaviors. To demonstrate any changes in these concepts after participating in the microplastics curriculum, an evaluation was designed. The evaluation was designed to determine if the curriculum was effective asking two research questions:

1. To what extent do awareness, knowledge, attitudes, and beliefs change after participating in this microplastics curriculum?
2. How do understanding and behaviors change after participating in this microplastics curriculum?

This thesis describes the development and evaluation of a middle school microplastics curriculum. The needs assessment (Chapter 2) describes an evaluation of existing marine debris curriculum, which informed the development of a new curriculum incorporating scientific data. The final curriculum is included (Chapter 3) along with the evaluation report (Chapter 4), which discusses the methodology and salient results from the evaluation. Lastly, a journal article is included (Chapter 5), created as one dissemination method targeting marine educators.

Research Design

The study was designed with four phases: curriculum development, formative evaluation, summative evaluation, and dissemination of the curriculum. The flow of the study is shown in Figure 1.3. A brief overview of the design is discussed here, and a more detailed account of methodology is included in the evaluation report (Chapter 4).
Figure 1.3. Research design showing needs assessment, development, formative evaluation, and summative evaluation phases

The design of the microplastics curriculum was based on the backwards planning design of Wiggins & McTighe (2005). The learning experiences stemmed from enduring understandings and concrete objectives aligned with learning standards. The lesson structure and learning experiences were based on teaching best practices. Current scientific data on microplastics was also an emphasis of the curriculum. Each lesson features a researcher who either works directly with microplastics or has encountered them in his or her research. The analysis of real data and practice in scientific thinking was incorporated into the curriculum wherever possible to increase science literacy. When the data is presented in the curriculum, each researcher is introduced and his or her work is described. These portions of the curriculum include an element of science career awareness, which may help students alter their concepts of scientists and see themselves in these careers (Magnuson & Starr, 2000).

The formative evaluation phase focused on gathering data to inform improvements to the curriculum before the final evaluation. This phase included pilot teaching the curriculum and holding a focus group with relevant educators. The first draft of the curriculum was taught with two summer camp programs for students ages 12-15 at Hatfield Marine Science Center in Newport, Oregon. The purpose of pilot teaching was to assess the appropriateness of the curriculum for the age group, the
engagement of students, and identify any confusion or gaps within the curriculum. The focus group was held with educators to gain feedback on the usability and aesthetic of the curriculum, as well as the likelihood that it would be implemented.

After using results from the formative evaluation to inform revisions to the curriculum, the summative evaluation was completed. The summative evaluation assessed the effectiveness of the final curriculum. This was done by teaching the curriculum in seven classes in Lincoln County School District (LCSD) on the Oregon coast. Evaluation data was collected through pre and post surveys of students and teachers along with student work and researcher fieldnotes. Summative evaluation results are the main focus of the evaluation report (Chapter 4).

The curriculum was revised once more based on summative evaluation results. The version of the curriculum included in this thesis (Chapter 3) is the most recent and includes summative evaluation revisions. The final phase of the study, disseminating the curriculum, was partly addressed by the article written for a journal targeting marine educators (Chapter 5). Other avenues of dissemination include making the curriculum available on the Oregon Sea Grant and Oregon Coast STEM Hub websites, sending it through a marine educators’ listserv, and also presenting the curriculum at a national conference for marine educators. The dissemination of the final curriculum has not been completed at the time of the writing of this thesis, but it is important to the study that the curriculum be shared widely with educators.

**Thesis Organization**

![Flow of the thesis](image)

Figure 1.4. Flow of the thesis
This thesis is organized into six chapters that follow the flow of the study from assessing gaps and developing the curriculum to evaluating its effectiveness and sharing the results with educators (Figure 1.4). The first chapter has described the context and importance of the study. Chapter two discusses the needs assessment that was completed before curriculum development to identify gaps in the existing marine debris curriculum. The next chapter includes all the curriculum documents that will be made available to educators online. The curriculum documents include teacher lesson plans, classroom materials, and an answer guide.

Chapter four is the evaluation report intended to evaluate the effectiveness of the curriculum. This chapter most thoroughly describes the methodology of the evaluation and focuses on important summative evaluation results. The evaluation report is aimed at educators who wish to understand the effectiveness of the curriculum or the methods and tools used for the evaluation. Chapter five is a manuscript written for the journal Current: The Journal of Marine Education. Current is a publication of the National Marine Educators Association (NMEA), reaching teachers, informal educators, researchers, and other groups involved in marine and aquatic education. The last chapter discusses overall findings, limitations, future directions, and recommendations based on the study.
NEEDS ASSESSMENT: REVIEW OF EXISTING MARINE DEBRIS CURRICULUM

A needs assessment was conducted as the first step in the curriculum evaluation. This evaluation is based on Stufflebeam’s (2014) Context, Input, Process, Product (CIPP) model. This model is a flexible method to evaluate a program or product. The CIPP model is described in more detail in the Microplastics Evaluation Report (Chapter 4). This needs assessment addresses the context portion of the model, in which “evaluators assess needs, problems, assets, and opportunities, plus relevant contextual conditions and dynamics” (Stufflebeam & Coryn, 2014, p. 312). The purpose of this needs assessment is twofold:

1. To better understand the landscape of marine debris curriculum, identifying any gaps that exist in content, grade level, or other aspects
2. To assess the merit of marine debris curriculum that is available online

Curriculum Landscape

The curriculum landscape was assessed as a way to determine the abundance and type of curriculum resources available to educators. This component of the needs assessment focused on the content covered in the lessons, grade levels targeted, teaching approaches used, or other aspects of the curriculum distinct from its merit. The purpose of this assessment of the landscape was mainly to identify gaps in content and grade levels among existing curriculum.

Curriculum Merit

Educators searching the internet for a marine debris lesson are confronted with a wide range of resources from all over the world. The lessons differ in length, scope, grade level, required materials, and quality. Assessing the merit of a written curriculum provides a way for educators to identify potentially useful lessons. While determining the value of a written curriculum is important in understanding if it is grounded in theory and teaching best practices, it is also important to distinguish this value from the
value a curriculum has in the classroom. This is described by Guba and Lincoln (1981) as
the difference between a curriculum’s merit and its worth. Merit, according to Guba and
Lincoln, is the intrinsic value of the work, out of context and free of any implementation.
The authors contrast merit with the concept of worth, which is the value of something
within context. In the case of curriculum, this is operational curriculum as discussed by
Posner (2004), which includes the way in which the curriculum is taught and the
emphasis placed on certain topics.

When educators search for curriculum, the document is out of context, and
therefore only its merit, not its worth, can be evaluated. In this chapter, the merit of the
existing marine debris curriculum available online is assessed. Establishing the merit of a
curriculum addresses its value as a document. The purpose of assessing the existing
marine debris curriculum is to identify strengths, weaknesses, and gaps that may be
complemented by a new curriculum.

Evaluating Merit

Curriculum Merit Checklist

A Curriculum Merit Checklist (Appendix A) was created to evaluate the merit of
curriculum. The checklist is based on teaching and curriculum development best
practices (e.g. Bransford, Brown, Cocking, Donovan, & Pellegrino, 2000; Oliveira et al.,
2012; Wiggins & McTighe, 2005). The purpose of the checklist is to evaluate a written
lesson or set of lessons. The Curriculum Merit Checklist consists of sections evaluating
the pedagogical and scientific merit, as well as the structure and potential usefulness of
the curriculum. The Curriculum Merit Checklist includes the sections listed below:

- Theoretical Foundation
- Scientific Accuracy
- Structural Components
- Usefulness
The theoretical foundation section of the checklist assesses pedagogical merit, including evidence of completing the learning cycle as described by Merrill (2002): (1) real-world problem solving, (2) activating prior knowledge, (3) demonstrating knowledge, (4) applying knowledge, and (5) helping students integrate knowledge into their own thinking. Although the effectiveness of designing for different learning styles is debated in the literature (Pashler, McDaniel, Rohrer, & Bjork, 2008), the theoretical foundations section of the checklist also covers ways in which each curriculum addresses preferences of learners for certain learning environments (Romanelli, Bird, & Ryan, 2009). Developmentally appropriate (Wiles & Bondi, 2011) and engaging (Henson, 2006) aspects of lessons are also included in this section of the checklist.

In the accuracy section of the checklist, scientific merit was initially assessed by checking the scientific content against knowledge gained by the researcher during a literature review. Then, the accuracy of the curricula underwent additional assessment, which included review by a researcher actively working in the field.

Assessment criteria for curriculum structural components are compiled from the effective design model Understanding by Design (Wiggins & McTighe, 2005) and best practices in lesson design (Merrill, 2002). Characteristics of the stated objectives, content, student practice, and assessments are evaluated in this section. The usefulness section incorporates an assessment of the flexibility, structure, and materials required for the lessons (Henson, 2006). A description of each item on the checklist can be found in Appendix A.

It is important to note that a curriculum considered to have merit will probably not check every item on this list. The checklist provides a guideline for thinking about merits of a curriculum and presents many possibilities that could be included. A curriculum does not have to check every box to be considered to have merit. Also, this checklist has been designed specifically to evaluate curriculum on marine debris. The checklist sections addressing scientific accuracy and informational details about the curriculum include science or microplastics. A more generic checklist without these
references, however, may be used to evaluate the merit of K-12 curriculum in any subject. This checklist has the potential to provide a curriculum merit evaluation tool to educators identifying resources or developing new resources.

Development of the Checklist

The Curriculum Merit Checklist was developed using a variety of sources and modified from a lesson evaluation guide written by Dr. Shawn Rowe (2010) for his course *Communicating Ocean Science to Informal Audiences* (COSIA) at Oregon State University. Items included in the checklist are grounded in theory and teaching best practices and were developed from primary education and evaluation literature.

Data Collection

The purpose of this marine debris curriculum needs assessment was to characterize the resources that middle school teachers might find with an internet search. For this reason, the existing marine debris curriculum was identified online through a keyword search in several different search engines. Curriculum published in academic journals was identified through a search of the Oregon State University online library catalog and The Education Resources Information Center (ERIC). Although resources from the university library are not free and open to educators generally, they are included in the evaluation for thoroughness. Marine debris curriculum was identified in the locations listed in Table 2.1. Lesson plans that included microplastics were indicated with a check mark. Although six items include microplastics, only three are focused on microplastics.

In addition to a keyword search, other institutions were targeted as possible sources of scientific or marine curriculum that were likely to be used by educators. These institutions included the Virginia Institute of Marine Science (VIMS BRIDGE), Public Broadcasting Service (PBS), Aquarium of the Bay, Shedd Aquarium, National Aquarium, Birch Aquarium, Lawrence Hall of Science, Environmental Protection Agency
(EPA), the Mote Marine Laboratory and Aquarium, Center for Microbial Oceanography: Research and Education (C-MORE), and the Oregon Coast Education Program (OCEP). In total, nineteen curricula are included in the evaluation of the existing marine debris curriculum using the Curriculum Merit Checklist.

Table 2.1. Sources and titles of curriculum included in the needs assessment

<table>
<thead>
<tr>
<th>Organization</th>
<th>Marine debris curriculum title</th>
<th>Includes microplastics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Websites</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOAA Marine Debris Program</td>
<td>Turning the Tide on Trash</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Winged Ambassadors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Papahānaumokuākea Marine National Monument(^1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>An Educators Guide to Marine Debris</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Talking Trash &amp; Taking Action</td>
<td>✓</td>
</tr>
<tr>
<td>5 Gyres</td>
<td>Plastic Pollution: Curriculum and Activity Guide</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Plastics in the Water Column (grades 6-8)</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Plastics: Reduce Use or Recycle? (grades 6-8)</td>
<td></td>
</tr>
<tr>
<td>Monterey Bay Aquarium</td>
<td>Gyre in a Bottle (grades 6-12)(^2)</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Plastics Use Audit (grades 6-12)</td>
<td></td>
</tr>
<tr>
<td>Monterey Bay Aquarium Research Institute</td>
<td>Ocean’s Deadliest Catch</td>
<td></td>
</tr>
<tr>
<td>Evergreen State College</td>
<td>Fishing for Microplastics in Your Home(^2)</td>
<td>✓</td>
</tr>
<tr>
<td>University of Georgia Aquarium</td>
<td>Exploring Along a Line of Micro particles(^2)</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Marine Debris and Me</td>
<td>✓</td>
</tr>
<tr>
<td>TeachWild</td>
<td>TeachWild Marine Debris Education Kit</td>
<td></td>
</tr>
<tr>
<td>Algalita Marine Research and Education</td>
<td>Environmental Changes: Plastic Pollution in the Pacific</td>
<td></td>
</tr>
<tr>
<td>Alaska Sea Grant</td>
<td>Ocean in Motion Unit: Debris Detectives</td>
<td></td>
</tr>
<tr>
<td>Facing the Future</td>
<td>Water, Science, and Civics: Engaging Students with Puget Sound</td>
<td></td>
</tr>
<tr>
<td>Academic Journals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>NIKE Athletic Shoes, Rubber Duckies and Ocean Currents</td>
<td></td>
</tr>
<tr>
<td>Learning and Leading with Technology</td>
<td>Talking Trash on the Internet</td>
<td></td>
</tr>
<tr>
<td><em><strong>Science Activities</strong></em></td>
<td>What is the Impact of Beach Debris?</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\)Curriculum is currently in development and not yet available online

\(^2\)Microplastics is the focus of this lesson/curriculum
Data Analysis

After collecting marine debris curricula, each lesson or set of lessons was read and scored on the Curriculum Merit Checklist. Additionally, notes were taken for each section where applicable. Scores for each item were coded as checked (1) or unchecked (0) and entered into a Microsoft Excel spreadsheet. Descriptive statistics were then calculated to analyze overall trends and characteristics of existing marine debris curriculum.

Curriculum Merit Results

The marine debris curriculum included in this evaluation dated back to at least 1997. Many lessons did not have dates, but the only dated lessons written before 2007 were published in journals, not online. Online resources were written as recently as 2015. Of the nineteen curricula, 6 (32%) included microplastics, and 5 (26%) stated that the lessons were evaluated in some way. Mean scores and checklist data are shown in Tables 2.2.a-d. Overall, the highest percentage of curricula (100%) included visual learning and real-world problem solving, and the lowest percentage (5%) of curricula included opportunities for metacognition.
Table 2.2.a. Merit items “checked” in the theoretical foundation category

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ((M)^1) ((N = 19))</td>
<td>100</td>
<td>58</td>
<td>68</td>
<td>58</td>
<td>79</td>
<td>84</td>
<td>84</td>
<td>100</td>
<td>79</td>
<td>68</td>
</tr>
<tr>
<td>TeachWild Kit</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ocean in Motion Unit: Debris Detectives</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turning the Tide on Trash</td>
<td>✔</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Papahānaumokuākea</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exploring along a line of micro particles</td>
<td>✔</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Plastic Pollution</td>
<td>✔</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Monterey Bay Aquarium 6-8</td>
<td>✔</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monterey Bay Aquarium 6-12</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAMEPA Guide</td>
<td>✔</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Ocean’s Deadliest Catch</td>
<td>✔</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marine Debris and Me</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water, Science, and Civics</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Talking Trash</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fishing for microplastics in your home</td>
<td>✔</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Albatross</td>
<td>✔</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Plastic Pollution, Algalita</td>
<td>✔</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>What is the Impact of Beach Debris?</td>
<td>✔</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>NIKE athletic shoes</td>
<td>✔</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Talking Trash on the internet</td>
<td>✔</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2.2.b. Merit items “checked” in the theoretical foundation (cont.) and accuracy category

<table>
<thead>
<tr>
<th>Curriculum</th>
<th>Theoretical Foundation</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Developmentally</td>
<td>Contains hook</td>
</tr>
<tr>
<td>Mean (M)(^1) (N = 19)</td>
<td>95 74 89 5 74 74 63</td>
<td>77 94</td>
</tr>
<tr>
<td>TeachWild Kit</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ocean in Motion Unit: Debris Detectives</td>
<td>✓ ✓ ✓ ✓ ✓ *</td>
<td>*</td>
</tr>
<tr>
<td>Turning the Tide on Trash</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>Papahānaumokuākea</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>Exploring along a line of micro particles</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>Plastic Pollution</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>Monterey Bay Aquarium 6-8</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>Monterey Bay Aquarium 6-12</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>NAMEPA Guide</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ocean’s Deadliest Catch</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>Marine Debris and Me</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>Water, Science, and Civics</td>
<td>✓ ✓ ✓ ✓ ✓ **</td>
<td>✓</td>
</tr>
<tr>
<td>Talking Trash</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>Fishing for microplastics in your home</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>Albatross</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>Plastic Pollution, Algalita</td>
<td>✓ ✓</td>
<td>✓ *</td>
</tr>
<tr>
<td>What is the Impact of Beach Debris?</td>
<td>✓ ✓ ✓ ✓ ✓ *</td>
<td>*</td>
</tr>
<tr>
<td>NIKE athletic shoes</td>
<td>✓ ✓ ✓ ✓ ✓ **</td>
<td>✓</td>
</tr>
<tr>
<td>Talking Trash on the internet</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ **</td>
<td>✓</td>
</tr>
</tbody>
</table>

\(^1\)Means are percentages of curricula that included that item (N = 19)

*Curricula does not include scientific content
Curricula content includes marine debris, but it is not the main focus.

Theoretical Foundation

The theoretical foundation category was the largest section of the checklist, including seventeen items (Table 2.2.a-b). This category included both the highest means (visual learning style and real-world problem solving) and the lowest mean (metacognitive). Visual learning style and real-world problem solving were present in every lesson or set of lessons. Mean scores in this category were generally high, although only one of the lessons had explicit opportunities for metacognition.

Guidance built into the lessons was present in only 58% of curricula. Guidance refers to materials that allow students to move through learning experiences in a structured way that builds as the lesson progresses. Algalita, for example, provides a scaffolded worksheet that guides students through the activity manipulating marine debris data sets online.

Scientific Accuracy

Checklist items in the scientific accuracy category focused on the accuracy of the educator background information and student texts. Most (77% of the curricula that included marine debris content) lessons were accurate. A few of the curricula (3) did not include scientific content information in the lesson plans, 3 included content information but did not focus on marine debris, and 3 did not use peer reviewed sources. For example, “What is the Impact of Beach Debris?” (Fortner & Jax, 2003) relied on news sources and presented information mostly about solid waste issues. Also, “NIKE Athletic Shoes, Rubber Duckies and Ocean Currents” (Clark, 1997) contained information about ocean currents, not marine debris, even though marine debris was used as a mechanism to explain ocean currents. In addition to lacking peer reviewed sources, many curricula did not clearly link concepts to their sources, although some used footnotes or in-text citations. In a science curriculum, this could possibly imply that
it is not always necessary to be clear about where information originated. It is important for educators to have both accurate information and accessible, reliable sources.

The curricula tended to be more accurate when they included a broader, more general description of marine debris. Specific statements tended to be used without appropriate citation or explanation, or used out of context to make a general statement about marine debris. For example, TeachWild (n.d.) stated that “in some areas the plastic outweighs plankton by a ratio of 6-1” to support the point that animals are being harmed by eating microplastics instead of plankton. This general statement was originally reported in a study (Moore, Moore, Leecaster, & Weisberg, 2001) done in the Pacific gyre, an oligotrophic area with relatively low nutrients and plankton populations. The context of the study is critical to accurately interpreting this result. Stating facts out of context can potentially lead to misconceptions about marine debris.

In addition to a lack of detail in the texts, the following concepts were problematic in multiple lessons. These concepts bring up points of concern that may require special attention in the development of future curriculum.

- **Buoyancy of marine debris** – Any plastic debris, even if it is buoyant when it enters the ocean, has the potential to sink. Biofilm can form on the surface of the debris and reduce its buoyancy (Lobelle & Cunliffe, 2011). In addition, animals that ingest plastic debris likely excrete fecal pellets containing plastics (Setälä, Fleming-Lehtinen, & Lehtiniemi, 2014), which sink through the water column. The “Turning the Tide on Trash” curriculum, for example, explains floating debris in a way that implies the buoyancy of marine debris remains constant over time. This can be problematic for understanding the distribution of marine debris in the ocean as well as the types of impacts it might have.

- **Plastics are not biodegradable** – Many plastics are not biodegradable. Biodegradable materials are able to be broken down and the carbon converted to carbon dioxide by living organisms (Andrady, 2011). In the ocean, many plastics break into smaller pieces, but do not degrade. Some plastics are biodegradable, which means that they are “designed to break down in a compost pile or landfill” (NOAA Marine Debris Program, 2016), although they do not necessarily break down quickly in the ocean.
Table 2.2.c. Merit items “checked” in the structure category

<table>
<thead>
<tr>
<th>Curriculum</th>
<th>Objectives: clearly written</th>
<th>Objectives: outcomes-oriented to standards</th>
<th>Objectives: aligned to standards</th>
<th>Content: clearly written</th>
<th>Content: instructor background</th>
<th>Content: Key points</th>
<th>Content: aligned to objectives</th>
<th>Practice: aligned to objectives</th>
<th>Authentic assessment</th>
<th>Assessment criteria provided</th>
<th>Formative</th>
<th>Summative</th>
</tr>
</thead>
<tbody>
<tr>
<td>TeachWild Kit</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Ocean in Motion Unit:</td>
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<tr>
<td>Debris Detectives</td>
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<tr>
<td>Turning the Tide on Trash</td>
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<tr>
<td>Papahānaumokuākea</td>
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<tr>
<td>Exploring along a line of micro particles</td>
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<td>Plastic Pollution</td>
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<td>Monterey Bay Aquarium 6-8</td>
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<td>Monterey Bay Aquarium 6-12</td>
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<td>NAMEPA Guide</td>
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<td>Ocean's Deadliest Catch</td>
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<td>Marine Debris and Me</td>
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<td>Water, Science, and Civics</td>
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<tr>
<td>Talking Trash</td>
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<td>Fishing for microplastics in your home</td>
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<td>Plastic Pollution, Algalita</td>
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<td>What is the Impact of Beach Debris?</td>
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<td>NIKE athletic shoes</td>
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<td>Talking Trash on the internet</td>
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</tbody>
</table>

1Means are percentages of curricula that included that item (N = 19)
Structure

In the structure category (Table 2.2.c), there was a wide range of scores. The highest mean was clearly written objectives (84), and the lowest was providing assessment criteria (16). There were many more curricula that provided summative assessments (74%) than formative assessments (32%).

This category also highlights the wide range of methods used to communicate curriculum. NOAA’s “Winged Ambassadors: Ocean Literacy through the Eyes of Albatross” curriculum was the only one that included each of the items in this category, and “Talking Trash on the Internet” did not check any of the criteria. “Talking Trash on the Internet” is a journal article that focuses on the incorporation of marine debris data available on the internet into classroom activities. The student activities are described in narrative form within the article text, but the article does not include a lesson plan structure characteristic of many other curricula.
### Table 2.2.d. Merit items “checked” in the usefulness category

<table>
<thead>
<tr>
<th>Curriculum</th>
<th>Flexibility: adaptable</th>
<th>Flexibility: easily differentiated</th>
<th>Structure: clear</th>
<th>Structure: comprehensive</th>
<th>Student materials included</th>
<th>Additional materials needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (M)(^1) (N = 19)</td>
<td>89</td>
<td>74</td>
<td>95</td>
<td>42</td>
<td>74</td>
<td>95</td>
</tr>
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<td>TeachWild Kit</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ocean in Motion Unit: Debris Detectives</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Turning the Tide on Trash</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
<td>✓</td>
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</tr>
<tr>
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<td>✓</td>
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<td>✓</td>
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<tr>
<td>Exploring along a line of micro particles</td>
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<td>✓</td>
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</tr>
<tr>
<td>Plastic Pollution</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Monterey Bay Aquarium 6-8</td>
<td>✓</td>
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<tr>
<td>Monterey Bay Aquarium 6-12</td>
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<tr>
<td>NAMEPA Guide</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Ocean’s Deadliest Catch</td>
<td>✓</td>
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</tr>
<tr>
<td>Marine Debris and Me</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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</tr>
<tr>
<td>Water, Science, and Civics</td>
<td>✓</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
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</tr>
<tr>
<td>Talking Trash</td>
<td>✓</td>
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<td>✓</td>
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<tr>
<td>Fishing for microplastics in your home</td>
<td>✓</td>
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<tr>
<td>Albatross</td>
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<tr>
<td>Plastic Pollution - Algalita</td>
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<tr>
<td>What is the Impact of Beach Debris?</td>
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<tr>
<td>NIKE athletic shoes</td>
<td>✓</td>
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<tr>
<td>Talking Trash on the internet</td>
<td>✓</td>
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<td>✓</td>
<td>✓</td>
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</tr>
</tbody>
</table>

\(^1\) Means are percentages of curricula that included that item (N = 19)
Usefulness

The usefulness category (Table 2.2.d) generally showed high means for each item. Being comprehensive was the lowest mean (42), while most curricula (95%) had a clear structure. Most curricula (95%) needed additional materials, and many (74%) included student materials such as student worksheets or texts.

Assessment of Needs

The marine debris curriculum available online varied in structure, usefulness, and the degree to which it was based on learning theory. Although there was a wide range, all curricula included in this assessment demonstrated merit in at least one of the categories. Most of the curriculum reviewed in this assessment stated clear objectives and lesson structure. Presenting content in a visual way and using real-world problem solving were strengths among the curricula. For example, a lesson from TeachWild (n.d.) asked students to analyze the contents of their classroom garbage can and determine how long it would take to degrade in the ocean if it became marine debris. Students were led through a series of scaffolded questions that allowed them to think through the ways in which trash from their classroom might enter and persist in the ocean. However, the prevalence of real-world problem solving may be due to the nature of the issue of marine debris. Marine debris is an ongoing environmental issue that is influenced by students’ actions. Engaging with this type of problem in the classroom is inherently real-world problem solving.

While it is not necessary for a curriculum to check every item on the list to be effective, there are some possibly important checklist items that very few of the curricula addressed. Formative assessments and opportunities for student metacognition were often lacking. Formative assessments are “ongoing assessments designed to make students’ thinking visible to both teachers and students” (Bransford et al., 2000, p. 24). Formative assessments are informal, and strategies range from teacher questioning to student written responses to questions (Wiggins & McTighe, 2005).
These checks for student understanding are important to identify student misconceptions so they can be corrected as necessary before reaching the summative assessment at the end of teaching.

Formative assessments were explicitly included in only 32% of the reviewed curricula. The “Plastics in the Water Column” lesson from the Monterey Bay Aquarium (n.d.) scripted questions for the teacher to ask students at various points in the lesson. One of the activities in this lesson directed students to place items made of plastic into a container of water and directed teachers to ask students “Which floated? Which sank? Why?” The class discussion included in the lesson could also be used as a formative assessment, although the teacher would need to purposefully direct the questions to understand the range of understandings in the class.

Metacognition was another weak point in the existing marine debris curriculum. In the context of this checklist, metacognition refers to students reflecting on their own learning, including both the process of learning and the knowledge they acquired (Bransford et al., 2000). Metacognition is important in learning because it helps students monitor their understanding in order to identify and address misconceptions when they arise. “What is the Impact of Beach Debris?” (Fortner & Jax, 2003) was the only lesson to include opportunities for student metacognition. This lesson focused on the impacts of marine debris. Students linked various “factors” written on cards and described how they would influence each other, resulting in a chain of influence starting with marine debris. Students were asked not only to place their cards, but to explain themselves. This explanation component allows the student and the teacher to assess the student’s understanding of these connections. This is the only example, however, and more consistent opportunities for metacognition would enhance learning and provide practice for students to monitor their own learning over time.

Overall, the body of curriculum assessed did not score highly on the comprehensive item. This is not necessarily to the detriment of the curriculum because each author has a different goal for their curriculum. There is a trade-off that is made
between the length of the curriculum document and the degree of completeness in the lesson explanations and content. The length of curriculum documents varied between one and 102 pages. Different levels of teacher guidance and lesson structure may be appealing to different educators.

Strong theoretical foundation and structure of learning experiences was not always supported by scientifically accurate information. Accuracy is important for all curriculum materials so that correct information is used to develop an understanding of lesson content. Several curricula used specific information out of context to state general knowledge and did not always make the connection between scientific concepts and their sources. This risks propagating misconceptions about marine debris and may imply that it is acceptable to generalize scientific information from one situation without explanation.

Opportunities to improve the body of marine debris curriculum exist in the content of the lessons and theoretical elements. Microplastics curriculum made up a very small portion of the available curriculum, and these were aimed at high school students. There is a gap in middle school curriculum specifically on microplastics. In addition, there is a need for increased inclusion of theoretical elements such as activating prior knowledge and metacognitive opportunities. The inclusion of formative assessments written into student materials or teacher lesson plans is another opportunity to address a gap. There are many other strong theoretical and structural elements that can be incorporated into new resources. It is important to build on existing strengths of curriculum while eliminating redundancies, which is the goal of this marine debris curriculum needs assessment.
MITIGATING MICROPLASTICS CURRICULUM

Overview

The documents in this chapter were created to meet a need for high quality, research-based curriculum about microplastics. The lessons were developed based on middle school standards, current research in microplastics, and research-based teaching practices (discussed in Chapter 1). The curriculum is divided into three lessons: sources of microplastics, impacts on the marine environment and people, and solutions. The following components are included in the curriculum:

1. Teacher Lesson Plans -
   Each lesson includes aligned standards, learning objectives, materials list, set-up, lesson outline, extension or adaptations, and educator background.

2. Student Notebook -
   All student handouts are compiled into one “laboratory notebook” for each student to write in when completing curriculum activities.

3. Lesson Materials -
   Additional informational handouts for student are provided.

4. Content Presentation -
   A Microsoft PowerPoint slideshow with activity directions and images guides the lessons and provides answers for student fill-in-the-blank notes.

5. Student Example (Teacher Answer Guide) -
   Exemplar responses to student notebook activities act as a guide for teachers.

The curriculum is included in its final version, which has been revised after analyzing data from the summative evaluation. Two important changes to the curriculum were the addition of the microbead ban newspaper clipping (p. 52) and the “misconception alert” (p. 33) in the teacher lesson plans. Because this version of the curriculum has been revised, it does not reflect exactly what students and teachers saw while participating in the study.
Teacher Lesson Plans

Mitigating Microplastics Teacher Lesson Plans
A middle school curriculum about microplastics in our ocean
Contents

Introduction

1. Bags, Bottles, and Beads: Sources of Microplastics
2. Small Plastics, Big Problem
3. Mitigating Microplastics

References

Introduction

**Grades: 6-8**

**Summary**

Each person’s actions have a collective and cumulative impact on the world, either in a positive or negative way. Marine debris is one issue facing our world’s ocean that is largely preventable through human actions. Marine debris is anything that does not belong in the ocean, from abandoned ships to tiny plastic fibers from clothes. Plastic marine debris less than 5mm is classified as microplastics. Microplastics can come directly from personal care products with microbeads and laundry lint that washes down the drain, or indirectly from larger plastic debris that fragments into smaller and smaller pieces in the ocean.

This curriculum includes three lessons intended to engage 6-8 grade students with the issue of microplastics in the ocean, analyzing both the problem and possible solutions. The lessons are structured to include opportunities for student inquiry, as well as collaboration and engagement with real data collected by scientific researchers working in the field. Each lesson includes an estimated length, which will vary by classroom. The entire curriculum is designed to take about one week, but may be extended by including a project at the end of the curriculum.

Curriculum materials include:

1. Teacher lesson plans with:
   a. Material lists with links to purchase materials when available
   b. Content background
2. Student handouts
   a. Student Lab Notebooks
   b. Student Solutions Guide
3. PowerPoint presentation with lesson content
4. Student Example (Teacher Answer Guide)
5. Trash, Manufactured supplemental video

**Enduring Understandings**

1. Everyone’s actions have an impact (both positive and negative) on the environment.
2. Scientists make observations, ask questions about the world, collect and analyze data, and work collaboratively in a continuous, nonlinear process.
3. Due to the physical properties of plastics, they have specific impacts on the marine environment.
4. Designing a solution to a problem requires collaboratively defining and constraining the problem, as well as testing and redesigning possible solutions.
Standards

Next Generation Science Standards

ESS3.C: Human Impacts on Earth Systems Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth’s environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3)

MS-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations

MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment

MS-ESS3-4 Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

MS-ESS3.C Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Patterns Graphs, charts, and images can be used to identify patterns in data. (MS-ESS3-2)

Common Core Standards

RST.6–8.1 – Cite specific textual evidence to support analysis of science and technical texts

RST.6–8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually

WHST.6–8.9 Draw evidence from informational texts to support analysis, reflection, and research

CCSS.MATH.CONTENT.7.G.B.6 Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms

Ocean Literacy Principles

6.D Human activity contributes to changes in the ocean and atmosphere.

6.D.17 Pollution affects life in the ocean.

6.D.18 Pollutants move from the land into the ocean as water flows through watersheds via runoff and rivers.

6.D.21 Marine organisms may ingest or absorb harmful toxicants, be impacted by water turbidity and get caught in and ingest marine debris.

6.E.1 Scientists are still learning a lot about marine organisms and ocean ecosystems. New information is useful for helping guide policy decision and individual actions.

6.E.7 Everyone can make informed decisions that reduce human impact on the ocean.

6.E.13 Everyone can make informed choices about what they purchase and which businesses they support in ways that are environmentally friendly.

6.E.15 Everyone can use their knowledge to vote on larger issues that affect the ocean.

6.E.15 Everyone can advocate through their actions and by sharing information about the wise use and protection of the ocean.
Oregon Environmental Literacy Strands

1. Understand the physical and biological world, and our interdependent relationship with it
   b. Structure, function and interconnected nature of human systems to the environment and sustainability, such as human choices about consumption, production, distribution and disposal of goods and services and their effect on the sustainability of earth’s natural, economic and social systems
   c. Interrelationships between people and the environment, such as how human activities and systems (social, cultural, political, and economic) change the environment including physical and living systems
      • How changes in the environment affect human systems (culture and language, economic systems, political systems, and social interactions)
      • How human activities and systems change the environment (physical systems and living systems)

4. Investigate, plan, and create a sustainable future
   c. Investigate and analyze strategies that address challenges and create desired futures
      • Evaluate the consequences of specific environmental changes, conditions, and issues for human and ecological systems, including: use the idea of cumulative effects to explain why one set of changes or human actions cannot be considered in isolation from others
   d. Decision-making and citizen action such as:
      • Plan and take action, including envision a desired endpoint, develop plans for individual and collective action, articulate clear reasons and goals for action, articulate measures for success consistent with their abilities and the capabilities of the groups involved
Bags, Bottles, and Beads: Sources of Microplastics

Enduring Understandings
Everyone’s actions have an impact (both positive and negative) on the environment.

Objectives
• Students will define marine debris and microplastics
• Students will explain sources of microplastics

Time
One 90 minute lesson

Materials
• Two sealing jars for each group/pair [Buy jars]
• Water (enough to fill each jar about half full)
• Liquid soap or face wash with microbeads
• Liquid soap or face wash with natural exfoliators [Check this microbead product list for plastic and natural soaps]
• Student notebook: Bags, Bottles, and Beads
• Sink
• Coffee filters
• Jar/bucket for microbead disposal

Standards

Next Generation Science Standards
ESS3.C: Human Impacts on Earth Systems Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth’s environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3)
Pattens Graphs, charts, and images can be used to identify patterns in data. (MS-ESS3-2)

Common Core
RST.6-8.1 – Cite specific textual evidence to support analysis of science and technical texts

Ocean Literacy
6.D Human activity contributes to changes in the ocean and atmosphere.
6.D.18 Pollutants move from the land into the ocean as water flows through watersheds via runoff and rivers.

Oregon Environmental Literacy Plan
1. Understand the physical and biological world, and our interdependent relationship with it
   a. Structure, function and interconnected nature of human systems to the environment and sustainability, such as human choices about consumption, production, distribution and disposal of goods and services and their effect on the sustainability of earth’s natural, economic and social systems
   b. Interrelationships between people and the environment, such as how human activities and systems (social, cultural, political, and economic) change the environment including physical and living systems

Set-Up
• Divide students into groups of 2-3
• With enough jars for each group to have two, label half of the jars “A” and the other half “B”
• Place about a tablespoon of soap in each jar
  o Soap with microbeads in jar “A” (For an alternative activity without microbeads, see p. 6)
  o Soap with natural exfoliators in jar “B”
• Make copies of Student notebook: Bags, Bottles, and Beads, page 1-5
• Have a disposal jar/bucket for microbead soap when the activity is over
Lesson Outline

1. Hook

Say: Look around the room and silently find as many plastic objects as you can in ten seconds... go! Time students for 10 s, then have students share some of the objects they identified.

Ask: Raise your hand if you agree that there is a lot of plastic in this classroom? If you agree that we use a lot of plastic in our daily lives?

Say: We use plastic every day, and many of the plastics are single-use. They are designed to be thrown away after being used once. We might not even realize all the products that have plastic, and we don’t always know what happens to them after they are thrown away.

2. Explore – “Soap suds and...plastic?”

*See “success story” below for alternative activities if no products with plastic microbeads are available

Say: Some products with plastics might surprise you. First, we will talk a little about plastic itself, and then you will have a chance to investigate for yourself.

- Students will complete the guided notes on page 1 of their notebooks.

Presentation slides include the text from the notebook with the blanks filled in (also see the student example for guided notes answers)

Say (referring to the image on page 1): Polyethylene is the plastic most microbeads are made from, and you can identify products with microbeads by looking at the ingredients for polyethylene. Repeat after me, “polyethylene.”

Hand out: two jars labeled “A” and “B” to each student group, but don’t tell them which soap is which.

- Students read and follow the directions in their notebooks.

Presentation slides also have activity directions for reference.

- Students first make observations of the two jars (color, texture, size and shape of particles, etc.)

- Students fill jars halfway with water, close it tightly, and shake the jars to dissolve the soap (there shouldn’t be any soap stuck to the bottom).

- Students write down what they observe and draw pictures in their notebooks of how the particles behave inside the soaps.

- Students answer the questions in their notebooks on page 2.

Ask: What did you notice that was different between the two jars? How did the particles in the soaps behave? Which one do you think has plastic in it? What evidence do you have?

Reveal the answer, that “A” has microplastics in it!

**MISCONCEPTION ALERT!**

Plastic microbeads will float in the water, but not all microplastics float! Microplastics can be found at many depths, including the ocean floor.

Before moving on to the next part of the lesson, clarify that while the plastic microbeads in the investigation floated, not ALL microplastics float in the ocean.

- Students read the “newspaper clipping” on page 2 of their notebook and answer the question.

Discuss: Why is the problem of microplastics not solved? Do you think this is a helpful law? Why or why not?
3. Debrief – “How do microplastics make it to the ocean?”

Say: One of the reasons the microplastics problem is not solved by this law is that there are many other ways microplastics get into the ocean. Presentation slides show “two main sources of microplastics.” See the student example for notes.

- Students will complete guided notes on page 3 of their notebooks

Say: There are two main ways that microplastics enter the ocean. One is directly as small pieces (show microplastics definition and have a student read it aloud). Plastics in toothpaste, face wash, and laundry lint can go directly into the ocean. Most microplastics are from larger plastic marine debris items that are fragmented once they get to the ocean (show marine debris definition and have a student read it aloud). Nurdles are small plastic pieces used in factories to make plastic products.

4. Connect – “Real researcher: Angel White”

Say: Now that we know about microplastics and where they come from, we are going to learn about a researcher who studies microplastics.

- Students will read “Real researcher: Angel White” on page 4 of the student notebook as an introduction to her data.
- Students will answer the questions about Angel’s data on page 5. See student example for correct responses. Answers are based on the data table and reading.

Say: Why is it important to study the amount of plastic in the ocean? Do a think-pair-share (students silently think about their response for 30 seconds, share with a partner, and then share with the class).

Ask: Why do you think scientists study microplastics in the ocean? What should scientists like Angel do with their results?

Clean Up

To keep microbeads from going down the sink drain, you can use a coffee filter to remove the microbeads from the soap. You can dry them and put them in a container to show the amount of plastic in the product!

© Success Story: Banning Personal Care Products with Microbeads

Plastic microbeads in personal care products like face wash and toothpaste have been shown to enter drains and eventually the ocean, and have largely unknown consequences on the marine environment. After nine states banned the manufacture and sale of products with microbeads, Congress passed the Microbead-Free Waters Act of 2015, banning the manufacture and sales of personal care products with plastic microbeads starting in 2017.

Because of this ban, personal care products with plastic microbeads will not be available to purchase beginning in 2017. The plastic from previously used products, however, is still in the ocean and microplastics are still a problem. Microbeads contribute a small part of the total microplastics in the ocean. Synthetic fibers from clothes, as well as the fragmentation of large plastic marine debris are important and present sources of plastic. Also, while products with plastic microbeads are banned in the US, there are many places around the world where microbeads are used. Microplastics is truly a global issue.

Alternative Activity

As an alternative to the first activity “soap suds and...plastic,” consider completing the challenge using just face wash with natural exfoliators.

- Have students observe and draw the particles, and then explain that some soaps used to have plastic instead of the natural material.
- Ask students to imagine those particles were plastic to get an idea of the number of microbeads that might enter the ocean from one product.
- Emphasize that there are other sources of microplastics that enter waterways, including plastic fibers from clothing, and that microplastics are generated all over the world.
**Educator Background**

**Microplastics**

Microplastics are very small pieces of plastic marine debris less than 5 mm in size that end up in the ocean. Marine debris is anything that ends up in the ocean that doesn’t belong there. The National Oceanic and Atmospheric Administration (NOAA) defines marine debris as “any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes.” Marine debris can be found in the ocean and rivers worldwide, and most of the debris is made up of plastics.

Properties of plastics

Plastics are long chains of hydrocarbons called polymers. Hydrocarbons usually come from petroleum or natural gas. There are several types of plastics with different physical properties that are used for different purposes. Polyethylene is the largest volume of plastic used in the world. Polyethylene is the plastic that makes up microbeads in some personal care products like face wash and toothpaste.

**Sources**

Sources of marine debris. Plastics can enter the ocean from anywhere. Marine debris can come from sources on land or the ocean, not just coastal communities and beach-goers. It is estimated that most marine debris (80%) originates on land. The following list describes some sources of marine debris.

- Individuals can be sources of marine debris if they do not manage their waste properly or if they litter
- Trash on the street (even in inland areas) can be blown into a nearby stream or washed down a drain
- Cities are potential sources of marine debris if there is insufficient infrastructure to capture debris on streets or landfills before it enters waterways
- Marine debris can originate in the ocean with lost fishing gear, dumping of trash, or abandoned boats
- Natural events can also create marine debris when storms wash debris into streams or the ocean

Sources of microplastics. Microplastics mainly enter the ocean in two ways: (1) through the fragmentation of larger plastic marine debris and (2) when small plastics enter waterways and travel to the ocean.

- Fragmentation of larger plastics – Plastics that enter the ocean have been found at the surface, on the bottom, and in between. Many plastic objects are buoyant and float at the surface of the ocean, being moved around by wind and surface currents. Plastics floating at the surface are exposed to sunlight. When they are exposed to UV waves, the plastic breaks into smaller and smaller pieces, or fragments. Plastics can also fragment when exposed to wind or wave action.
• Small plastic pieces entering waterways – One source of small plastics is industrial materials such as resin pellets (nurdles). Nurdles can be lost during transportation and become debris. Another source of microplastics is personal care products. Many face wash, body wash, and toothpaste products contain plastic microbeads that act as exfoliators. The plastic microbeads in these products are designed to wash down the drain and are too small to be captured by water treatment facilities. Synthetic fibers from clothing such as fleece also travel through waterways to the ocean. One study found synthetic fibers on 18 beaches around the world and determined that washing one clothing item can produce more than 1,900 fibers that enter the sewage system.  

Sinks
Microplastics can be found not only in the ocean worldwide, but also in rivers and streams. Many plastics are buoyant, and stay at the surface of the ocean. However, other sinks of microplastics include sand on beaches and offshore. A collaborative study published in 2014 combined data taken by researchers all over the world about the abundance of plastics in the ocean. The data set include 680 tows, in which nets are dragged along the surface of the ocean and then the contents are analyzed. The study estimates that there are about 5.25 trillion plastic particles on the ocean surface. The team also found that there were fewer microplastics particles than they had expected, which may indicate that they are being removed by some process such as degradation, being eaten by animals, or sinking when small organisms attach. There is ongoing research about the sinks and potential impacts of microplastics in the ocean.

Glossary
Fragment – To break into smaller pieces
Marine debris – Anything man-made that ends up in the ocean or the Great Lakes and doesn’t belong there
Microbeads – Small plastic beads used in personal care products as exfoliators. Microbeads are commonly made out of polyethylene.
Microplastics – Plastic marine debris that is less than 5 mm.
Nurdles – Small pre-manufacture resin pellets
Degradation – The process of objects breaking down, in the case of microplastics, by UV light
Photodegradation – destruction of a material by UV radiation
Plastic – Manufactured chains of hydrocarbons often derived from natural gas or petroleum
Resin pellets – Pre-manufacture plastic pellets that are used to manufacture plastic products
Sink – Where something ends up
Weathering – Mechanical weathering is the process of breaking down materials into smaller pieces (by wind, waves, etc.).
Small Plastics, Big Problem

**Enduring Understandings**
Due to the physical properties of plastics, they have specific impacts on the marine environment.

Scientists make observations, ask questions about the world, collect and analyze data, and work collaboratively in a continuous, nonlinear process.

**Objectives**
- Students will articulate at least two possible impacts of microplastics on the marine environment
- Students will create an argument using evidence that supports an explanation
- Students will calculate the surface area of rectangular prisms of various sizes

**Prior Knowledge**
Students should be able to define and calculate surface area of rectangular prisms.

**Time**
One 90 minute lesson

**Materials**
- Card stock or cardboard (Manila folders work!)
- Scissors
- Tape/glue
- 1 inch foam cubes (other sizes can be used) x 27 for each group [Buy 1 in. cubes]
- Calculators (optional)

**Standards**

*Next Generation Science Standards*

**MS-LS2-4** Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations

*Common core*

**CCSS.MATH.CONTENT.7.G.B.6** Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.

*Ocean Literacy*

**6.D.17** Pollution affects life in the ocean.
**6.D.21** Marine organisms may ingest or absorb harmful toxicants, be impacted by water turbidity and get caught in and ingest marine debris.

*Oregon Environmental Literacy*

1. Understand the physical and biological world, and our interdependent relationship with it
   - c. Interrelationships between people and the environment such as:
     - How changes in the environment affect human systems (culture and language, economic systems, political systems, and social interactions)
     - How human activities and systems change the environment (physical systems and living systems)

4. Investigate, plan, and create a sustainable future
   - c. Investigate and analyze strategies that address challenges and create desired futures
     - Evaluate the consequences of specific environmental changes, conditions, and issues for human and ecological systems, including; use the idea of cumulative effects to explain why one set of changes or human actions cannot be considered in isolation from others.

**Set-Up**
- Use the template on p. 19 to make paper box for each foam cube “marine debris” piece
- Make copies of the student notebook *small plastics, big problem* (p. 6-9)
- Divide students into groups of 2-4
Lesson outline

1. **Hook – “See-Think-Wonder”**
   
   **Presentation** slides have the “see-think-wonder” photo for students to observe.
   
   **Say:** Observe this photo carefully and write down everything you see, think, and wonder about it.
   
   - Students will observe the photograph in their notebook on page 6, completing the graphic organizer

   **Discuss:** What did you see? What did you think about it? What do you wonder?

   **Say:** This fish seems to have plastic pieces in its stomach. I wonder where they came from. We have learned sources of microplastics, and today we will talk about the possible impacts, or effects, of microplastics on the ocean.

2. **Explore – What happens when plastic fragments in the ocean?**

   **Say:** Now we are going to read about the possible impacts of microplastics on the ocean.
   
   - Students read “Plastics in the environment” on page 6 as a group
   - Students continue reading on page 7 “what happens when plastic fragments in the ocean?”

   **Say:** Microplastics act differently than big plastic marine debris. We will find out how in this activity.

   Review surface area with students by doing a think-pair-share (students silently think about what surface area is for 30 seconds, then share with a partner, then share with the whole class). Surface area is the total area of all the sides of a shape.

   **Say:** Now we are going to go through an example of calculating the surface area of an object.

3. **Debrief**

   **Discuss:** What was the highest total surface area you calculated? What happened to the total surface area when the marine debris fragmented? What does this mean for toxins? What does this mean for microbes that live on the outside of plastic marine debris?

4. **Connect – “Real researcher: Laurie Weitkamp”**

   **Say:** Now we are going to meet another researcher who collected data on the impacts of microplastics. This researcher doesn’t study microplastics, though. She studies juvenile fish in the Columbia River Estuary in Oregon.

   - Students read “Real researcher: Laurie Weitkamp” on page 8 as a class
   - Students answer the questions about Laurie’s data
   - Go through the answers to the questions (see student example responses)

   **Say:** We don’t really know the impacts of microplastics, but microplastics have more total surface area for toxins to stick. Next, we are going to think about what we can do to solve this problem.
Extensions/Adaptations

- Using surface area to volume ratio of plastics breaking down in the environment adds complexity.
- If students have not yet learned surface area, an alternative demonstration can be used:
  - *Using the cubes* – Instead of having student groups calculate the total surface area, walk the class through a couple steps of fragmenting, and talk about what changes. The inside of the marine debris is exposed when it is broken apart, which provides new surface where something like toxins could stick.
  - *No materials* – Lead the class in a demonstration using your fists held together representing the piece of marine debris. When you “break” the marine debris by pulling your two fists away from each other, the parts of your hands that were inside are now exposed to toxins.

**Educator Background**

**Microplastics** are small pieces of plastic 5mm or less in size that enter the ocean\(^1\). They can make it to the ocean when tiny plastic particles in personal care products or synthetic clothing fibers are washed down the drain, or from the breakdown of larger plastic debris. Microplastics are a size category of **marine debris**. Marine debris is anything man-made that doesn’t belong in the ocean or Great Lakes.

**Potential Impacts of Microplastics**

There is ongoing research about the impacts of marine debris, and specifically microplastics, on the ocean and the organisms that live there. Microplastics can be found from the surface to the bottom of the ocean all over the world, which makes the impacts they have on the marine environment a global concern. Potential impacts of microplastics include the accumulation of **toxins** on their surface, ingestion of plastics by organisms, and the colonization of **microbes** on their surface.

It is important to note that the term *impacts* simply means effects. It is also important to know that the ways in which small plastics in the ocean are affecting marine environments are continually being discovered, and the subtle implications of these effects are still not well known. At this time, there is not substantial evidence that plastics or any associated chemicals are transferred through the food web in a way that is harmful to humans.

**Accumulation of toxins.** Toxins is a somewhat ambiguous term used to describe different harmful substances. In this lesson, the toxins referred to are chemical toxins. The US Environmental Protection Agency (EPA) defines something toxic as “any chemical or mixture that may be harmful to the environment and to human health if inhaled, swallowed, or adsorbed through the skin.”\(^2\) Toxic substances have been shown to adsorb to the surface of plastic marine debris. Researchers in Tokyo showed that PCBs (polychlorinated biphenyls), DDE (dichlordiphenylchloroethylene), and NP (nonylphenols) in seawater adsorbed to the surface of plastic.\(^3\) While toxins have been shown to stick to plastics, the extent to which this happens in nature and the impacts on the marine environment are still being studied. There is a need for more information on this topic.

**Ingestion of microplastics by organisms.** Many organisms have been shown to ingest microplastics, from small filter feeders to larger animals. They can ingest plastics indirectly if they eat another organism containing microplastics, directly when mistaking microplastics for food, or accidentally. Smaller organisms such as plankton\(^4\) and marine isopods,\(^5\)
and filter feeders such as sea cucumbers\textsuperscript{16} and oysters\textsuperscript{17} have been reported to eat microplastics. A species of lobster was shown to eat microplastics present in its food, and the plastics remained in the lobsters’ stomachs.\textsuperscript{18} Larger animals such as harbor seals\textsuperscript{19} and many species of fish and sea bird\textsuperscript{20} have had plastics found in their stomachs. The actual impacts of microplastics ingested by these animals is still unclear. There may be physical or chemical impacts of eating microplastics.

\textit{Impacts of ingestion.} Larger microplastics may block the digestive tract of small organisms, but not in others. There is not much evidence for this. The impacts of organisms ingesting plastics are not well known.

\textit{Potential impacts on humans.} There is not sufficient research to make determinations about the safety of seafood due to microplastics. Microplastics have been found in some oysters that were raised for food.\textsuperscript{17} The impacts on the marine food web are not clear. Negative impacts on marine ecosystems does potentially have negative impacts on marine resources that people rely on, marine recreation, and economics. There is the possibility for microplastics to impact fisheries, the viewshed, and other services provided by the ocean and its connecting waterways.

Surface area

\[ \text{Surface area} = SA = 6 l^2 \]

As a cube is broken down into smaller cubes, the total volume stays the same, but the total surface area increases. The equation above is used only to determine the surface area of a cube. To find the surface area of other objects, it is necessary to find the area of each separate surface and add them together.

\textbf{Example:}

\begin{align*}
(2 \text{ in} \times 2 \text{ in}) \times 2 &= 8 \text{ in}^2 \\
(2 \text{ in} \times 5 \text{ in}) \times 4 &= 40 \text{ in}^2 \\
SA &= 8 \text{ in}^2 + 40 \text{ in}^2 = 48 \text{ in}^2
\end{align*}

\begin{align*}
6 \times (2 \text{ in})^2 &= 6 \times 4 \text{ in}^2 = 24 \text{ in}^2 \\
(2 \text{ in} \times 2 \text{ in}) \times 2 &= 8 \text{ in}^2 \\
(2 \text{ in} \times 3 \text{ in}) \times 4 &= 24 \text{ in}^2 \\
8 \text{ in}^2 + 24 \text{ in}^2 &= 32 \text{ in}^2 \\
\text{Total } SA &= 24 \text{ in}^2 + 32 \text{ in}^2 = 56 \text{ in}^2
\end{align*}

\textbf{Glossary}

\textit{Impacts} – The effects of something, either positive or negative

\textit{Marine debris} – Anything man-made that ends up in the ocean or the Great Lakes and doesn’t belong there

\textit{Microbes} – Microscopic organisms that are found everywhere on Earth

\textit{Microplastics} – Plastic marine debris that is less than 5 mm

\textit{Surface Area} – The area of the outermost layer of an object

\textit{Toxins} – “any chemical or mixture that may be harmful to the environment and to human health if inhaled, swallowed, or adsorbed through the skin” (US EPA)
Mitigating Microplastics

Enduring Understandings
Everyone’s actions have an impact (both positive and negative) on the environment.

Designing a solution to a problem requires collaboratively defining and constraining the problem, as well as testing and redesigning possible solutions.

Objectives
- Students will use scientific data to design a solution to reduce microplastics
- Students will articulate the costs and benefits of their solution to humans and the natural environment

Time
Time for this lesson will vary. At least one 60 minute lesson for discussion and generating solutions will be required, along with any additional time to implement students’ plans.

Materials
- Student notebooks
- Folders or large paper
- Markers, crayons, or colored pencils
- Chart paper
- Folders with “student solutions guide” information
  - Individual actions
  - Making laws
  - Education

Standards

Next Generation Science Standards

MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3-4 Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

MS-ESS3.C Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Common Core

RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.

WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research.

Ocean Literacy

6.E.3 Scientists are still learning a lot about marine organisms and ocean ecosystems. New information is useful for helping guide policy decisions and individual actions.

6.E.7 Everyone can make informed decisions that reduce human impact on the ocean.

6.E.13 Everyone can make informed choices about what they purchase and which businesses they support in ways that are environmentally friendly.

6.E.15 Everyone can use their knowledge to vote on larger issues that affect the ocean.

6.E.15 Everyone can advocate through their actions and by sharing information about the wise use and protection of the ocean.

Oregon Environmental Literacy

4 Investigate, plan and create a sustainable future
  d. Decision-making and citizen action such as:
    - Plan and take action, including envision a desired endpoint, develop plans for individual and collective action, articulate clear reasons and goals for action, articulate measures for success consistent with their abilities and the capabilities of the groups involved.
Set-Up
- Inside 5 folders, write the following questions. (alternately, the questions can be written on chart paper or simply used as discussion questions)
  - What’s the problem with microplastics?
  - Can we stop using plastic? Why or why not?
  - Do you think plastics are good or bad? Why?
  - How does plastic affect the ocean?
  - Do you think we can clean up all the plastic in the ocean? Why or why not?
- Put students in groups (groups of 2-4, but may vary depending on the project)
- Make copies of Student Solutions Guide pages for each group of students and place each set in a folder for easier distribution
- Make copies of Student Notebook p. 10-21 Designing Solutions for Microplastics for each student

Lesson outline

1. Hook – defining the problem “chalk talk”
   Place the folders with questions open around the room.
   Say: There are five folders around the room with discussion questions. We are going to have a silent discussion about microplastics. You will take a pencil and respond to the question on the folder. If someone else has already responded, you can write a response to that person or write a separate thought. Make sure to read everything before choosing how to respond.
   - Students circulate around the room, responding to the question or a comment made by another student. Give students 3-4 minutes at each question, depending on their pace. (If you prefer students to discuss, each group can discuss aloud before writing on the folder).
   - Give students time to revisit their first station and read the responses, then debrief with the class.
   Ask: What surprised you? Is plastic in the ocean an easy problem to solve? What makes it easy or difficult? Why is it important to discuss issues like microplastics with people who have different opinions? How do you feel about this problem?

2. Group solution design project
   Hand out “student solutions guide” folders with existing projects and actions people have taken to reduce microplastics in the ocean.
   Say: Now that you know about where microplastics come from and some of the problems that occur when they end up in the ocean, it is your challenge to develop a solution to the problem. We are all able to make a change in our environment, and it is important to use this power to make a positive change. You have a folder with different actions people are taking to address the problem. In your group, you will review these solutions, and then come up with your own. It is important that the solutions that you and your group develop are effective and that you are able to actually make this change (for example, building a machine to clean up the gyre may not be feasible for this project).
   - Students first review the existing solutions and then individually brainstorm ideas for actions they can take to reduce microplastics.
   - Students use the graphic organizer on page 10 of their notebook to guide their conversation about a feasible, actionable solution to microplastics.
   - Students should discuss each section of the graphic organizer and each student writes the group’s thoughts in their notebook.
   - Students create a presentation for their solution and explain it to the group.
   (This can be formal or informal, depending on the time and technology available for this lesson. Students can receive feedback on their ideas, or
the class can develop a single project from their ideas to implement together.)
Help students implement their ideas! This depends on the time and resources of each classroom. I would encourage you to help students choose projects that are feasible but ambitious.

3. Debrief

Ask: What are some challenges in designing a solution to microplastics?
What were the challenges in implementing your solution? What was easy about it?
Why do you think it’s important for students to think about issues like microplastics?

Extensions

The solutions that student groups design can be implemented within the classroom or community. This can be done in a variety of ways depending on your school. The implementation phase gives students a sense of empowerment around the issue of microplastics that can seem daunting. Building community, promoting awareness, and taking concrete actions helps students think about their world differently.

Educator Background

Microplastics are small, plastic marine debris, commonly defined as less than 5 mm in size. The impacts of these plastic pieces on the marine ecosystem are not well understood, and more plastics are entering the oceans every day. Action is needed to reduce the amount of plastic in the ocean. There is no one “right” solution to marine debris and effective solutions will require creativity, collaboration, and dedication from many groups. A few ways people are addressing the issue, including legislation, education, and individual actions, are described below.

Legislation

Bans on microbeads in personal care products – Illinois was the first state to pass legislation addressing plastic microbeads. This state banned personal care products with microbeads in June 2014.21 By December 2015, when the federal Microbead-Free Waters Act of 201522 was passed, nine states had banned the manufacture and sales of microbeads and several others (Massachusetts, Michigan, Minnesota, and Oregon) were considering similar legislation. Table 1 includes details of the microbead ban bills that have passed. Laws are listed in order of passage, with the most recent at the top. This table has been adapted from 5 Gyres.23
The laws provide phase-out dates for the manufacture and sale of personal care products and over-the-counter products containing plastic microbeads. The table rates each law as “strong” or “weak.” This rating is based largely on analysis by environmental groups, and focuses on the definitions of plastic microbeads and the presence of loopholes. The “biodegradable” column provides information about whether or not the term biodegradable is defined in the law or if there is a loophole for “biodegradable plastics.” The development and potential of such materials is a topic of uncertainty at the time of writing this curriculum.

**Bans on larger plastic products** – In addition to legislative bans on microbeads, bans on other plastic products impact the abundance of microplastics in the ocean. For example, banning plastic items reduces the amount of plastics available to enter the waterways. The following list includes states where some of their cities or counties have banned plastic bags. Some include a charge on paper bags to encourage use of reusable bags.

- Alaska
- District of Columbia
- Maine
- New York
- Rhode Island
- California
- Florida
- Maryland
- North Carolina
- Washington
- Colorado
- Hawaii
- Massachusetts
- Oregon
- New Mexico
- Texas

Individual use plastic water bottles have also been banned in multiple US cities, notably Concord, Massachusetts, and San Francisco, California.
Education

Education about marine debris and microplastics is important to promote awareness of the issue, change behaviors, and inspire responsibility and stewardship for the environment. Educating people about what marine debris is, where it comes from, and what individuals can do about it empowers positive change. This can happen on the individual, school, community, or global levels. The list in Table 2 includes organizations that are dedicated to educating people about the issue of marine debris and promoting change.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Description</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Gyres</td>
<td>The mission of 5 Gyres is to involve people in designing solutions to plastic pollution.</td>
<td><a href="http://www.5gyres.org">www.5gyres.org</a></td>
</tr>
<tr>
<td>Algalita: Marine Research and Education</td>
<td>Founded by Captain Charles Moore, Algalita strives to protect marine ecosystems through research and education. The website includes research as well as classroom resources.</td>
<td><a href="http://www.algalita.org">www.algalita.org</a></td>
</tr>
<tr>
<td>Beat the Microbead</td>
<td>An international campaign to eliminate microbeads. The site includes research, policies, and an app to help consumers identify products containing microbeads.</td>
<td><a href="http://www.beatthemicrobead.org">www.beatthemicrobead.org</a></td>
</tr>
<tr>
<td>US Environmental Protection Agency (EPA)</td>
<td>The EPA website has informational resources including sources, prevention, legislation, and research.</td>
<td>water.epa.gov/type/oceb/marinedebris</td>
</tr>
<tr>
<td>NOAA Marine Debris Program</td>
<td>This NOAA website houses informational pages, research, and K-12 resources on marine debris.</td>
<td>marinedebris.noaa.gov</td>
</tr>
<tr>
<td>Oregon Coast STEM Hub</td>
<td>This page contains teacher resources for grades 4-12.</td>
<td>oregoncoaststem.oregonstate.edu/marine-debris-steamss</td>
</tr>
<tr>
<td>Sea Education Association (SEA)</td>
<td>An environmental education opportunity for undergraduate students, SEA cruises collect data on plastics, and have access to research and K-12 lesson plans on their website.</td>
<td><a href="http://www.sea.edu">www.sea.edu</a></td>
</tr>
<tr>
<td>Surfrider Foundation</td>
<td>An activist network of people dedicated to protecting marine ecosystems and resources. They promote campaigns and organize events around the country.</td>
<td><a href="http://www.surfrider.org">www.surfrider.org</a></td>
</tr>
</tbody>
</table>
Individual Actions
Although small in scale, individual actions are important in reducing the amount of plastics in the ocean. Changing our individual behaviors can not only reduce our personal plastic contribution, can act as an example to inspire change in others. Some possible individual actions include:

- Recycling
- Using reusable containers (bags, water bottles, etc.)
- Managing personal waste in a responsible way
- Avoiding products with microbeads

A note on cleaning up marine debris as a solution
It has been estimated that there are over 5.25 trillion pieces of plastic marine debris\(^9\) floating in our ocean. Plastic can be found not only on the surface, but at all depths as well as in the sediment. Because marine debris is so extensive, cleaning up all the plastics currently in the ocean is not a feasible solution. While beach clean-ups and other removal activities have positive results, a substantial change in the abundance of plastics in the ocean will not happen without efforts to reduce the plastics being put into the ocean and waterways.

Glossary

*Marine debris* – Anything man-made in the ocean or the Great Lakes and doesn’t belong there

*Microbeads* – Small plastic beads in personal care products, commonly made of polyethylene.

*Microplastics* – Plastic marine debris that is less than 5mm

*Personal care products* – A non-prescription product used for personal hygiene or beauty.
Paper Cube Template

If you are using the 1 in. cubes, the box will need to be a little more than 3 in. in each direction (these squares are 3.2 in). Thin cardboard (cereal boxes, etc.) seems to work best because it is large and sturdy.

Directions:
1. Print out this template on 11 x 17 paper and trace it on a piece of cardboard
2. Cut out the shape
3. Fold the flaps up along the dotted lines
4. Fold each side of the box up, gluing the flaps on the inside of the box
References


23. Environmental Protection Act, 415 ILCS § 5/42.


Student Notebooks

Name: _____________________

Date: ___________

Microplastics

Laboratory notebook
1. **Bags, Bottle, and Beads: Sources of Microplastics**

   - Microplastics
   - Polyethylene
   - Marine debris
   - Nurdle
   - Manta trawl
   - Dilute
   - Plastic

2. **Small plastics, big problem**

   - Fragment
   - Toxin
   - Organisms
   - Surface area
   - Microbes

3. **Designing Solutions to Microplastics**

   - Microplastics
   - Reduction
   - Ban
   - Marine debris
Lesson 1
Bags, Bottles, and Beads: Sources of Microplastics

Soap suds and...plastic?
Plastics can be found in many products at school and home. Plastics are created by ____________ from ________ or _____________. There are lots of types of plastics.

One surprising product that has plastic in it is ___________. Some soaps have small pieces of ____________, (a type of plastic), which are called ________________.

CHALLENGE: Which soap has plastic in it?

STEPS:
1. Observe the two soaps using your senses of smell and sight (NOT taste or touch)
2. Fill the jar half-way with water, put the lid on your jar, and shake it up!
3. Observe again with words and pictures, using your sight (NOT taste or touch)
4. Answer the questions on the next page.

<table>
<thead>
<tr>
<th>Observations</th>
<th>Jar _____</th>
<th>Jar _____</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>1.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>2.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>3.</td>
<td></td>
</tr>
</tbody>
</table>
CONCLUSIONS:

1. What was different about the two soaps?

2. Which jar do you think has plastic in it? Explain your reasoning. Be specific.

3. What do you think happens to the plastic in the soap after someone uses it to wash their face?

President Obama Signs Microbead-Free Waters Act of 2015

December 28, 2015

Washington D.C. — A federal law was passed and signed by President Obama that bans the production and sale of personal care products with plastic microbeads. Some personal care products like toothpaste and face wash have plastic microbeads that can go down the drain and into the ocean. Scientists are not sure how these small plastic beads affect the ocean environment. To stop more plastic from going into the ocean, Congress decided to ban personal care products with microbeads starting in 2017! People will not be allowed to make or sell personal care products with microbeads anywhere in the United States.
Main Sources of Microplastics:

________________________ are small particles of ___________
________________________ that are less than ______ and end up in the ____________.

Microplastics are found in:

________________________ is anything that ends up in the ocean or Great Lakes that
doesn’t belong there. Plastic marine debris ________________ in the ocean.

Microplastics can also come from ___________ that use small plastic pellets to make their products. These pellets are called ______________. They are light in color and about this big _____.
From the Field

Name: Angel White

Career:
Researcher at Oregon State University

Education:
Bachelor’s degree in Biology from University of Alabama
Master’s degree in Biology from University of Alabama
PhD in Biological Oceanography from Oregon State University

Research: how materials move through ecosystems, phytoplankton, harmful algal blooms

Notes:
In 2008, Angel had the chance to go on an expedition with other scientists to study the amount of plastic in the ocean. To do this research, Angel went with a team of scientists to the Pacific Ocean (shown by the star on the map below). Angel had heard that there were big patches of garbage in the middle of the ocean. However, when she went out on the expedition, she did not see piles of trash floating in the water. In fact, the water looked clean! She sampled the water using a manta trawl. A manta trawl is a large net with a bottle at the end that captures anything too big to fit through the net (like plastic in the water). Scientists pull the manta trawl behind a boat along the surface of the water, and then analyze what is caught in the net. Each time the net was dragged behind the boat it is called a tow. Each tow filtered about 360 m$^3$ of water, which is about the size of a school swimming pool. The scientists separated the plastic from the net and counted the number of pieces in each sample. After looking at the data, Angel was surprised that the plastic was so dilute even though plastic can be found all over the ocean!
The data in the table was collected by Angel and the other scientists on her expedition to the Pacific Ocean. Even though many researchers have found plastic in the ocean, people continue to study the amount of plastic in the ocean, where plastic can be found, and what type of plastic is in the ocean. This is important because people want to know how plastic in the ocean will affect living things.

Look at the table that shows Angel’s data, then answer the questions.

### Angel White’s Data:
Plastics found in 10 tows in the Pacific Ocean

<table>
<thead>
<tr>
<th>Tow Number</th>
<th>Total Number of Plastics* (2mm + 5mm)</th>
<th>Volume of water (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>127</td>
<td>362</td>
</tr>
<tr>
<td>2</td>
<td>127</td>
<td>361</td>
</tr>
<tr>
<td>3</td>
<td>504</td>
<td>320</td>
</tr>
<tr>
<td>4</td>
<td>343</td>
<td>357</td>
</tr>
<tr>
<td>5</td>
<td>320</td>
<td>359</td>
</tr>
<tr>
<td>6</td>
<td>281</td>
<td>358</td>
</tr>
<tr>
<td>7</td>
<td>901</td>
<td>361</td>
</tr>
<tr>
<td>8</td>
<td>543</td>
<td>360</td>
</tr>
<tr>
<td>9</td>
<td>1334</td>
<td>360</td>
</tr>
<tr>
<td>10</td>
<td>515</td>
<td>360</td>
</tr>
</tbody>
</table>

1. Circle the tow number with the largest number of plastics found. What is the value? ______
   Draw a box around the tow number with the least plastics. What is the value? ______

2. How deep in the water did these microplastics come from? Underline your evidence in the text.

3. What are two possible sources of the microplastics that Angel and the research team found?

4. Angel had heard that she would find a large island of trash. What did she find instead?

5. Another team with scientists from all over the world did a study about how much plastic was in the ocean. They collected data from net tows and visual surveys (scientists looked over the side of a boat and recorded all the trash they saw), and 92.3% of the tows had plastic in them. The scientists used the data to create a computer model that estimated how much plastic was in the ocean. The model showed that there should have been a lot more microplastics! Where are they going? Scientists aren’t sure, and they will have to do more research to find out!

5. After reading about this world-wide research about plastic in the ocean, was Angel’s data unusual or does it fit in with this data? How do you know?

---

Lesson 2
Small plastics, big problem

See-Think-Wonder
Study the picture and describe what you see, what you think about it, and what you wonder about the image.

I see

I think

I wonder

(Photo credit: Marcus Eriksen)

Plastics in the environment
Anything that doesn’t belong in the ocean is marine debris. Plastic marine debris comes in many shapes, sizes, and colors. It ends up on beaches, floating at the surface, sinking to the bottom, and many places in between. Plastics in the ocean are exposed to waves, wind, and sunlight, which causes them to break into smaller and smaller pieces over time, or fragment. This is one way that plastic marine debris becomes microplastics.

Like the fish pictured above, debris like microplastics can be eaten by animals. The animals might mistake the plastic pieces for prey or they might be filter feeders, which means they take in whatever is in the water. Sometimes, microplastics can get stuck in the guts of animals and cause problems. Another possible problem with microplastics is that the plastic attracts toxins from the water that stick to the surface of the plastic. Researchers have also found that microbes, very small organisms, form colonies (groups) on the surface of plastic marine debris. These are all impacts, or effects.
What happens when plastic fragments in the ocean?
To find out what happens to plastic when it breaks into smaller pieces in the ocean, you will use plastic cubes to represent marine debris. Over time, plastic marine debris is exposed to sunlight, wind, and seawater, and fragments. Your challenge is to find out how the total surface area of plastic changes when it fragments.

*To calculate surface area of a cube or rectangular prism, find the area of all the sides and add them up.*

**Example:**

![Diagram of a cube](image)

Record how your marine debris fragments in the table below.

<table>
<thead>
<tr>
<th>Number of pieces</th>
<th>Work</th>
<th>Total Surface Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="image" alt="Diagram of a cube" /></td>
<td>![Table placeholder]</td>
</tr>
</tbody>
</table>

Questions

1. When did this marine debris have the smallest surface area? The biggest surface area?

2. When more surface area is exposed to water, there is more space for toxins or microbes to attach. Does marine debris hold more toxins when it is big or when it is fragmented into microplastics? Why?
Read the text and look at the data table below, then answer the questions.

**From the Field**

**Name:** Laurie Weitkamp

**Career:** Fisheries biologist with NOAA (National Oceanic and Atmospheric Administration)

**Education:** Bachelor’s degree in zoology from University of Washington
Master’s degree in fisheries from University of Washington
PhD in aquatic and fisheries science from University of Washington

**Research:** Pacific salmon and factors that affect their survival

---

**Notes:**

Laurie and her team work in the Columbia River Estuary, which is between Oregon and Washington, where the Columbia River meets the Pacific Ocean. They wanted to find out what juvenile salmon in the Columbia River were eating. They wanted to understand their biology and wondered if they get food from the marshes people have been restoring nearby. Salmon mostly eat small animals such as insects. The scientists looked inside the salmon’s stomachs, and some of them had plastic inside. The plastic pieces were about the same size as the insects, but were found in many different colors (white, red, blue, and black). The scientists recorded the plastic they saw, but not how much or what kind. Sometimes scientists make observations and record data on something completely different from the focus of their work!

![Wild Juvenile Steelhead](Photo credit: Laurie Weitkamp)

---

**Laurie Weitkamp’s Data: Juvenile salmon diets in the Columbia River Estuary**

<table>
<thead>
<tr>
<th>Species</th>
<th>Total number of fish</th>
<th>Number with plastic in their stomachs</th>
<th>Percent of fish with plastic in their stomachs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook</td>
<td>1,009</td>
<td>28</td>
<td>3%</td>
</tr>
<tr>
<td>Coho</td>
<td>174</td>
<td>12</td>
<td>7%</td>
</tr>
<tr>
<td>Steelhead</td>
<td>219</td>
<td>3</td>
<td>1%</td>
</tr>
</tbody>
</table>

1. How many Steelhead had plastic found in their stomachs? __________

2. Which species had the highest percentage of fish with plastic in their stomachs? ________________
3. What does this data tell you about what juvenile salmon in the Columbia River Estuary are eating?

4. Support your statement from #3 with specific evidence from the data table.

5. Do you think it is acceptable for these juvenile salmon to have plastic in their stomachs? Why or why not?

6. A student named Sara looked at Laurie’s data and said, “These fish are eating plastic because they look like bugs!” Is this a claim she can make from the data shown in the table? If it isn’t, state the evidence from the table. If it isn’t, correct her statement.

7. List two impacts of microplastics on the ocean.

<table>
<thead>
<tr>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
</tr>
<tr>
<td>2.</td>
</tr>
</tbody>
</table>
Lesson 3
Designing Solutions to Microplastics

Using the information in your notebook and the scientific data to develop a possible solution to microplastics. Think about the plan’s costs and benefits as well as its feasibility (if it’s possible). Answer the questions in the graphic organizer below, then put all your ideas together.

<table>
<thead>
<tr>
<th>The Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are microplastics?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Our Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>What solution did your group decide on?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evidence to Support our Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>What evidence supports your solution?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Costs and Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs of your solution:</td>
</tr>
<tr>
<td>To humans</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>To nature</td>
</tr>
</tbody>
</table>
Glossary

Dilute – Less concentrated because water has been added to it

Degradation - The process of objects breaking down, in the case of microplastics, by UV waves (photodegradation)

Ecosystem – All the living organisms and non-living things in an environment

Estuary – An area where fresh water and salt water mix

Fragment – To break down into smaller pieces

Impacts – The effects of something, either positive or negative

Manta trawl – A net with floats and a bottle at the end to capture small particles at the surface of the ocean

Marine Debris - Any trash or other solid material that ends up in the ocean or the Great Lakes without a purpose.

Microbes – Tiny organisms that live everywhere on Earth

Microbeads - Tiny plastic particles added to many types of personal care products

Microplastics - Plastic marine debris that is less than 5 mm.

Nurdles - Small pre-manufacture plastic pellets

Plastic - Manufactured long chains of hydrocarbons often derived from natural gas or petroleum

Polyethylene – The most common type of plastics, with a wide variety of uses, including packaging, shopping bags, and clothes

Prey – An animal that is eaten for food

Organism – A living animal, plant, or single-celled creature

Sink - Where something ends up

Surface Area - The area of the outermost layer of an object

Toxin – poisonous substance

Weathering - Mechanical weathering is the process of breaking down materials into smaller pieces
Lesson Materials

Solution: Individual Actions

These are examples of actions people can take to reduce the amount of plastic that entering rivers and the ocean. These are not the only possible actions!

- Recycling
- Not buying products with microbeads
- Placing waste in the proper place
- Using reusable bags

Things to think about:
- What other things can individuals do to reduce plastic going into the ocean?
- Will doing this make a difference?
- What are you already doing to reduce the amount of plastic going into the ocean?
Solution: Making Laws

A possible solution to microplastics is to make laws that stop companies from making and selling microplastics. If we don’t use them they won’t go into the ocean, right?

- In June 2014, Illinois was the first state to pass a law to ban the making and selling of microbeads in personal care products (face wash, soaps, etc.).

- In addition to Illinois, the states listed in the table have also passed laws that restrict products with microplastics.

<table>
<thead>
<tr>
<th>New Jersey</th>
<th>Indiana</th>
<th>Wisconsin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maine</td>
<td>Maryland</td>
<td>California</td>
</tr>
<tr>
<td>Colorado</td>
<td></td>
<td>Connecticut</td>
</tr>
</tbody>
</table>

- Products with plastic microbeads were banned in the United States. When this ban occurred in 2015, other countries were still producing products with microbeads.

- Products with plastic microbeads were banned in the United States. When this ban occurred in 2015, other countries were still producing products with microbeads.

President Obama Signs *Microbead-Free Waters Act of 2015*

December 28, 2015

Washington D.C. – A federal law was passed and signed by President Obama that bans the production and sale of personal care products with plastic microbeads. Some personal care products like toothpaste and face wash have plastic microbeads that can go down the drain and into the ocean. Scientists are not sure how these small plastic beads affect the ocean environment. To stop more plastic from going into the ocean, Congress decided to ban personal care products with microbeads starting in 2017! People will not be allowed to make or sell personal care products with microbeads anywhere in the United States.

Things to think about:
- Do these laws stop the problem of microplastics?
- How can students help with this?
Solution: Education

From the Field

Name: Marcus Eriksen

Career: Director of Research and Co-founder of 5 Gyres. 5 Gyres is an organization that works to end plastic pollution in the ocean. They study marine debris, educate people about the issue, and work with people making laws.

Education: PhD in Science Education from the University of Southern California

Research: Marine debris

Notes: In 2014, Marcus was part of a team that published a paper about the amount of plastic in the ocean. They estimated that there were more than 5 trillion pieces of plastic floating in our ocean! Marcus describes a big part of his job as “myth-busting.” Many people think that there is a big garbage patch floating in the ocean, but Marcus has reported that it’s more like “plastic smog.” Like air pollution, it’s a difficult task to clean up plastic that is in the ocean. That means that we will have to work together to come up with creative solutions to plastic marine debris. 5 Gyres works to stop marine debris through educating students, decision-makers, and people who can help reduce marine debris (that’s everyone!). Marcus feels that his job is rewarding and working to prevent marine debris is the right thing to do.

Advice:
1. Explore your core values to find what is important to you
2. Be part of a team
3. Commit to your cause
Microplastics

Pointing out Plastic

Plastics can be found in many products at school and home. Plastics are created by people from oil or natural gas. There are lots of types of plastics.

(Photo credit: Marie Kowalski)
One surprising product that has plastic in it is **some soap**. Some soaps have small pieces of **polyethylene** (a type of plastic), which are called **microbeads**.

---

**Which soap has plastic in it?**

**CHALLENGE:** Which soap has plastic in it?

**STEPS:**

1. Observe the two soaps using your senses of smell and sight (NOT taste or touch)
2. Fill the jar half-way with water, then put the lid on your jar and shake it up!
3. Observe again with words and pictures, using your sight (NOT taste or touch)
4. Answer the questions on the next page.
Microplastics are small particles of plastic marine debris that are less than 5 mm and end up in the ocean. Microplastics are found in soap, toothpaste, laundry lint.

Marine debris is anything that ends up in the ocean or Great Lakes that doesn't belong there. Plastic marine debris fragments in the ocean.

Microplastics can also come from factories that use small plastic pellets to make their products. These pellets are called nurdles. They are light in color and about this big.
Angel White’s Data:
Plastics found in 10 tows in the Pacific Ocean

<table>
<thead>
<tr>
<th>Tow Number</th>
<th>Total Number of Plastics* (2mm + 5mm)</th>
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<td>504</td>
<td>320</td>
</tr>
<tr>
<td>4</td>
<td>343</td>
<td>357</td>
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<td>10</td>
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<td>360</td>
</tr>
</tbody>
</table>

Small plastics, big problem

*(Photo credit: Angel White)*

*(Photo credit: Marcus Eriksen)
What happens when plastic fragments in the ocean?

Example:

\[
\begin{align*}
4(5\text{ in} \times 2\text{ in}) + 2(2\text{ in} \times 2\text{ in}) &= 4(10 \text{ in}^2) + 2(4 \text{ in}^2) \\
&= 40 \text{ in}^2 + 8 \text{ in}^2 \\
&= 48 \text{ in}^2 \\
\end{align*}
\]

\[
\begin{align*}
6(2 \text{ in} \times 2 \text{ in}) &= 6(4 \text{ in}^2) = 24 \text{ in}^2 \\
4(3\text{ in} \times 2\text{ in}) + 2(2\text{ in} \times 2\text{ in}) &= 4(6 \text{ in}^2) + 2(4 \text{ in}^2) \\
&= 24 \text{ in}^2 + 8 \text{ in}^2 = 32 \text{ in}^2 \\
24 \text{ in}^2 + 32 \text{ in}^2 &= 56 \text{ in}^2
\end{align*}
\]

What happens when plastic fragments in the ocean?

Example:

<table>
<thead>
<tr>
<th>Number of pieces</th>
<th>Work</th>
<th>Total Surface Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Surface Area</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(6(3\text{ in} \times 3\text{ in}))</td>
<td>(6(9\text{ in}^2) = 54 \text{ in}^2)</td>
</tr>
<tr>
<td></td>
<td>(= 54 \text{ in}^2)</td>
<td>(= 54 \text{ in}^2)</td>
</tr>
</tbody>
</table>
Laurie Weitkamp’s Data

<table>
<thead>
<tr>
<th>Species</th>
<th>Total number of fish</th>
<th>Number with plastic in their stomachs</th>
<th>Percent of fish with plastic in their stomachs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook</td>
<td>1,009</td>
<td>28</td>
<td>3%</td>
</tr>
<tr>
<td>Coho</td>
<td>174</td>
<td>12</td>
<td>7%</td>
</tr>
<tr>
<td>Steelhead</td>
<td>219</td>
<td>3</td>
<td>1%</td>
</tr>
</tbody>
</table>

Designing solutions to microplastics

<table>
<thead>
<tr>
<th>Individual Actions</th>
<th>Making Laws</th>
<th>Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reusable Bag</td>
<td>Law</td>
<td>(Photo credit: Marcus Erikson)</td>
</tr>
</tbody>
</table>

(Photo credit: Laurie Weitkamp)
Designing solutions to microplastics

1. Work with your team to review the materials in the “Solutions” folder and the data in your notebook
2. Design a solution to microplastics. Use page 10 of your notebook to think about the details of your plan
3. Use the poster paper to create a visual to help you explain your solution everyone
4. Share your idea!
Microplastics – Student Example

Teacher Answer Guide

This “Student Example” document includes exemplar student responses. The purpose of this document is to provide insight into the questions in the student notebook and show an example of high quality student work. Many of the questions do not require one correct answer and may vary in detail or focus. In these cases, the example response is just one possible response and a note is made by the author. Additional content information can be found in the “Educator Background” section of each lesson plan.
Words to know:

1. Bags, Bottle, and Beads: Sources of Microplastics

Microplastics Plastic marine debris less than 5mm

Polyethylene The most common type of plastic

Marine debris Anything that ends up in the ocean or Great Lakes that does not belong

Nurdle Small pre-manufacture plastic pellets

Manta trawl A net used to capture small particles at the surface of the ocean

Dilute Less concentrated because water has been added to it

Plastic Made by people from oil or natural gas

2. Small plastics, big problem

Fragment To break into smaller pieces

Toxin Poisonous substance

Organisms A living animal, plant, or single-celled creature

Surface area The area of the outermost layer of an object

Microbes Tiny organisms that live everywhere on Earth

3. Designing Solutions to Microplastics

Microplastics Plastic marine debris less than 5mm

Reduction Making the amount of something smaller

Ban Making it illegal to make or sell something

Marine debris Anything that ends up in the ocean or Great Lakes that does not belong
Lesson 1
Bags, Bottles, and Beads: Sources of Microplastics

Soap suds and... plastic?
Plastics can be found in many products at school and home. Plastics are created by _______ people _______ from _______ oil _________ or _______ natural gas ________. There are lots of types of plastics. One surprising product that has plastic in it is _______ some soaps _______. Some soaps have small pieces of _______ polyethylene ________ (a type of plastic), which are called _______ microbeads _______.

CHALLENGE: Which soap has plastic in it?

STEPs:
1. Observe the two soaps using your senses of smell and sight (NOT taste or touch)
2. Fill the jar half-way with water, put the lid on your jar, and shake it up!
3. Observe again with words and pictures, using your sight (NOT taste or touch)
4. Answer the questions on the next page.

<table>
<thead>
<tr>
<th>Jar A</th>
<th>Jar B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td>Observations</td>
</tr>
<tr>
<td>1. There is white foam at the top of the mixture.</td>
<td>1. The pieces in the mixture sink to the bottom</td>
</tr>
<tr>
<td>2. The water and soap mix, and the whole mixture is blue.</td>
<td>2. The mixture is orange</td>
</tr>
<tr>
<td>3. The blue pieces float to the top of the liquid.</td>
<td>3. There is white foam at the top</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pictures (after shaking)</th>
<th>Pictures (after shaking)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Jar A" /></td>
<td><img src="image2" alt="Jar B" /></td>
</tr>
</tbody>
</table>
CONCLUSIONS:

1. What was different about the two soaps?
   When we shook up both jars, the pieces in jar A floated to the top of the liquid, and the pieces in jar B sank to the bottom.

2. Which jar do you think has plastic in it? Explain your reasoning. Be specific.
   I think that jar A has plastic in it because it floats in water.

3. What do you think happens to the plastic in the soap after someone uses it to wash their face?
   After someone uses one of these soaps to wash their face, they rinse it into the drain and it travels out into rivers and oceans.

President Obama Signs Microbead-Free Waters Act of 2015

December 28, 2015

Washington D.C. – A federal law was passed and signed by President Obama that bans the production and sale of personal care products with plastic microbeads. Some personal care products like toothpaste and face wash have plastic microbeads that can go down the drain and into the ocean. Scientists are not sure how these small plastic beads affect the ocean environment. To stop more plastic from going into the ocean, Congress decided to ban personal care products with microbeads starting in 2017! People will not be allowed to make or sell personal care products with microbeads anywhere in the United States.

Do you think this solves the problem of microplastics in the ocean? Why or why not?
   I do not think that this law solves the problem of microplastics because there are many other ways that plastic gets into the ocean. Microbeads make up a small portion of the plastics that end up in the ocean, and it is important to address those too. The law also only applies to the US. There are other countries that use products with plastic microbeads. This law was important in raising awareness about microbeads in personal care products, and it is also important in reducing the amount of plastic in the ocean.
Main Sources of Microplastics:

Microplastics are small particles of plastic that are less than 5 mm and end up in the ocean. Microplastics are found in: Soap, toothpaste, laundry lint.

Marine debris is anything that ends up in the ocean or Great Lakes that doesn't belong there. Plastic marine debris fragments in the ocean.

Microplastics can also come from factories that use small plastic pellets to make their products. These pellets are called nurdles. They are light in color and about this big.
From the Field

Name: Angel White

Career:
Researcher at Oregon State University

Education:
Bachelor's degree in Biology from University of Alabama
Master's degree in Biology from University of Alabama
PhD in Biological Oceanography from Oregon State University

Research: phytoplankton, how materials move through ecosystems, harmful algal blooms

Notes:
In 2008, Angel had the chance to go on an expedition with other scientists to study the amount of plastic in the ocean. To do this research, Angel went with a team of scientists to the Pacific Ocean (shown by the star on the map below). Angel had heard that there were big patches of garbage in the middle of the ocean. However, when she went out on the expedition, she did not see piles of trash floating in the water. In fact, the water looked clean! She sampled the water using a manta trawl. A manta trawl is a large net with a bottle at the end that captures anything too big to fit through the net (like plastic in the water). Scientists pull the manta trawl behind a boat along the surface of the water, and then analyze what is caught in the net. Each time the net was dragged behind the boat it is called a tow. Each tow filtered about 360 m³ of water, which is about the size of a school swimming pool. The scientists separated the plastic from the net and counted the number of pieces in each sample. After looking at the data, Angel was surprised that the plastic was so dilute even though plastic can be found all over the ocean!
The data in the table was collected by Angel and the other scientists on her expedition to the Pacific Ocean. Even though many researchers have found plastic in the ocean, people continue to study the amount of plastic in the ocean, where plastic can be found, and what type of plastic is in the ocean. This is important because people want to know how plastic in the ocean will affect living things.

Look at the table that shows Angel’s data, then answer the questions.

Angel White’s Data:
Plastics found in 10 tows in the Pacific Ocean

<table>
<thead>
<tr>
<th>Tow Number</th>
<th>Total Number of Plastics* (2mm + 5mm)</th>
<th>Volume of water (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>127</td>
<td>362</td>
</tr>
<tr>
<td>2</td>
<td>127</td>
<td>361</td>
</tr>
<tr>
<td>3</td>
<td>504</td>
<td>320</td>
</tr>
<tr>
<td>4</td>
<td>343</td>
<td>357</td>
</tr>
<tr>
<td>5</td>
<td>320</td>
<td>359</td>
</tr>
<tr>
<td>6</td>
<td>281</td>
<td>358</td>
</tr>
<tr>
<td>7</td>
<td>901</td>
<td>361</td>
</tr>
<tr>
<td>8</td>
<td>543</td>
<td>360</td>
</tr>
<tr>
<td>9 (marked)</td>
<td>1334</td>
<td>360</td>
</tr>
<tr>
<td>10</td>
<td>515</td>
<td>360</td>
</tr>
</tbody>
</table>

1. Circle the tow number with the largest number of plastics found. What is the value? 1334 plastics

2. Draw a box around the tow number with the least plastics. What is the value? 127 plastics

3. How deep in the water did these microplastics come from? Underline your evidence in the text.

   The microplastics came from the surface of the water.

4. What are two possible sources of the microplastics that Angel and the research team found?

   Two possible sources of the microplastics are laundry lint or fragmented large plastic debris (there are other possible answers).

5. Angel had heard that she would find a large island of trash. What did she find instead?

   Angel said that the water looked clean, but when she towed the manta trawl, there were lots of very small plastics on the surface of the ocean.

Another team with scientists from all over the world did a study about how much plastic was in the ocean. They collected data from net tows and visual surveys (scientists looked over the side of a boat and recorded all the trash they saw), and 92.3% of the tows had plastic in them. The scientists used the data to create a computer model that estimated how much plastic was in the ocean. The model showed that there should have been a lot more microplastics! Where are they going? Scientists aren’t sure, and they will have to do more research to find out!

Lesson 2
Small plastics, big problem

See-Think-Wonder
Study the picture and describe what you see, what you think about it, and what you wonder about the image.

I see

I think

I wonder

(Photocredit: Marcus Eriksen)

Plastics in the environment
Anything that doesn’t belong in the ocean is marine debris. Plastic marine debris comes in many shapes, sizes, and colors. It ends up on beaches, floating at the surface, sinking to the bottom, and many places in between. Plastics in the ocean are exposed to waves, wind, and sunlight, which causes them to break into smaller and smaller pieces over time, or fragment. This is one way that plastic marine debris becomes microplastics.

Like the fish pictured above, debris like microplastics can be eaten by animals. The animals might mistake the plastic pieces for prey or they might be filter feeders, which means they take in whatever is in the water. Sometimes, microplastics can get stuck in the guts of animals and cause problems. Another possible problem with microplastics is that the plastic attracts toxins from the water that stick to the surface of the plastic. Researchers have also found that microbes, very small organisms, form colonies (groups) on the surface of plastic marine debris. These are all impacts, or effects.
What happens when plastic fragments in the ocean?

Example:

$$\begin{align*}
(2 \text{ in} \times 2 \text{ in}) \times 2 &= 8 \text{ in}^2 \\
(2 \text{ in} \times 5 \text{ in}) \times 4 &= 40 \text{ in}^2 \\
\text{SA} &= 8 \text{ in}^2 + 40 \text{ in}^2 = 48 \text{ in}^2
\end{align*}$$

$$\begin{align*}
6 \times 2 \text{ in}^2 &= 6 \times 4 \text{ in}^2 = 24 \text{ in}^2 \\
(2 \text{ in} \times 2 \text{ in}) \times 2 &= 8 \text{ in}^2 \\
(2 \text{ in} \times 3 \text{ in}) \times 4 &= 24 \text{ in}^2 \\
8 \text{ in}^2 + 24 \text{ in}^2 &= 32 \text{ in}^2 \\
\text{Total SA} &= 24 \text{ in}^2 + 32 \text{ in}^2 = 56 \text{ in}^2
\end{align*}$$

Record how your marine debris fragments in the table below.

<table>
<thead>
<tr>
<th>Number of pieces</th>
<th>Surface Area</th>
<th>Total Surface Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
|                  | $$\begin{align*}
= (3 \text{ in} \times 3 \text{ in}) \times 6 \\
= 9 \text{ in}^2 \times 6 = 54 \text{ in}^2
\end{align*}$$ | = 54 \text{ in}^2 |
| 2                |              |                    |
|                  | $$\begin{align*}
4(2\text{ in} \times 3\text{ in}) + 2(3\text{ in} \times 3\text{ in}) &= 42\text{ in}^2 \\
4(1\text{ in} \times 3\text{ in}) + 2(3\text{ in} \times 3\text{ in}) &= 30\text{ in}^2 \\
42\text{ in}^2 + 30\text{ in}^2 &= 72 \text{ in}^2
\end{align*}$$ | = 72 \text{ in}^2 |
| 3                |              |                    |
|                  | $$\begin{align*}
4(2\text{ in} \times 3\text{ in}) + 2(3\text{ in} \times 3\text{ in}) &= 42\text{ in}^2 \\
2(1\text{ in} \times 3\text{ in}) + 2(3\text{ in} \times 2\text{ in}) &= 22\text{ in}^2 \\
4(1\text{ in} \times 3\text{ in}) + 2(1\text{ in} \times 1\text{ in}) &= 14\text{ in}^2 \\
42\text{ in}^2 + 22\text{ in}^2 + 14\text{ in}^2 &= 78 \text{ in}^2
\end{align*}$$ | = 78 \text{ in}^2 |
| 5                |              |                    |
|                  | $$\begin{align*}
4(2\text{ in} \times 3\text{ in}) + 2(3\text{ in} \times 3\text{ in}) &= 42\text{ in}^2 \\
2(1\text{ in} \times 3\text{ in}) + 2(1\text{ in} \times 2\text{ in}) + 2(3\text{ in} \times 2\text{ in}) &= 22\text{ in}^2 \\
3(6(1\text{ in} \times 1\text{ in})) &= 18\text{ in}^2 \\
42\text{ in}^2 + 22\text{ in}^2 + 18\text{ in}^2 &= 82 \text{ in}^2
\end{align*}$$ | = 82 \text{ in}^2 |

Questions

1. When did this marine debris have the smallest surface area? The biggest surface area?
   The marine debris had the smallest surface area when it was one large piece. It had the biggest surface area when it was broken up into smaller pieces.

2. When more surface area is exposed to water, there is more space for toxins or microbes to attach. Does marine debris hold more toxins when it is big or when it is fragmented into microplastics? Why?
   Marine debris holds more toxins when it is fragmented into microplastics because microplastics have more total surface area.
Read the text and look at the data table below, then answer the questions.

From the Field

Name: Laurie Weitkamp

Career: Fisheries biologist with NOAA (National Oceanic and Atmospheric Administration)

Education: Bachelor's degree in zoology from University of Washington
Master's degree in fisheries from University of Washington
PhD in aquatic and fisheries science from University of Washington

Research: Pacific salmon and factors that affect their survival

Notes:
Laurie and her team work in the Columbia River Estuary, which is between Oregon and Washington, where the Columbia River meets the Pacific Ocean. They wanted to find out what juvenile salmon in the Columbia River were eating. They wanted to understand their biology and wondered if they get food from the marshes people have been restoring nearby. Salmon mostly eat small animals such as insects. The scientists looked inside the salmon's stomachs, and some of them had plastic inside. The plastic pieces were about the same size as the insects, but were found in many different colors (white, red, blue, and black). The scientists recorded the plastic they saw, but not how much or what kind. Sometimes scientists make observations and record data on something completely different from the focus of their work!

Laurie Weitkamp's Data: Juvenile salmon diets in the Columbia River Estuary

<table>
<thead>
<tr>
<th>Species</th>
<th>Total number of fish</th>
<th>Number with plastic in their stomachs</th>
<th>Percent of fish with plastic in their stomachs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook</td>
<td>1,009</td>
<td>28</td>
<td>3%</td>
</tr>
<tr>
<td>Coho</td>
<td>174</td>
<td>12</td>
<td>7%</td>
</tr>
<tr>
<td>Steelhead</td>
<td>219</td>
<td>3</td>
<td>1%</td>
</tr>
</tbody>
</table>

1. How many Steelhead had plastic found in their stomachs? __3 Steelhead__

2. Which species had the highest percentage of fish with plastic in their stomachs? __Coho__
3. What does this data tell you about what juvenile salmon in the Columbia River Estuary are eating?
   This data tells me that juvenile salmon in the Columbia River Estuary are eating plastic in the water.

4. Support your statement from #3 with specific evidence from the data table.
   I know that there is plastic in the estuary because there were fish with plastics found in their stomachs.

5. Do you think it is acceptable for these juvenile salmon to have plastic in their stomachs? Why or why not?
   This is an opinion question that will vary.

6. A student named Sara looked at Laurie’s data and said, “These fish are eating plastic because they look like bugs!” Is this a claim she can make from the data shown in the table? If it is, state the evidence from the table. If it isn’t, correct her statement.
   This is not a claim that Sara can make about the data because the data in the table shows that the fish have plastic in their stomachs, but not why they have ingested the plastic.

7. List two impacts of microplastics on the ocean.
<table>
<thead>
<tr>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Microplastics can get eaten by small animals and stuck in their gut.</td>
</tr>
<tr>
<td>2. Microplastics can attract toxins, which might hurt animals if they are eaten.</td>
</tr>
</tbody>
</table>
Lesson 3
Designing Solutions to Microplastics

Using the information in your notebook and the scientific data to develop a possible solution to microplastics. Think about the plan’s costs and benefits as well as its feasibility (if it’s possible). Answer the questions in the graphic organizer below, then put all your ideas together.

<table>
<thead>
<tr>
<th>The Problem</th>
<th>How do microplastics get in the ocean?</th>
<th>What is the problem with microplastics?</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are microplastics?</td>
<td>Directly when small plastics like microbeads in personal care products are washed down the drain or indirectly when large plastic marine debris breaks down in the marine environment.</td>
<td></td>
</tr>
<tr>
<td>Microplastics are plastic marine debris less than 5mm.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Our Solution</th>
<th>What made you decide on this solution?</th>
</tr>
</thead>
<tbody>
<tr>
<td>What solution did your group decide on?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evidence to Support our Solution</th>
<th>What evidence does not support your solution?</th>
</tr>
</thead>
<tbody>
<tr>
<td>What evidence supports your solution?</td>
<td></td>
</tr>
<tr>
<td>*Use evidence from student notebooks, the &quot;student solutions guide,&quot; or other informational sources.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Costs and Benefits</th>
<th>Benefits of your solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs of your solution:</td>
<td>Benefits of your solution</td>
</tr>
<tr>
<td>To humans</td>
<td>To humans</td>
</tr>
<tr>
<td>To nature</td>
<td>To nature</td>
</tr>
</tbody>
</table>
MICROPLASTICS CURRICULUM EVALUATION REPORT

Introduction

Microplastics, plastic debris less than 5 mm in size, are ubiquitous in our oceans (Law & Thompson, 2014). These small pieces of plastic mostly originate on land, and often result from larger plastic marine debris fragmenting when exposed to sunlight, wave action, and biological activity. Small plastic particles can also enter waterways directly via sewer systems (Browne, 2015). Direct sources of microplastics include laundry lint (Browne et al., 2011) and personal care products such as toothpaste and face wash (Fendall & Sewell, 2009). Small plastic microbeads are added to some personal care products as exfoliants, and are intended to be washed down the drain. Microbeads bypass water treatment plants because of their small size (Fendall & Sewell, 2009). Once in the aquatic and marine environment, microplastics have been shown to accumulate toxins (Mato et al., 2001), provide substrate for microbial communities (Harrison et al., 2014), and be ingested by various species of organisms (Cole et al., 2013; Van Cauwenberghe & Janssen, 2014; van Franeker et al., 2011). Research on this topic is ongoing, and many of the impacts of microplastics in the ocean are unknown.

The issue of microplastics pollution is large-scale and complex. Solutions must also be large-scale, collaborative, and focused on source reduction methods. Current efforts to address the issue include scientific research to better assess abundance and impacts, legislative action such as the passage of the Microbead-Free Waters Act of 2015, and innovative technologies. Education also plays an important role in reducing plastic in the ocean. Awareness of environmental issues like microplastics in the ocean is associated with people feeling concern for their environment (Gelcich et al., 2014). Changing beliefs and feelings of self-efficacy around the issue (Stern, 2000) as well as increasing awareness and accurate knowledge can potentially promote behaviors that lead to a reduction of plastics in the marine environment.
Following a needs assessment to understand the state of available marine debris curriculum, which identified microplastics as a gap (Chapter 2), a middle school curriculum was developed using current microplastics research (Chapter 3). This evaluation report discusses the curriculum evaluation methods and results and also includes recommendations for future adaptation or implementation of the curriculum. This report emphasizes the results from the summative evaluation, which assesses the effectiveness of the final curriculum product. The summative evaluation focuses on the worth of the curriculum. The worth (Guba & Lincoln, 1981) refers to its usefulness in the context of teaching.

**Goals and Evaluation Questions**

The goal of the curriculum is to increase the knowledge, understanding, and awareness of microplastics in middle school students and teachers while inspiring behaviors and attitudes that support the reduction of marine debris and microplastics. The curriculum has the potential to impact the community more broadly through the spread of knowledge and actions. The evaluation was based on two questions:

1. To what extent do knowledge, attitudes, and beliefs change after participating in this microplastics curriculum?
2. How do understanding and behaviors change after participating in this microplastics curriculum?

**Evaluation Design**

*CIPP Model*

The Context, Input, Process, Product (CIPP) evaluation model was used to design this evaluation. The CIPP model takes an approach designed to be flexible, common-sense, and comprehensive (Stufflebeam & Coryn, 2014). The CIPP model can be used as both a formative and summative evaluation. Formative evaluation collects information on a program or product during the development process, allowing the developer to improve the program or product *before* implementation. Summative evaluation collects
information on the final product after implementation to determine the effectiveness of a program or product and inform the development of future products (Diamond, Luke, & Uttal, 2009). This evaluation focused on formative and summative evaluation of the curriculum and did not include the long-term impacts. The evaluation of the microplastics curriculum also did not focus on the process component of the CIPP evaluation model. The process refers to the evaluation process, which is partly addressed in the limitations section of the conclusion (Chapter 6).

The evaluation included many nonlinear steps, some of which are not the focus of this report, such as the needs assessment (Chapter 2). Each of the four evaluation components of the CIPP model and the ways in which they were incorporated in the curriculum evaluation are listed below.

- **Context** – The context of the curriculum was determined through a needs assessment to identify the merit, or usefulness out of context (Guba & Lincoln, 1981), and gaps in existing marine debris curriculum.

- **Input** – Each input was not independently evaluated by the evaluator. Teaching strategies were taken from the literature and the *Communicating Ocean Science to Informal Audiences* guide (Rowe, 2010). Scientific content included in the lessons was assumed to be rigorous due to the peer review process. Education standards were also assumed to be rigorously developed by researchers and educators.

- **Process** – In this component, data on the process was collected to improve the implementation of the evaluation methods. This component was not a focus of this evaluation.

- **Product** – The product evaluation included the formative and summative evaluations of the curriculum.
Figure 4.1. Microplastics curriculum evaluation process showing how each component fits into the CIPP model

The full evaluation design (Figure 4.1) contained all components of the CIPP model but process, which focuses on the evaluation process. The needs assessment (Chapter 2) provided the context and input components of the evaluation. This evaluation report focuses on the product evaluation component, which includes both formative and summative phases.

**Evaluation Site**

All evaluation activities took place in Lincoln County School District (LCSD), Oregon (Figure 4.2.a). LCSD was chosen for this evaluation because this district partners with Oregon Sea Grant and Oregon State University’s Hatfield Marine Science Center (HMSC) for support in marine science, and teachers in this district have participated in marine debris professional development workshops at HMSC. LCSD is a rural, coastal school district with 17 schools housing 5,418 students and 255 teachers. The demographics of students in LCSD are shown in Figure 4.2.b. Lincoln County School District has a universal free school breakfast and lunch program (Figure 4.2.c).
Figure 4.2.a. Map of Oregon counties with the filled area representing Lincoln County. Image from Wikimedia Commons (Benbennick, 2006)

Figure 4.2.b. Demographic information for students in Lincoln County School District in the 2014-2015 school year

Lincoln County School District student demographics

- White 66%
- Hispanic/Latino 19%
- Native American 6%
- Asian 1%
- Multi-Ethnic 7%
- Black/African American 1%

66% of students in Lincoln County School District qualify for free or reduced lunch

Figure 4.2.c. Percentage of students in Lincoln County School District receiving free or reduced lunch in the 2014-2015 school year
Formative Evaluation

Pilot Teaching

Data Collection

Formative evaluation was the first phase of the product evaluation and included two parts: pilot teaching and a teacher focus group. The goal of pilot teaching the initial curriculum was to inform changes that would improve the ability of the curriculum to engage students and convey its message. The full curriculum was taught in two marine science summer camps at Hatfield Marine Science Center (HMSC) in Newport, Oregon. Data collection took place in July and August 2015. All data collection instruments were used during pilot teaching, including student surveys, student lesson materials, and researcher fieldnotes. A total of 47 students (Table 4.1) participated in the two camps.

Table 4.1. Pilot teaching participants

<table>
<thead>
<tr>
<th></th>
<th>Age range</th>
<th>Number of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>July summer camp</td>
<td>12-15</td>
<td>20</td>
</tr>
<tr>
<td>August summer camp</td>
<td>12-15</td>
<td>27</td>
</tr>
</tbody>
</table>

Data Analysis

Pilot teaching data was coded (see Appendix D for coding scheme) and entered into Microsoft Office Excel. The evaluator looked for responses indicating confusion. Revisions to the curriculum made from pilot teaching data mainly came from observations and notes during teaching.

Results

Revisions to the initial curriculum were mainly taken from student questions during teaching and evaluator fieldnotes. Questions and texts in student handouts were revised based on student confusion, and the timing of activities was noted. Revisions continued throughout the development process to improve clarity, rigor, and aesthetic
appeal of materials. For example, questions asking students to identify data from a table were clarified to explicitly ask for the value. Also, the student reading passages were changed to include more detail and analogies to promote understanding.

Focus Group

Data Collection

In addition to pilot teaching the curriculum, a focus group was used to gain feedback on the content and usability of the curriculum, as well as the likelihood that educators would use the curriculum. Focus group participants were recruited from middle school teachers who had previously participated in marine debris workshops at HMSC and people working with curriculum within LCSD. All focus group participants are associated with LCSD. Six participants (Table 4.2) attended the focus group held in November 2015 at HMSC. Participants were given a copy of the curriculum to review prior to the focus group, and additional copies were provided on the day of the focus group. The focus group lasted about an hour and was audio recorded and transcribed by the evaluator.

Table 4.2. Focus group participants

<table>
<thead>
<tr>
<th>Participant type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-8 grade teacher, self-contained</td>
<td>2</td>
</tr>
<tr>
<td>6-8 grade science teacher</td>
<td>2</td>
</tr>
<tr>
<td>K-12 School Liaison for an informal education institution</td>
<td>1</td>
</tr>
<tr>
<td>LCSD Curriculum Resource Liaison</td>
<td>1</td>
</tr>
</tbody>
</table>
Data Analysis

Focus group data was transcribed and coded (Appendix D) using a combination of axial (top down) coding and in vivo (bottom up) coding (Berg & Lune, 2012) in the program Dedoose, a web application for mixed methods analysis. Coding was done initially using evaluator-imposed codes of “change” representing suggestions of changes to the curriculum and “keep” representing something participants liked or thought should not change. Data was further grouped into “teacher instructions,” “aesthetics,” “materials,” and “content.”

Results

During the focus group, participants discussed both parts of the curriculum they felt should be changed and kept. Participants talked the most about the content of the curriculum, focusing mainly on photos in the student materials and opportunities for using technology, but also the wording of questions and presentation of data in student materials. In the teacher instructions category, participants suggested more changes than parts to keep. Salient suggestions for teacher instructions included adding increased structure to the lesson plans by making them more scripted and explicit, changing the way vocabulary is presented, and incorporating more opportunities for student discussion.

Throughout the formative evaluation process, many changes were made to the curriculum. A few of the important changes are included below:

- Researcher data tables were explained more thoroughly
- A vocabulary page was added to the front of the student notebook
- Discussion questions were included in all lesson plans
- A supplemental video was added
- Lesson plans were re-written in a more script-like format with pictures, templates, and links to purchase materials where possible
- New graphics were incorporated to better accommodate greyscale printing
**Summative Evaluation**

*Data Collection*

The summative evaluation was the final phase of the product evaluation. It aimed to determine the effectiveness, or worth, of the curriculum in the context of LCSD middle school classrooms. The summative evaluation data consisted of quantitative and qualitative data from a student and teacher survey designed to assess awareness, attitudes, beliefs, understanding, knowledge, and behaviors. Changes in attitudes, beliefs, understanding, and behaviors were measured using a pre and post survey design. Evaluation instrument development (Appendix B), survey items (Appendix C) and codes (Appendix D) can be found in the appendices. Student knowledge was measured with assessments embedded within the curriculum at the end of each lesson. Any unanticipated outcomes were captured in evaluator fieldnotes.

Summative evaluation data collection took place in December 2015 and January 2016. The evaluator taught the entire curriculum to seven classes in LCSD. A total of 110 students participated in the curriculum. Teachers who participated in the focus group were invited to participate in the summative evaluation. Each class was visited for four consecutive days. A more detailed profile of student participants is shown in Table 4.3 and Figure 4.3. Class lengths varied between 45-60 minutes.

### Table 4.3. Student participants by grade and class size

<table>
<thead>
<tr>
<th>Class</th>
<th>Grade</th>
<th>Number of students</th>
<th>Number of student participants(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>32</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>5/6</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>30</td>
<td>26</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>17</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>33</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>32</td>
<td>15</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>25</td>
<td>16</td>
</tr>
</tbody>
</table>

\(^1\)Number of students who signed an assent form and returned a signed parent consent form
Data Analysis

Summative evaluation data was coded (see Appendix D) and entered into Microsoft Office Excel. Descriptive statistics as well as nonparametric statistical tests were performed using SPSS after importing raw data from Excel. Qualitative data was coded again in Dedoose.

Awareness was assessed using one item on the pre survey, “Have you heard of microplastics before today?” coded yes (1) or no (0), and analyzed using descriptive statistics. Awareness after participating in the curriculum was inferred from student knowledge of microplastics.

Knowledge was assessed using questions embedded within the student materials. Each learning objective was measured with one question with the exception of identifying sources of microplastics, which had three questions. Student responses were coded correct (1) or incorrect (0). Each student was given a score for each objective of 0, 1, or a mean index in the case of identifying sources of microplastics. Overall knowledge scores were calculated as a mean index of the five curriculum objectives. Students who did not respond to two or more of the items were not included in the calculation. Written responses to evaluation items were coded in Dedoose.
Understanding was assessed using a written response question on the pre and post survey modeled after Keeley’s (2009) series of understanding probes in Uncovering Student Ideas in Science. Responses were analyzed on a rubric (Appendix D) with three categories: misconceptions, explanation quality, and information from the curriculum. Students could score high (3), medium (2), or low (1) in each category. Student responses were also coded using a combination of axial (top down) coding and in vivo (bottom up) coding, focusing on student misconceptions.

Attitudes and beliefs were assessed using eight identical survey items on both the pre and post survey. Each of these items was measured on a Likert-type scale from 1 “strongly disagree” to 5 “strongly agree.” The three variables measuring beliefs, “my behaviors do not make a difference in the amount of microplastics in the ocean,” “I can make a difference in the amount of microplastics in the ocean,” and “my actions affect the amount of microplastics in the ocean” were combined into a mean index on the pre and post surveys. The overall reliability (Appendix E) using Cronbach alpha was .78 for pre survey beliefs items and .73 for post survey beliefs items. Because these Cronbach alpha values were high, the three variables were all included in the mean index. In the pre survey, none of the beliefs items raised the overall alpha when deleted, so each was included in the index. In the post survey, removing “I can make a difference in the amount of microplastics in the ocean” increased the Cronbach alpha to .77, but it was included to be consistent between the pre and post survey. An exploratory factor analysis grouped each of the three beliefs items together on both the pre and post survey, which further justified the calculation of a beliefs index. Attitudes questions did not group consistently in the exploratory factor analysis, and therefore attitudes items were analyzed separately.

Behaviors were assessed with a survey item asking students to “List actions someone could take to reduce the amount of microplastics in the ocean.” The total number of behaviors listed per student was calculated by the evaluator, and the content of student responses was coded (Appendix D), identifying patterns and common
responses among students. Behavior data indicates students’ ability to generate ideas about behaviors that might reduce microplastics in the ocean. This data does not speak to changes in behavior or intended behavior, but to the expanded knowledge of possibilities for microplastics-reducing behaviors. Changes in behavior and long term impacts of the curriculum are beyond the scope of this evaluation.

Results

This section describes significant and salient results from the summative phase of the evaluation. A summary of important results is shown in Figure 4.4, and a full report of results can be found in Appendix E.

Figure 4.4. Summary of important results

Attitudes and Beliefs
• Increased feelings of personal responsibility

Awareness
• Increased awareness of the issue

Knowledge
• Increased knowledge of microplastics-reducing behaviors
• More nuanced knowledge of the issue

Understanding
• Fewer misconceptions
• Shift from general to specific understanding

Attitudes

After participating in the curriculum students felt significantly more concern about microplastics ($p < .001, Z = 3.43$). Students came to the lessons with a general concept of microplastics as a broad, serious problem, particularly for marine animals.
There was also uncertainty about the problems microplastics cause for people. The attitude that microplastics is a serious problem for people increased slightly over time, perhaps with the acquisition of more detailed knowledge of the issue. This uncertainty may be an indication of the need in the curriculum to explicitly state ways in which microplastics impact humans.

All teachers responded “strongly agree” for all attitudes statements on the pre and post survey, which may be a reflection of their strong feelings that microplastics are a problem. This result supports the idea that the teachers had a prior interest in microplastics and felt it was an important topic for students. Additionally, Lincoln County School District (LCSD) has adopted an Ocean Literacy initiative. The Ocean literacy initiative is a partnership between LCSD, the Oregon Coast Aquarium, and Oregon Sea Grant to improve local ocean literacy through teacher professional development, the integration of ocean science into classrooms, and the development of ocean literacy curriculum (West Coast Governor’s Alliance on Ocean Health, n.d.).

Beliefs

Before participating in the curriculum, students already had a high degree of self-efficacy about the issue. This means that students felt that they were able to take meaningful action to address the problem. A Wilcoxon Sign Rank test was used to compare the beliefs concept between the pre and post surveys. Beliefs showed an increasing trend, but it was not significant \( (p = .153, Z = 3.93) \). Teachers also showed high agreement, between 3.67 and 5.00, on all beliefs items.

Awareness

Before starting the lessons, 47% of students had heard of microplastics. This might have been influenced by the location of students (two of the three schools were in coastal towns) and the teachers’ prior interest in marine debris. Awareness after participating in the curriculum was inferred from student knowledge scores. Students
scored over 80% correct on each knowledge objective requiring awareness of microplastics and marine debris.

All teachers had heard about microplastics before the first lesson of the curriculum was taught in their classrooms. This is consistent with the facts that teachers had previously participated in a marine debris workshop and curriculum pilot program and also that they showed high interest and concern for the issue of microplastics on the pre survey.

Behaviors

Students listed more behaviors to reduce the amount of microplastics in the post survey as compared to the pre survey. This increase was significant ($p = .021$) and the effect size (.16) was between small and medium (Cohen, 1988) or between minimal and typical (Vaske, 2008). This trend remained the same when students were grouped by grade level. Fifth and sixth grade students did not show a significant increase, implying that the increase in number of behaviors was mainly due to eighth grade students.

Types of behaviors listed by students shifted between the pre and post surveys. Before the lessons, students mainly identified behaviors that targeted managing waste and preventing it from entering the ocean (“not littering”). After the lessons, many students focused on behaviors that targeted managing consumption like “limit plastic use” and “do not use products containing polyethylene/micro-beads.”

The mean number of behaviors listed by teachers decreased from the pre ($M = 4$) to post survey ($M = 3.67$). This may be due to time constraints or pressure to generate behaviors that were not listed on the pre survey. The types of behaviors listed by teachers, however, were very similar between the pre and the post surveys. Before and after the curriculum was taught, teachers tended to list consumption behaviors such as "purchase items that do not use plastics.” This stability in teacher responses was consistent with the high awareness teachers reported prior to experiencing the microplastics curriculum.
Knowledge

Students’ mean overall knowledge score was 86% correct responses (Figure 4.5). When grouped by grade, eighth grade students had a higher overall knowledge score (89%) than fifth and sixth grade students (79%). Eighth grade students scored higher on every objective except identifying sources of microplastics.

The mean knowledge score for defining microplastics was 82%. Almost 20% of students responded with multiple answers (Figure 4.6), indicating that they believed more than one of the possible answers would be considered microplastics. All multiple responses were a combination of the plastic bag, bottle, cap, and plastic nurdles. Explanations mostly justified their choice by stating that each answer chosen was made of plastic, with multiple students explaining that the plastic bag or bottle cap had the potential to become microplastics.
None of the students chose “seed” or “bottle cap” as a single response, even though a bottle cap was identified as a potential source of microplastics by students who chose multiple responses. The bottle cap was the only choice made of plastic but did not have the word plastic in its description. Most students (76% of the students who responded) gave the correct answer: plastic nurdle. However, explanations varied. Common patterns among correct responses included identifying the size and composition of the nurdle. Most explanations included both size and composition.

Students were asked to name three possible sources of microplastics. Correct student responses were generally described by five categories: personal care products, industry, large plastic debris, fibers, and trash. Common responses and their frequency are shown in Table 4.4.

If all of the following items were found floating in the ocean, which would be described as microplastics?

<table>
<thead>
<tr>
<th>Item</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic bag</td>
<td>5%</td>
</tr>
<tr>
<td>Seed</td>
<td>0%</td>
</tr>
<tr>
<td>Bottle cap</td>
<td>0%</td>
</tr>
<tr>
<td>Plastic nurdle</td>
<td>76%</td>
</tr>
<tr>
<td>Multiple responses</td>
<td>19%</td>
</tr>
</tbody>
</table>

Figure 4.6. Student responses to knowledge item in the “defining microplastics” objective
Table 4.4. Frequencies of student responses to “list possible sources of microplastics”

<table>
<thead>
<tr>
<th>Category</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal care products</td>
<td>103</td>
</tr>
<tr>
<td>Toothpaste</td>
<td>37</td>
</tr>
<tr>
<td>Face wash</td>
<td>32</td>
</tr>
<tr>
<td>Soap</td>
<td>31</td>
</tr>
<tr>
<td>Large plastic debris</td>
<td>28</td>
</tr>
<tr>
<td>Industry/nurdles</td>
<td>22</td>
</tr>
<tr>
<td>Fibers</td>
<td>22</td>
</tr>
<tr>
<td>Trash</td>
<td>17</td>
</tr>
</tbody>
</table>

The most common response was personal care products. Trash is a major source of marine debris and microplastics, although it was not frequently mentioned by students. This may indicate the need to emphasize the idea that most marine debris is land-based in the curriculum.

Most (87%) fifth and sixth grade students and all eighth grade students who responded to the question about the abundance of microplastics did so correctly. The fifth and sixth grade students who did not choose the correct response all chose “microplastics are only found in the middle of the ocean.” Overall, students were able to describe the abundance of microplastics. This is consistent with their generally strong attitude that marine debris is a problem all over the world.

Eighth grade students who responded to surface area questions tended to answer them correctly more often (67%) than fifth and sixth grade students (60%). This may be due in part to the different ways in which this part of the lesson was taught. Fifth and sixth grade students did not have prior knowledge of surface area. Sixth grade Common Core State Standards include finding the area of flat surfaces and using this knowledge to solve real-world problems. The standards do not include calculating the surface area of rectangular prisms until seventh grade.
Understanding

On the post survey, students tended to respond using fewer misconceptions about marine debris or microplastics compared to the pre survey. Students also tended to provide more specific explanations in their responses on the post survey. This not only shows that students incorporated specific details, but is consistent with the idea that concepts learned in school change from more abstract at first to more concrete over time (Howe, 1996). The number of misconceptions ranged between zero and two per student on both the pre and post survey, and the mean number of misconceptions decreased from .51 ($N = 102$ students) on the pre survey to .35 ($N = 103$ students) on the post survey.

On the pre survey, misconceptions tended to include sources of microplastics ("people littering on the beach") and the mechanism by which microplastics are produced ("plastic trash that was left that decomposed into smaller pieces of plastic"). The most common misconceptions after participating in the lessons were that all "plastic floats on the top of the water," most debris comes from the beach, and that all animals die when they eat plastic.

Discussion & Recommendations

Overall, attitudes about the scope and severity of the microplastics issue and beliefs that students could influence the problem increased after participating in the curriculum. Students were more worried about the issue, but a sense of personal responsibility is important when combined with knowledge of solution-oriented behaviors. Student self-efficacy was generally high, even before participating in the lessons. High self-efficacy may indicate that while students might feel more concerned, they will also feel that they are able to do something about it.

The curriculum was effective in increasing students’ awareness and understanding of the issue of microplastics. Students were able to use knowledge gained from the curriculum to respond to a scenario in the post survey. They were also
able to list behaviors to reduce microplastics, focusing on consumer behaviors instead of management of debris. This shows that students have a more comprehensive understanding of the sources of microplastics and the actions that might effectively lead to source reduction. While this study did not assess students' behaviors or intended behaviors outside the classroom, it is possible that the combination of personal responsibility and knowledge of effective behaviors will lead to a change in the students’ behaviors.

A few results from the summative evaluation suggest the need for revisions before disseminating the final curriculum. These final revisions are listed below:

- The need to focus on fibers and large plastic debris because they represent a large portion of microplastics sources. These items were not mentioned as sources of microplastics as frequently as personal care products, which is featured prominently in the curriculum.
- Explicitly stating that microplastics are a global issue. Solutions to microplastics will take efforts on a global scale.
- More examples of collective actions as solutions may help students generate ideas beyond individual actions.
- Explicitly addressing the misconceptions that all microplastics float, plastic decomposes, marine debris is primarily from the beach, and that any ingestion of microplastics kills animals.
- Clarifying impacts of microplastics on people.

Making generalizations about the effectiveness of this curriculum outside of the coastal communities where it was evaluated is not possible. In the context of this study, however, the microplastics curriculum was effective.
Abstract

Microplastics, plastic marine debris less than 5 mm across, is a threat to the health of our oceans. One important way to reduce microplastics in our oceans is to educate people about the issue, particularly future decision-makers. A middle school curriculum was developed using current scientific data and evaluated using the Context, Input, Process, Product (CIPP) model. The curriculum includes lessons on sources, impacts, and solutions to microplastics. Students participating in the curriculum gained detailed knowledge and awareness of microplastics in addition to demonstrating increased feelings of personal responsibility.

Introduction

Our ocean is a valuable resource that provides important services, from fisheries to recreation, in addition to habitat for many organisms. The global health of our ocean is threatened by marine debris, or litter in the ocean. Most marine debris is plastic (Thiel et al., 2013) and can range in size from abandoned boats to microplastics less than 5 mm across (Law & Thompson, 2014). Marine debris is everywhere, and it is largely preventable through changes in people’s behaviors. Reducing marine debris, however, is a complex problem.

While picking up litter is important, education and scientific research are also critical components of reducing marine debris (Thompson, Moore, vom Saal, & Swan, 2009). Awareness of marine issues is associated with feeling concern for the environment (Gelcich et al., 2014). Inspiring and empowering young people to take action is an important part of reducing marine debris.

This article describes a three-part middle school curriculum developed using current research on microplastics. An overview of the curriculum development and evaluation is discussed. An excerpt from the curriculum is included with access to the
full curriculum available online. While the curriculum was designed and evaluated with a formal middle school classroom in mind, the lesson activities can also be adapted for use in informal settings.

The Issue with Microplastics

Sources and Sinks

It has been estimated that over five trillion pieces of plastic are floating in the ocean and over 90% are microplastics (Eriksen et al., 2014). Most marine debris (about 80%) originates on land (Derraik, 2002). Microplastics primarily enter the ocean when larger plastic marine debris fragments, but also when small plastic objects end up in the ocean (Browne, 2015). Small plastics in personal care products such as some face washes and toothpastes, as well as plastic fibers in laundry lint, go down household drains and are not removed by water treatment facilities (Fendall & Sewell, 2009).

Possible Impacts

Once in the ocean, the impacts of microplastics are largely unknown. However, ongoing research has demonstrated that potential impacts include the accumulation of toxins on the surface of microplastics (Mato et al., 2001) and organisms’ ingestion of plastics. Microbes have also been shown to colonize on the surface of microplastics, potentially being transported to new parts of the ocean or sinking plastic from surface waters (Zettler, Mincer, & Amaral-Zettler, 2013). Smaller organisms such as plankton (Cole et al., 2013) and filter feeders such oysters (Van Cauwenberghe & Janssen, 2014) have been reported to eat microplastics along with many species of fish and sea bird (Codina-García, Militão, Moreno, & González-Solís, 2013). The impacts of microplastics after consumption by many of these animals is still unclear. Microplastics can be found from the surface to the bottom of the ocean all over the world. This makes the impacts of microplastics on the marine environment a global concern.
Solutions

For an issue that has no “right” solution, effective methods to address marine debris will require creativity and collaboration among many groups. Three categories of actions include legislation, education, and individual actions.

- **Legislation** – The federal *Microbead-Free Waters Act of 2015* banned the manufacture and sale of personal care products with plastic microbeads.
- **Education** – Educating people about marine debris has the potential to inspire reduction of marine debris at multiple scales.
- **Individual Actions** – Individual actions such as recycling and avoiding plastic products, while small in scale, can reduce our personal plastic contribution and inspire others to change, thereby having a large impact.

Curriculum Design

Inputs

The curriculum was created through the backwards planning design of Wiggins & McTighe (2005). Lessons were grounded in enduring understandings and learning objectives aligned with the middle school Next Generation Science Standards (NGSS), Common Core State Standards, Ocean Literacy Principles, and the Oregon Environmental Literacy Plan. Lessons were also developed around data provided by researchers working in the field. Each researcher had data on microplastics and was working on the US West coast. Two of the researchers were local to the study site.

Overview

The curriculum consists of three lessons designed for 6-8 grade students:

1. **Bags, Bottles, and Beads: Sources of Microplastics**
   Students investigate personal care products with plastic microbeads, explore the main sources of microplastics, and work with data on microplastics abundance collected in the Pacific Ocean.

2. **Small Plastics, Big Problem**
   Students simulate the fragmentation of plastic marine debris to determine how its surface area changes and then work with data from the Columbia River Estuary in Oregon to explore some potential impacts of plastics in waterways.
3. *Mitigating Microplastics*
Students work in groups to generate possible solutions to the problem of microplastics and implement their ideas.

The curriculum available online contains a set of teacher lesson plans with aligned standards, materials, lesson outlines, extension and adaptation suggestions, and background content information. A presentation slide show with lesson content is also available along with student handouts, an answer guide, and a supplemental video.

**Curriculum Evaluation**

*Evaluation Model*

The evaluation of this curriculum was based on the Context, Input, Process, Product (CIPP) model (Stufflebeam & Coryn, 2014). This model was chosen because of its flexibility and ability to be used as a model for both the formative and summative evaluation. Figure 5.1 depicts the evaluation model and the flow of the project.

The goal of the formative evaluation was to get initial feedback on the curriculum from students and to assess its usefulness and likelihood of being implemented by teachers. Data collected during the formative evaluation was used to make revisions to the curriculum.

The goal of the summative evaluation was to evaluate the effectiveness of the final curriculum and document certain changes in participants. The summative evaluation was guided by two questions:

1. To what extent do knowledge, attitudes, and beliefs change after participating in this microplastics curriculum?
2. How do understanding and behaviors change after participating in this microplastics curriculum?
Figure 5.1. Evaluation design for assessing the effectiveness of this curriculum
Data Collection

Formative evaluation data was collected in two parts: pilot teaching the curriculum and a teacher focus group. The pilot version of the curriculum was taught at two marine science summer camps with a total of 47 students between the ages of 12-15. Data on the timing of the lessons, student questions during teaching, and student responses on handouts were collected via researcher fieldnotes and used to make changes to the curriculum. After revising the curriculum, it was reviewed by a group of four middle school teachers, a curriculum resource liaison, and a K-12 liaison at a marine science institution. A focus group was held to obtain feedback on the content, layout, usability, and likelihood that the curriculum would be used in the classroom. This feedback was also used to revise the curriculum.

Summative evaluation data was collected using pre and post surveys before the first lesson and after the third lesson was taught. The survey was used with 110 students and three teachers in a total of seven classes. The concepts addressed through the survey were awareness, attitudes, beliefs, understanding, and behaviors, which are considered by Allen et al. (2008) to be areas of “impact” for science education experiences. Data on knowledge gained during the lessons was collected using questions embedded within student lesson materials.

Data Analysis

Quantitative data (awareness, attitudes, beliefs, number of behaviors, and knowledge scores) was coded and analyzed in SPSS using descriptive statistics and any differences between the pre and post surveys were determined using nonparametric statistical tests, specifically the Wilcoxon Sign Rank test. Qualitative data (understanding, behaviors, and some knowledge items) were coded in Dedoose, a web application for mixed methods analysis, using a combination of in vivo (bottom up) coding and axial (top down) coding (Berg & Lune, 2012).
Evaluation Results

The evaluation results reported in Table 5.1 are from the summative evaluation of the curriculum. Of the seven classes and 110 students who participated in the evaluation, 24% were in fifth or sixth grade, and 76% were in eighth grade. More than half (53%) of students had not heard of microplastics before participating in the lessons. Selected evaluation results are highlighted below.

Table 5.1. Selected microplastics curriculum evaluation results

<table>
<thead>
<tr>
<th>Concept</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>• Post lessons, students scored 80% or above on every objective, except in surface area students scored 65%.</td>
</tr>
<tr>
<td>Behaviors</td>
<td>• After the lessons, students were able to list more behaviors to reduce microplastics in the ocean than listed previously. The mean number of behaviors listed per student increased from 3.52 to 3.83.</td>
</tr>
<tr>
<td></td>
<td>• Pre survey behaviors were focused on managing waste (recycling and not littering).</td>
</tr>
<tr>
<td></td>
<td>• Post survey behaviors were focused on managing consumption (buying non-plastic items or reducing their use of plastics).</td>
</tr>
<tr>
<td>Understanding</td>
<td>• After the lessons, students tended to include fewer misconceptions (the mean number of misconceptions per student decrease from 0.51 in the pre survey to 0.35 in the post survey) and more detailed explanations in their responses.</td>
</tr>
<tr>
<td></td>
<td>• Some students showed persistent misconceptions that all plastic floats and that microplastics kill all marine life.</td>
</tr>
<tr>
<td>Beliefs</td>
<td>• Students tended to believe they could make a difference in the microplastics issue both before and after the lessons.</td>
</tr>
<tr>
<td>Attitudes</td>
<td>After the lessons, students tended to:</td>
</tr>
<tr>
<td></td>
<td>• Be significantly more worried about the issue</td>
</tr>
<tr>
<td></td>
<td>• Think microplastics is a more challenging problem</td>
</tr>
<tr>
<td></td>
<td>• Be unsure about the impacts of microplastics on people</td>
</tr>
</tbody>
</table>

Overall, eighth grade students scored higher on knowledge questions (defining marine debris and microplastics, articulating the abundance of microplastics, and explaining how surface area changes when an object fragments) with the exception of
identifying sources of microplastics. Additionally, all students struggled with explaining how the total surface area changed as a piece of marine debris fragmented over time. The challenge was likely due to the sequence of math standards. Common Core State Standards do not include calculating the surface area of rectangular prisms until seventh grade. Another aspect of this struggle may have been misconceptions around mathematical formulas and physical objects. Introducing formulas early in teaching can lead students to rely on the formula and not make the connection between the formula and the physical area (Zacharos, 2006). This section of the curriculum is most appropriate for students who are already familiar with the concept of surface area and are able to calculate it.

The shifts in student misconceptions and types of behaviors suggest that the curriculum was able to get students thinking about the issue in a fairly broad and more accurate way, correcting some misconceptions. There are several opportunities for misconceptions to develop within the curriculum that are pointed out in the lesson plans. With more awareness and accurate knowledge of the microplastics issue, students might be able to develop innovative solutions for our future.

Generally, attitudes about the scope and severity of the microplastics issue and beliefs that students could influence the problem increased after participating in the curriculum. Students were more worried about the issue, but a sense of personal responsibility is important when combined with knowledge about solution-oriented behaviors. Self-efficacy was generally high in students, even before the lessons, indicating that even if students feel worried, they will feel that they can do something about it.

This middle school microplastics curriculum was developed and evaluated using both formative and summative evaluation techniques. Because the curriculum was evaluated in a rural, coastal school district in Oregon, the results cannot be generalized to communities outside this area. In this context, however, the microplastics curriculum was effective in raising awareness, knowledge, and feelings of personal responsibility.
among students as well as developing more specific understanding of microplastics. Students’ high self-efficacy can also be an opportunity to engage them in creating and implementing solutions in the classroom and beyond. The first lesson from this curriculum is outlined below, with images of the supporting student materials. The full curriculum is available online. A link is available in the resources section of this article.

**Lesson Plan Excerpt**

Table 5.2. Standards aligned with microplastics lesson 1

<table>
<thead>
<tr>
<th>NGSS</th>
<th>Ocean Literacy</th>
<th>Oregon Environmental Literacy Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ESS3.C: Human Impacts on Earth Systems</strong></td>
<td>Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth’s environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3)</td>
<td>1. Understand the physical and biological world, and our interdependent relationship with it</td>
</tr>
<tr>
<td><strong>Patterns</strong></td>
<td>Graphs, charts, and images can be used to identify patterns in data. (MS-ESS3-2)</td>
<td>1b. Structure, function and interconnected nature of human systems to the environment and sustainability, such as human choices about consumption, production, distribution and disposal of goods and services and their effect on the sustainability of earth’s natural, economic and social systems</td>
</tr>
</tbody>
</table>

**Enduring Understandings**

Everyone’s actions have an impact (both positive and negative) on the environment.
Objectives

- Students will define marine debris and microplastics
- Students will explain sources of microplastics

Time

One 90 minute lesson

Materials

- Two sealing jars for each group/pair
- Water (enough to fill each jar about half full)
- Liquid soap or face wash with microbeads
- Liquid soap or face wash with natural exfoliators
- Student notebook: Bags, Bottles, and Beads
- Sink
- Coffee filters
- Jar/bucket for microbead disposal

Set-up

- Divide students into groups of 2-3
- With two jars for each group, label half the jars “A” and the other half “B”
- Place about a tablespoon of soap in each jar
  - Soap with microbeads in jar “A”
  - Soap with natural exfoliators in jar “B”
- Have a disposal jar/bucket for microbead soap when the activity is over
Lesson Outline

1. Hook

**Say:** Look around the room and silently find as many plastic objects as you can in ten seconds... go!

Time students for 10 s., then have students share some of the objects they identified.

**Ask:** Raise your hand if you agree that there is a lot of plastic in this classroom? If you agree that we use a lot of plastic in our daily lives?

**Say:** We use plastic every day, and many of the plastics are single-use. They are designed to be thrown away after being used once. We might not realize which products have plastic, and we don’t always know what happens to them after they are thrown away.

2. Explore – “Soap suds and... plastic?”

**Say:** Some products with plastics might surprise you. First, we will talk a little about plastic itself, and then you will have a chance to investigate for yourself.

- Students will complete the guided notes on page 1 of their notebooks.

**Presentation** slides include the text from the notebook with the blanks filled in (also see the student example for guided notes answers)

**Say:** Polyethylene is the plastic most microbeads are made of, and you can identify products with microbeads by looking at the ingredients for polyethylene. Repeat after me, “polyethylene.”

**Hand out:** an “A” and “B” jar to each student group, don’t tell them which soap is which.

**Alternative Activity**
As an alternative to the first activity “soap suds and... plastic,” consider completing the challenge using just face wash with natural exfoliators.

- Have students observe and draw the particles, and then explain that some soaps used to have plastic instead of the natural material.

- Ask students to imagine those particles were plastic to get an idea of the number of microbeads that might enter the ocean from one product.

Emphasize that there are other sources of microplastics that enter waterways, including plastic fibers from clothing, and that microplastics are generated all over the world.

- Students read and follow the directions in their notebooks.

**Presentation** slides also have activity directions for reference.
Students first make observations of the two jars (color, texture, size and shape of particles, etc.)

- Students fill jars halfway with water, close it tightly, and shake the jars to dissolve the soap (there shouldn’t be any soap stuck to the bottom).
- Students write down what they observe and draw pictures in their notebooks of how the particles behave inside the soaps.
- Students answer the questions in their notebooks on page 2.

Figure 5.2. Example of student materials in the “soap suds and plastic” activity in lesson 1 of the curriculum

**Ask:** What did you notice that was different between the two jars? How did the particles in the soaps behave? Which one do you think has plastic in it? What evidence do you have?

Reveal the answer, that “A” has microplastics in it!

**MISCONCEPTION ALERT!** Plastic microbeads will float in the water, but not all microplastics float! Microplastics can be found at many depths, including the ocean floor. Before moving on to the next part of the lesson, clarify that while the plastic microbeads in the investigation floated, not ALL microplastics float in the ocean.

- Students read the “newspaper clipping” on page 2 of their notebook and answer the question.

**Discuss:** Why is the problem of microplastics not solved? Do you think this is a helpful law? Why or why not?
3. Debrief – “How do microplastics make it to the ocean?”

**Say:** One of the reasons the microplastics problem is not solved by this law is that there are many other ways microplastics get into the ocean.

**Presentation** slides show “two main sources of microplastics.” See student example for notes.

- Students will complete guided notes on page 3 of their notebooks

**Say:** There are two main ways that microplastics enter the ocean. One is directly as small pieces (show microplastics definition and have a student read it aloud). Plastics in toothpaste, face wash, and laundry lint can go directly into the ocean. Most microplastics are from larger plastic marine debris items that are fragmented once they get to the ocean (show marine debris definition and have a student read it aloud). Nurdles are small plastic pieces used in factories to make plastic products.

4. Practice – “Real researcher: Angel White”

**Say:** Now that we know about microplastics and where they come from, we are going to learn about a researcher who studies microplastics.

- Students will read “Real researcher: Angel White” on page 4 of the student notebook as an introduction to her data.

- Students will answer the questions about Angel’s data on page 5. See student example for correct responses. Answers are based on the data table and reading.

**Ask:** Why do you think scientists study microplastics in the ocean? What should scientists like Angel do with their results?

**Clean Up**

To keep microbeads from going down the sink drain, you can use a coffee filter to remove the microbeads from the soap. You can dry them and put them in a container to show the amount of plastic in the product!

**Success Story: Banning Personal Care Products with Microbeads**

Plastic microbeads in personal care products like face wash and toothpaste have been shown to enter drains and eventually the ocean, and have largely unknown consequences on the marine environment. After nine states banned the manufacture
and sale of products with microbeads, Congress passed the *Microbead-Free Waters Act of 2015*, banning the manufacture and sales of personal care products with plastic microbeads starting in 2017.

Because of this ban, personal care products with plastic microbeads will not be available to purchase beginning in 2017. The plastic from previously used products, however, is still in the ocean and microplastics are still a problem. Microbeads contribute a small part of the total microplastics in the ocean. Synthetic fibers from clothes, as well as the fragmentation of large plastic marine debris are important sources of plastic. Also, while products with plastic microbeads are banned in the US, there are many places around the world where microbeads are used. Microplastics is truly a global issue.

![Figure 5.3. Excerpt from student materials for lesson 1 of the Mitigating Microplastics curriculum](image-url)
Resources

Curriculum
- Mitigating Microplastics curriculum - [link to curriculum]

Marine Debris and Evaluation
- NOAA Marine Debris Program - http://marinedebris.noaa.gov/info/plastic.html
- Eriksen et al. (2014) study on the abundance of plastic marine debris - http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0111913

References


CONCLUSION

Curriculum Merit and Worth

This study evaluated the merit and worth of a microplastics curriculum that was developed by the researcher. In the context of the study, the curriculum was shown to have both merit, its value out of context, and worth, its value in context (Guba & Lincoln, 1981). The merit of the curriculum was based on the theoretical, accuracy, structural, and usability criteria listed in the Curriculum Merit Checklist (Appendix A). The worth was determined through the analysis of data collected while teaching the curriculum. Because the worth of a curriculum is only applicable within a particular context by definition, it is not possible to generalize the findings of this study. The results of this study however, may be indicative of larger trends that speak to the effectiveness of the curriculum. Three main conclusions about the effectiveness of the curriculum in this context can be made from the results of this study.

1. This curriculum allowed students to successfully meet learning objectives about the sources, definitions, abundance, and behaviors to reduce microplastics, but not surface area.

2. This curriculum allowed students to demonstrate increased detail and accuracy in their understanding of the issue of microplastics.

3. This curriculum is appropriate as additional instruction on the aligned learning standards (not the only instruction and not the first instruction in surface area).

Multiple impacts of the curriculum were recorded within the scope of this study, however there is a potential for the impact of the curriculum to be broader.
**Broad Curriculum Impacts**

This middle school curriculum on microplastics has the opportunity to engage and inspire students and their communities beyond the scope of the classroom. Teaching this microplastics curriculum in a middle school has the potential to raise knowledge and awareness of the issue, raise science career awareness, and elevate the issue of microplastics as a problem requiring action. All of these potential impacts have implications for the larger issue of microplastics and the health of our ocean.

When students increase their awareness, knowledge, and understanding of microplastics, there is potential to inspire conversations with each other as well as with their family and community members. As a result, microplastics-focused curriculum in school can lead to increased learning in the adults in the community. Duvall and Zint (2007) identified several strategies that facilitate this type of learning, some of which are included in the curriculum, including students taking action to address environmental problems and working on local issues. Changes in behavior, while not addressed in this curriculum evaluation, may also be influenced by increased knowledge and awareness of the issue. Following through on behaviors like the ones identified by students in this evaluation would decrease microplastics in the ocean, addressing the ultimate goal of the curriculum. Additionally, increasing the awareness, knowledge, and feelings of responsibility in middle school students influences the educators, voters, consumers, decision-makers, and managers of the present and future.

Including researchers and their stories in the lessons along with their data was a more subtle, but also potentially powerful component of the curriculum. Although not specifically evaluated, incorporating researcher profiles and photos along with their data adds career awareness to the curriculum. Talking with students about what marine researchers do and what they really look like can help students see themselves as researchers and know more about what types of careers are available. More interest in marine science careers has the potential to improve the field in the future.
The development of this microplastics curriculum also speaks to the importance of the issue. By writing and disseminating this curriculum, microplastics is supported as an important issue. The microplastics issue may be addressed through education, outreach, research, and policy to improve the situation, and it is critical for people in these areas to believe that the issue is serious for this to happen.

**Limitations and Future Directions**

To determine the effectiveness of the curriculum, data on students’ knowledge, understanding, beliefs, attitudes, and awareness was collected. Students’ knowledge of behaviors to reduce microplastics was also collected, but the study did not collect data on students’ behaviors. While the survey and student materials provided a picture of how students were thinking about the issue and what was changing or not changing over the three lessons, there were additional impacts of the curriculum that were not captured in the evaluation.

Ideas about the purpose and methods of evaluation have changed over time. Michael Scriven’s highly influential model, for example, emphasizes the importance of qualitative data and unexpected outcomes. The CIPP model used in this curriculum evaluation also strives to be comprehensive and address unexpected outcomes. In this evaluation, however, there were several possibly important impacts of the curriculum that were only captured in fieldnotes. More comprehensive and robust methods for collecting data on these impacts would improve future evaluations. These potential impacts include the spread of knowledge and awareness outside the classroom and teacher interactions with the curriculum.

**Spread of Knowledge Outside the Classroom**

One of these potential impacts was the dissemination of knowledge and awareness outside of the classroom. This was discussed earlier as a potentially important mechanism to create change in a community, and is therefore an impact
worth looking into more closely. There was evidence that knowledge was being transmitted beyond the classroom from a conversation the researcher had with one of the parents of a student participant.

I just spoke with one of the parents of one of the kids who participated in the lessons. The parent had called to talk to us (the research team) about the child’s disability. I told her that we were done with the lessons, and I thought they went well and I enjoyed it. The parent said (when I asked if the child had said anything about the lessons) that the child had a piece of plastic that he took to school today to show the class. The child had found the piece of plastic on the beach and wanted to take it to school because it was made of microplastics. The parent also said that the child told her that their toothpaste and face wash had plastic in it. I asked if he had told the parent how to check to see if it has plastic and she said something about polyurethane. I said, polyethylene. She said the child is very literal, so if I said toothpaste has plastic in it, he won’t want to brush his teeth for a week. I apologized, but she wasn’t worried or upset.

- Researcher’s fieldnotes, December 14, 2015

Even though this represents one student’s experience, there is evidence of the student communicating specific, scientific information to the parent. The student was also making connections to his life at home, wanting to share it with his classmates. Another example of the spread of knowledge took place during the teaching of the first lesson.

One of the students also told me that she knew what the answer to the microbead activity was. Another student had told her earlier in the day. This means they were talking to each other about the lesson outside of class.

- Researcher’s fieldnotes, January 8, 2016

This is an example of the curriculum being discussed outside the classroom. These types of impacts have the potential to be powerful and should be included and measured more comprehensively in future studies.
Teacher Interactions

Another salient impact was the interactions between teachers and students during the lessons. This evaluation did not address teacher influence beyond what might be implied by their attitudes, beliefs, awareness, and understanding. The researcher taught all the lessons for consistency and because the focus of the evaluation was to determine the effectiveness of the curriculum. The teachers’ interactions with the curriculum and their interactions with students during teaching would be a different, but important study to investigate the ways in which the curriculum is modified and how effective it is in different classrooms with different teachers.

One kid was struggling with the difference between no plastic and organic. She told me that natural soap or shampoo that was organic didn’t have sulfates, so it must not have plastic. I heard her talking through this with the teacher a little later, the teacher pointing out that natural toothpaste, for example, still comes in a plastic tube.

- Researcher’s fieldnotes, December 11, 2015

This example describes a teacher demonstrating knowledge of the differences between the concepts of plastic-free and organic and also addressing a student’s misconceptions about these concepts. Studying the curriculum in this way ceases to become an evaluation of the curriculum itself and instead allows the researcher to ask questions about how teachers’ attitudes, beliefs, knowledge, and understanding might influence their teaching of this microplastics curriculum.

Classroom Discussion

In addition to these potential impacts of the curriculum, there was additional data that could not have been feasibly collected in this evaluation. One source of data is student discussions. Student discussions in small groups or as a whole class could possibly offer rich data on the students’ concept development, ways in which students make the curriculum personally relevant, and ideas that are particularly salient to them.
While there is no data about student discussion from this evaluation, this could be a source of rich data if the resources are available to collect it. This type of data is beyond the scope of a curriculum evaluation such as this one, but could offer detailed information for a more in-depth study.

**Differences Between Classes**

Differences exist between grades, teachers, schools, and geographic regions. While this curriculum was designed to be relevant to students and teachers in any region of the country, this evaluation focused on rural, coastal Oregon. Evaluating this curriculum in an inland area, for example, would most likely attain different results. Evaluating this curriculum in the same area but a different school or with a different teacher would also be likely to find different results. The important point, however, is that while all students and classes are different and come to the lessons with different prior knowledge and experiences, there are opportunities in the curriculum to make personal connections. Everyone lives in a watershed.

Collecting evaluation data on this curriculum and comparing the awareness, attitudes, beliefs, knowledge, and understanding of students and teachers in inland areas would offer a complement to this evaluation, and give a richer view of its worth. This is an extension of this evaluation, however, and is not necessary to establish the worth of the microplastics curriculum in its current context.

**Recommendations**

The results from the evaluation of this curriculum demonstrate that it is possible to increase the knowledge, understanding, and concern of middle school students in their classroom through effective curriculum. While each class is different and demands special considerations, there are general concerns and highlights from this curriculum that may help educators developing curriculum, educators implementing this curriculum, and researchers using this curriculum or thinking about similar projects.
Future curriculum development can draw on the methods and instruments used in the needs assessment (Chapter 2). The Curriculum Merit Checklist (Appendix A) can serve as a guide for developing curriculum that has merit, and the process of reviewing existing curriculum on a particular topic can reveal gaps that a new curriculum can address. Below are recommendations for using the Curriculum Merit Checklist tool and creating curriculum with merit. These apply to curriculum in any subject area and in both formal classroom settings and informal out-of-school settings:

- **A meritorious curriculum is grounded in learning theory.** Learning experiences within a curriculum should be explicitly designed to guide students through the learning cycle, address multiple learning styles, and engage students’ minds. Opportunities for metacognition was demonstrated to be a weakness in marine debris curriculum. This aspect of curriculum is important for students to monitor their own learning and offers an opportunity for future curriculum to address.

- **Assessment is important.** Including both formative and summative assessments within the curriculum helps teachers check for student misconceptions and better guide their learning.

- **Be clear and explicit in the structure of the curriculum.** Clearly written learning objectives that are aligned to relevant standards are a good starting place to review or build a lesson. It is also important that the teacher be able to quickly and accurately read the lesson plans.

- **Include substantial teacher guidance in the lesson plan.** Giving teachers enough structure so that they can follow the lesson exactly can help teachers teach the content more accurately. For example, scripting important parts of the lesson without using an overwhelming amount of text can give teachers an idea of how the author is thinking about the content and which points are most important.

This evaluation also provides insights for educators interested in implementing the microplastics curriculum. There were multiple points in the summative evaluation where student misconceptions and opportunities for improvement were identified. For example, revising the curriculum to include a section focused on the impacts microplastics have on people stemmed from students’ apparent confusion on this topic. Although the curriculum has been revised to clarify some of the identified misconceptions that surfaced during the evaluation, every classroom is different and
teachers should be aware of the ways in which their specific classes are understanding the lesson concepts.

The summative evaluation also revealed broader considerations when implementing this curriculum:

- **Accuracy is important.** Students incorporated vocabulary and facts directly from the curriculum into their knowledge and understanding of the topic. Accurate information and accurate instructor knowledge are important to changing students’ ideas about microplastics and how the issue might be effectively addressed through their own actions.

- **For a rich understanding, this curriculum should not be the only time students are taught the standards or the topic of marine debris.** The curriculum is a part of the process of building understanding, which takes time and repetition. Include all the pieces of the curriculum and have students complete a local, concrete project.

- **Build on students’ existing beliefs and attitudes.** Students showed high self-efficacy around this global microplastics issue. This is an opportunity to provide the knowledge and resources for students to take action.

In addition to educators, researchers have an important role to play in the development, evaluation, and dissemination of science curriculum. The scientific research included in the microplastics curriculum enhanced the opportunities for real-world problem solving, engagement, and scientific accuracy, which are all criteria included in the Curriculum Merit Checklist (Appendix A). Researchers are in a position to share new knowledge with students who may not have prior knowledge on the topic or are not aware of a problem, microplastics in this case. The following list offers recommendations for researchers:

- **It is important to share your data and stories.** Students were able to use raw data to draw conclusions and discuss its implications.

- **Make your research relevant to the audience.** Students most often identified personal care products, and toothpaste in particular, as sources of microplastics. Students were familiar with this product and had a personal connection to it.

- **Give accurate information and explain it.** Students had misconceptions about the “Pacific garbage patch” and how plastic fragments into smaller and smaller
pieces. Using accurate terms and explanations instead of generalizations will increase students’ knowledge of these ideas and decrease misconceptions. Students were able to incorporate the scientific terms and ideas used in the curriculum.

- **Work with educators to increase knowledge and awareness in young people.** Sharing stories and data, talking with students, and getting students involved in research can influence students’ awareness, knowledge, and understanding of an issue like microplastics.

Continuing to understand the issue of microplastics as well as how people think about it and actions they take will help develop ways to reduce the amount of microplastics in the ocean. This curriculum and evaluation aimed to achieve this through the implementation of an effective middle school microplastics curriculum. And with the help of middle school students, who knows what solutions the future will hold.
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NJ Code § 58.


Wisc. Code § 299.50.


# APPENDIX A. CURRICULUM MERIT CHECKLIST

## Checklist

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<th>Curriculum Information</th>
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</tr>
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<tr>
<td><strong>Learning cycle:</strong></td>
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<tr>
<td>Problem-centered</td>
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<tr>
<td>□ Use of real-world problem solving</td>
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</tr>
<tr>
<td>□ Activation of prior knowledge</td>
</tr>
<tr>
<td>Demonstration</td>
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<tr>
<td>□ Learning objectives are demonstrated instead of told as information</td>
</tr>
<tr>
<td>□ Learner guidance is built into the experience</td>
</tr>
<tr>
<td>Application</td>
</tr>
<tr>
<td>□ Practice and assessment are aligned to learning objectives</td>
</tr>
<tr>
<td>□ Problems are scaffolded</td>
</tr>
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**NOTES:**
**Addresses multiple learning styles**
- [ ] Verbal
- [ ] Visual
- [ ] Kinesthetic
- [ ] Collaborative

**NOTES:**

**Developmentally appropriate**
- [ ] Developmentally appropriate

**NOTES:**

**Engagement**
- [ ] Contains a hook
- [ ] Minds on
- [ ] Metacognitive
- [ ] Includes several levels of questioning (scaffolded to higher-order thinking)
- [ ] Hands on
- [ ] Relevant to students

**NOTES:**

**Scientific Accuracy**
- [ ] Content is scientifically accurate
- [ ] Activities are aligned to scientific content

**NOTES:**

**Structural Components**

**Objectives**
- [ ] Clearly written
- [ ] Outcomes-oriented
- [ ] Aligned to standards
  - Standards:

**NOTES:**
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<th>Content</th>
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Curriculum Merit Checklist Glossary

**Activation of prior knowledge**
Students begin any learning experiences with prior knowledge. Activating prior knowledge, or background knowledge, allows teachers to address misconceptions, build on existing knowledge with new ideas, and help students make connections and change their thinking. This activation step is one of Merrill’s first principles (2002).

**Aligned to standards**
There are several sets of standards used to align lessons. Many states have standards specific to particular fields or topics. The following are some of the standards used nationally.

- Common Core State Standards (Common Core State Standards Initiative, 2010) – Common Core State Standards are K-12 academic standards in math and English language arts (ELA).
- Next Generation Science Standards (National Research Council, National Science Teachers Association, American Association for the Advancement of Science, & Achieve, 2013) – The Next Generation Science Standards (NGSS) are K-12 science standards written within a framework developed by the National Research Council.
- Ocean Literacy Standards (Ocean Literacy Network, 2010) – Ocean Literacy standards were developed by scientists and science educators and include seven ocean principles with more specific standards under each principle. Ocean Literacy Principles cover grades K-12.

**Assessment criteria**
Assessment criteria describe what students must do to meet the learning objective. Often, assessment criteria are presented as a rubric. Rubrics are particularly useful in assessing real-world tasks (University of Central Florida, 2014).

**Authentic assessment**
Authentic assessments are real. They represent the complexity of problem solving that people encounter outside the classroom. Grant Wiggins (1993) describes one of the characteristics of authentic assessment as “engaging and worthy problems or questions of importance, in which students must use knowledge to fashion performances effectively and creatively. The tasks are either replicas of or analogous to the kinds of problems faced by adult citizens and consumers or professionals in the field” (p. 206).
Developmentally appropriate
Curriculum that is developmentally appropriate includes content that is age appropriate (cognitively as well as emotionally) and strategies that are tailored to the age of the students. Curriculum should have texts at accessible reading levels for the age group.

Differentiated
Differentiated instruction addresses the individual needs of students. Carol Ann Tomlinson (2013) defines differentiated instruction as a way of “addressing student differences in readiness, interest, and learning profile, with the goal of maximizing the capacity of each learner” (p. 287).

Formative assessment
Formative assessment occurs throughout the curriculum. Formative assessments range from checking students’ understanding during a lesson to a more formal quiz that tells the educator what students know (West Virginia Department of Education, n.d.). The information collected by formative assessments can help the educator address misunderstandings, plan more purposefully for future lessons, and reteach concepts as needed.

Hands-on
Hands-on lessons engage students with physical materials that allow them to explore or demonstrate concepts. Conducting an experiment, using manipulatives, or exploring a physical object are examples of hands-on activities (Northern Illinois University, n.d.).

Higher-order thinking
Higher-order thinking is based on Bloom’s taxonomy (1956). This classification system moves from knowledge up to evaluation. Skills beyond knowledge and higher on the pyramid diagram are considered “higher-order thinking skills.” The taxonomy was updated in 2001 (Figure A.1) to make it more relevant for modern teaching and learning (Anderson & Krathwohl, 2001).
Hook
The hook in a lesson plan is the first activity that engages students and gets them invested in the rest of the learning experience. An effective hook activity is important because it helps students understand why a topic is important and builds interest. A hook can be puzzle, discrepant event, demonstration, or mystery related to the essential question of the lesson (Wiggins & McTighe, 2005).

Learning cycle
David Merrill’s (2002) model of the five first principles of instruction is based on a review of learning models and theories. The principles include (1) engaging students in real-world problems solving, (2) activating prior knowledge, (3) demonstrating knowledge, (4) applying knowledge, and (5) facilitating students’ integration of the new knowledge into their thinking. These five principles are described as separate terms in this checklist.

Learning objectives
Learning objectives are specific statements of what students should be able to do at the end of a learning experience. Anderson and Krathwohl (2001) describe objectives as containing a statement of both the cognitive process and content to be learned.
Learning styles

Learning styles are learner preferences for a certain type of learning environment (Romanelli, Bird, & Ryan, 2009). There is debate in the education literature about whether or not learning styles are effective (Pashler, McDaniel, Rohrer, & Bjork, 2008). In this checklist, learning style refers to the acknowledgement of different learner preferences and the merit of using various modes of instruction.

Metacognitive

Lessons that have metacognitive components allow students to reflect on how they are thinking about concepts and the process of learning (Vanderbilt, 2016). Metacognition can be promoted in lessons through various strategies including connecting concepts to students’ prior knowledge and explaining how they developed responses to questions (Teaching Excellence in Adult Literacy, n.d.).

Minds-on

Minds-on learning is associated with inquiry learning. Inquiry allows students to ask questions and analyze data to make conclusions (Bell, Smetana, & Binns, 2005). Inquiry is not just applicable in science classrooms.

Outcomes-oriented

Curriculum that is outcomes-oriented is based on the learning outcomes, not the activities that make up the lessons. This strategy for designing learning experiences stems from Wiggins & McTighe’s (2005) backwards design process.

Real-world problem solving

Real-world problem solving involves engaging students in true, meaningful questions about their world. It is related to experiential learning, which allows students to apply their knowledge to a new, real situation (Nagel, 1999).

Scaffolding

Scaffolding is the process of using temporary support structures to help learners in their tasks (IRIS Center for Training Enhancements, 2005). The concept can apply to any learning task and involves the teacher gradually releasing responsibility of the task to the student.

Summative assessment

Summative assessments measure what students have learned at the end of teaching. The goal of summative assessments is not to inform further instruction (this is formative assessment), but to measure an end point. Examples of summative assessments include final exams, final papers, or capstone projects (Garrison & Ehringhaus, 2009).
APPENDIX B. EVALUATION INSTRUMENT DESIGN

This Appendix addresses the process of designing the instruments used in this microplastics curriculum evaluation. The concepts measured, types of questions, and theoretical foundation are discussed for each instrument. A pre and post survey design was used to measure any changes in student or teacher awareness, attitudes, beliefs, behaviors, knowledge, or understanding after participating in the curriculum.

Student Pre Survey

The student pre survey was designed to assess students’ awareness, attitudes, beliefs, behaviors, and understanding of microplastics. Allen et al. (2008) identifies these concepts as “impact categories,” or categories commonly influenced by science education experiences. Awareness, knowledge, and understanding are combined into Allen et al.’s “knowledge” category. This curriculum evaluation separated the knowledge category into three distinct concepts. Awareness was assessed in the evaluation by asking participants to report whether or not they were previously knowledgeable of microplastics. Awareness was measured in the pre survey with a single-item (Vaske, 2008) close-ended (Salant & Dillman, 1994) question. Knowledge was not assessed on the pre and post surveys, but instead with questions embedded within the curriculum.

Understanding was assessed as a student’s ability to transfer and connect knowledge. Wiggins & McTighe (2005) explain understanding as not only a body of facts, but also the meaning behind them, a working theory that connects them, and the ability to transfer that theory to new situations. Students’ understanding of microplastics was assessed using researcher-designed probes. These probes were based on Keeley’s (2009) series of understanding probes in Uncovering Student Ideas in Science. The purpose of Keeley’s books is to help teachers collect formative assessment data to inform their instruction. Most probes present a scenario and ask students to choose a possible explanation or explanations, then elaborate on their thinking.
Another impact category addressed in this evaluation is attitudes. Although combined as “attitudes” in Allen et al., this evaluation differentiates between beliefs and attitudes. Beliefs are centered around the concept of self-efficacy, which Bandura (1993) describes as people’s beliefs about their ability to influence themselves and the world around them. Attitudes are “long-term perspectives” (Allen et al., 2008, p. 22) about a topic and remain relatively stable over time. To account for the complex nature of attitudes and beliefs, they were measured using multiple-item, (Vaske, 2008) scaled (Salant & Dillman, 1994) questions. Questions were asked on a five-point scale from 1 “strongly disagree” to 5 “strongly agree.”

The survey questions were arranged to maximize flow and scaffolded beginning with structured opinion questions such as awareness and attitudes, to questions that might be perceived as more challenging and content-based, such as understanding. Images were used wherever possible to promote engagement and understanding.

**Student Post Survey**

The student post survey assessed the same concepts as the student pre survey: attitudes, beliefs, behaviors, and understanding. Awareness was not assessed on the post survey because it was assumed that all students taking the survey immediately after finishing the curriculum would be aware of microplastics. Attitude and behavior questions were identical to the pre survey and are presented in the same order. The behavior question also included an additional frequency column asking students to report whether or not they planned to engage in the listed activity in the future. Understanding was assessed using the same type of probe as in the pre survey, but using a different scenario.
Teacher Surveys

The teacher pre survey was identical to student pre survey. The only difference was in the presentation of the questions. Teacher surveys had a number in the top right-hand corner of their survey to identify them, whereas student surveys had a space to write their birthdays. Additionally, teachers did not have an image on their understanding question. These changes helped the researcher identify the teacher surveys, and make a distinction between materials the students and teachers were getting during the study.

Similarly, teacher post surveys had all the same questions as the student post surveys with an identifying number and no image. Teacher post surveys also included an extra section at the end. This section asked for feedback on the lessons using scaled questions (Salant & Dillman, 1994) and an open-ended comments section at the end of the survey. This section was intended to collect data on overall impressions and general attitudes about the curriculum after the teacher had seen it taught by the researcher.

Student Knowledge Questions

Knowledge was defined as content-related facts explicitly taught in the curriculum. It was operationalized in this evaluation through a series of content questions embedded within the student lesson materials. Knowledge questions were a mixture of multiple choice and open-ended questions.

Focus Group

The focus group was designed to elicit critical feedback on the written microplastics curriculum and inform revisions to the curriculum. The focus group guide was designed based on guidelines from Ernst, Monroe, & Simmons (2009) and Berg & Lune (2012). The focus group was held at Hatfield Marine Science Center on a weekday evening because the facility had been used for teacher activities such as professional development in the past. The focus group was facilitated by a recent alumna graduate
student of Oregon State University. The researcher was present in the room throughout the focus group in order to provide clarification for technical questions or concerns, but did not participate in the discussion. The researcher took notes and avoided engaging with the group unless asked a direct question. The entire focus group was audio recorded.
APPENDIX C. EVALUATION INSTRUMENTS

Student Pre Survey

Microplastics in the Ocean

DIRECTIONS: Read each question carefully and answer honestly. The questions ask how you think and feel, so there are no right or wrong answers.

Definition:
Marine debris is any trash or other solid material that ends up in the ocean or the great lakes without a purpose. Microplastics are plastic marine debris pieces in the ocean that are smaller than 5 mm.

1. Have you heard of microplastics before today?
   □ Yes  □ No

2. What is one possible problem with microplastics?

________________________________________________________________________

Read each statement and show how much you agree or disagree by circling one number for each statement.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. I do not need to worry about microplastics.</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4. I can make a difference in the amount of microplastics in the ocean.</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5. My actions affect the amount of microplastics in the ocean.</td>
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<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6. Microplastics cause a problem for people.</td>
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<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7. Microplastics cause a problem in the ocean all over the world.</td>
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<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>8. Microplastics is an easy problem to solve.</td>
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</tr>
<tr>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
11. List actions someone **could** take to reduce the amount of microplastics in the ocean. Then, **circle** the number that shows how often you do each action.

<table>
<thead>
<tr>
<th>Action</th>
<th>I don't do this</th>
<th>I do this rarely</th>
<th>I do this sometimes</th>
<th>I do this every time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
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<tr>
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</table>

12. Six friends were spending the afternoon at the beach. Sandra and Maritza were making a sand castle together, when Sandra noticed that there were tiny pieces of colorful plastic in the sand. Each of the friends had a different idea about how the plastic ended up in the sand.

Maritza said, “I think the plastic is naturally part of the sand.”

Jenny: “I think the little plastic pieces were spilled from a truck.”

Jamie: “I think the plastic came from big pieces of plastic trash that broke down into small pieces.”

Sandra: “I think they are pieces of confetti from a beach birthday party.”

Robert: “I don’t think those are plastics. I think those are colorful grains of sand.”

Malik: “I think the plastic came from rocks breaking down when waves crash on the beach.”

Which person do you most agree with? ____________________________

Explain your thinking about where the small plastic pieces on the beach came from.

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

*Thank you!*
Student Post Survey

Microplastics in the Ocean

DIRECTIONS: Read each question carefully and answer honestly. The questions ask how you think and feel, so there are no right or wrong answers.

Definition:
Marine debris is any trash or other solid material that ends up in the ocean or the great lakes without a purpose. Microplastics are plastic marine debris pieces in the ocean that are smaller than 5 mm.

1. What is one possible problem with microplastics that was not mentioned in this lesson?

__________________________________________________________________________

Read each statement and show how much you agree or disagree by circling one number for each statement.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>I do not need to worry about microplastics.</td>
<td>1</td>
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<td>3</td>
<td>4</td>
</tr>
<tr>
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<td>I can make a difference in the amount of microplastics in the ocean.</td>
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<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4.</td>
<td>My actions affect the amount of microplastics in the ocean.</td>
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<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5.</td>
<td>Microplastics cause a problem for people.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6.</td>
<td>Microplastics cause a problem in the ocean all over the world.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7.</td>
<td>Microplastics is an easy problem to solve.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>8.</td>
<td>My behaviors do not make a difference in the amount of microplastics in the ocean.</td>
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<td>1</td>
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</tbody>
</table>
10. List actions someone **could** take to reduce the amount of microplastics in the ocean. Then, **circle** the number that shows how often you do each action and check if you plan to do the action in the future.

<table>
<thead>
<tr>
<th>Action</th>
<th>I don't do this</th>
<th>I do this rarely</th>
<th>I do this sometimes</th>
<th>I do this every time</th>
<th>I plan to do this in the future</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>□</td>
</tr>
</tbody>
</table>

11. Courtney went on a field trip with her 7th grade class. They went on a boat in the ocean to collect plankton for the class to look at under a microscope. They brought a net to catch the plankton. Courtney’s group put the net in the water and then pulled it up. When they looked closely at the water they had collected, they saw small, colorful pieces floating in the water. Her group had several ideas about the small pieces.

Courtney: “I think those pieces are phytoplankton because they are floating at the surface of the water.”

Jonathan: “I think those pieces are plastic pieces that floated up from the bottom of the ocean.”

Tricia: “I think those pieces are little animals that live in the water.”

Samara: “I think those pieces are plastics that were carried here by the wind.”

Daniel: “I think those are plastic pieces that washed into the ocean from land.”

Which student do you most agree with? ________________________________

Explain your thinking about what these pieces are and where they came from.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

*Thank you!*
Student Knowledge Questions

Bags, Bottles, and Beads: Sources of Microplastics Micro-assessment

Objective: Define marine debris and microplastics
1. What is marine debris?

2. If all of the following items were found floating in the ocean, which would be described as microplastics?
   a. Plastic bag
   b. Seed
   c. Bottle cap
   d. Plastic nurdles

   Explain your answer.

Objective: Explain sources of microplastics
3. What are two ways microplastics can get into the ocean?
   a. ____________________________
   b. ____________________________

   List two possible sources of microplastics.
4. a. ____________________________
   b. ____________________________

5. What is one possible source of microplastics in your classroom now?

6. Circle the statement that accurately describes the abundance of microplastics.
   a. Microplastics are only found near beaches
   b. Microplastics are found all over the world
   c. Microplastics are only found in the middle of the ocean
   d. Microplastics are found only in rivers

   Explain your answer.

7. What do you think happens to microplastics in the ocean?
Small Plastics, Big Problem Micro-assessment

Objective: Articulate at least two impacts of microplastics on the marine environment
1. List two impacts of microplastics on the ocean and indicate if they are positive or negative impacts.

<table>
<thead>
<tr>
<th>Impact</th>
<th>Positive or Negative?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
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<td>2.</td>
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</table>

Objective: Describe how surface area changes when an object fragments.
2. What happens to the total surface area of an object when it fragments into smaller pieces?
__________________________________________________________________________________

3. Can more microbes live on marine debris when it is whole, or when it is broken into small pieces? Why is this true?
__________________________________________________________________________________
__________________________________________________________________________________

2. When more surface area is exposed to water, there is more space for toxins or microbes to attach. Does marine debris hold more toxins when it is big or when it is fragmented into microplastics? Why?
__________________________________________________________________________________
Teacher Pre Survey

Microplastics in the Ocean

Please answer the following questions honestly.

**Definition:**
Marine debris is any trash or other solid material that ends up in the ocean or the great lakes without a purpose. Microplastics are plastic marine debris pieces in the ocean that are smaller than 5 mm.

1. Have you heard of microplastics before today?  
   - [ ] Yes  
   - [ ] No

2. What is one possible problem with microplastics?

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Read each statement and show how much you agree or disagree by circling one number for each statement.

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________________________________________________________________________

________________________________________________________________________

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Thank you!
## Teacher Post Survey

Microplastics in the Ocean

*Please answer the following questions honestly.*

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<thead>
<tr>
<th>Definition: Marine debris is any trash or other solid material that ends up in the ocean or the great lakes without a purpose. Microplastics are plastic marine debris pieces in the ocean that are smaller than 5 mm.</th>
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1. What is one possible problem with microplastics that was not mentioned in this lesson?

---

Read each statement and show how much you agree or disagree by *circling* one number for each statement.

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<tr>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>8. My behaviors do not make a difference in the amount of microplastics in the ocean.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>9. Microplastics cause a problem for life in the ocean.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
10. List actions someone could take to reduce the amount of microplastics in the ocean. Then, circle the number that shows how often you do each action.

<table>
<thead>
<tr>
<th>Action</th>
<th>I don't do this</th>
<th>I do this rarely</th>
<th>I do this sometimes</th>
<th>I do this every time</th>
<th>I plan to do this in the future</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>□</td>
</tr>
</tbody>
</table>

11. Courtney went on a field trip with her 7th grade class. They went on a boat in the ocean to collect plankton for the class to look at under a microscope. They brought a net to catch the plankton. Courtney’s group put the net in the water and then pulled it up. When they looked closely at the water they had collected, they saw small, colorful pieces floating in the water. Her group had several ideas about the small pieces.

Courtney: “I think those pieces are phytoplankton because they are floating at the surface of the water.”

Jonathan: “I think those pieces are plastic pieces that floated up from the bottom of the ocean.”

Tricia: “I think those pieces are little animals that live in the water.”

Samara: “I think those pieces are plastics that were carried here by the wind.”

Daniel: “I think those are plastic pieces that washed into the ocean from land.”

Which student do you most agree with? ________________________________

Explain your thinking about what these pieces are and where they came from.

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

Please indicate how strongly you agree or disagree with each statement by circling one number for each.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. The microplastics lessons fit well into my existing curriculum</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>13. I am interested in teaching this curriculum in my classroom</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>14. This curriculum is aligned to the standards for my grade level</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>15. The curriculum addresses an important topic</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>16. I would use this curriculum</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

17. Do you have any additional comments about the curriculum?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Thank you!
Focus Group Guide

Microplastics Curriculum Evaluation

Question Guide for Teacher Focus Group

This is a guide for the focus group facilitator. The questions are meant to be posed to the group, and then followed up with additional questions and conversation from the participants. Participants are 6-8 grade teachers.

NOTES:
Teachers will have already received (via email)
- The written curriculum document
- A list of the focus group questions
- Research consent document

TIME: 90 minutes

AGENDA AND QUESTIONS:
1. Explanation of research and expectations for the focus group session
2. Introductions – Please tell us your name, a little bit about how you have been teaching marine debris in your classroom.
3. Which NGSS standards are you currently teaching if you are using them?
   a. Do you feel that these lessons support the standards you are teaching? How could they be more supportive?
4. Do you have any questions about the lessons?
   a. Did anyone else have a different question?
5. What about the teacher directions were hard to understand? Easy to understand?
   a. Can you explain?
   b. Did anyone have a different experience reading the lessons?
6. Do you think the curriculum addresses relevant topics for middle school?
   a. Can you explain?
   b. Does anyone have a different idea?
   c. What would make it more relevant?
7. Do you think the curriculum is appropriate for middle school kids? Explain.
   a. Does anyone have a different idea? Explain.
8. How do you see using this curriculum in your classroom?
9. What do you think I could change to encourage teacher use?
10. What in this curriculum do you think would be engaging for students?
11. What in this curriculum do you think would not be engaging for students?
12. Do you have any other comments or suggestions about the curriculum?

13. Thank you!
APPENDIX D. CODE BOOK

This code book includes coding methods for the pre survey, post survey, and student notebook responses. The questions are grouped by instrument and therefore do not appear in the same order that respondents saw them and the item numbers do not correspond to items on the survey or in the student notebooks.

Pre and Post Survey Codes

The following 8 survey items were presented on a 5-point scale from strongly disagree (1) to strongly agree (5). Codes were recorded as the actual number response. Indicated items were reverse coded. Items where respondents circled more than one number were coded as “no response.”

1. I do not need to worry about microplastics. (reverse coded)
2. I can make a difference in the amount of microplastics in the ocean.
3. My actions affect the amount of microplastics in the ocean.
5. Microplastics cause a problem everywhere.
6. Microplastics is an easy problem to solve. (reverse coded)
7. My behaviors do not make a difference in the amount of microplastics in the ocean. (reverse coded)
8. Microplastics cause a problem for life in the ocean.

9. List actions someone could take to reduce the amount of microplastics in the ocean. Then, circle the number that shows how often you do each action.

This item has multiple responses:

- The number of behaviors listed was recorded for each respondent.
- Frequency of each action was coded as the number indicated by each respondent.
- A combination of axial (top down) coding and in vivo (bottom up) coding was used. The codes used for this item included:
  - Collective action
  - Individual consumption
  - Waste – preventive
  - Waste - reactive
Pre Survey Codes

10. Have you heard of microplastics before today?
   - Yes (1)
   - No (0)

11. What is one possible problem with microplastics?
   - This question was coded to identify common problems perceived by the students and teachers in the study.
   - After initial analysis of this item, it was determined not to add substantially to the study and was not coded further.

12. Six friends were spending the afternoon at the beach. Sandra and Maritza were making a sand castle together, when Sandra noticed that there were tiny pieces of colorful plastic in the sand. Each of the friends had a different idea about how the plastic ended up in the sand.

   Maritza said, “I think the plastic is naturally part of the sand.”
   Jenny: “I think the little plastic pieces were spilled from a truck.”
   Jamie: “I think the plastic came from big pieces of plastic trash that broke down into small pieces.”
   Sandra: “I think they are pieces of confetti from a beach birthday party.”
   Robert: “I don’t think those are plastics. I think those are colorful grains of sand.”
   Malik: “I think the plastic came from rocks breaking down when waves crash on the beach.”

Which person do you most agree with?
Explain your thinking about where the small plastic pieces on the beach came from.

   - This item was coded using axial (top down) coding. Codes were determined by the researcher and derived from the evaluation questions.
     - Misconceptions
     - Accurate scientific information
     - Specific information from the curriculum
   - The codes “misconceptions” and “specific information from the curriculum” were coded again using in vivo (bottom up) into the following topics:
     - Misconceptions
       - Sources (pre)
       - Mechanism (pre)
       - Impacts (pre)
• Specific information from the curriculum
  - Specific sources
  - Vocabulary (polyethylene, nurdles, fragment)
  - Size of microplastics
  - Pathway to the ocean

• Responses to this question were also scored using a rubric. The rubric was scored on three categories (misconceptions, explanation quality, and information from the curriculum) and had three levels: high (3), medium (2), and low (1). The rubric is below:

Table D.1 Understanding rubric

<table>
<thead>
<tr>
<th></th>
<th>High (3)</th>
<th>Medium (2)</th>
<th>Low (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misconceptions</td>
<td>• Does not describe misconceptions about marine debris and microplastics in explanations</td>
<td>• Uses few misconceptions about marine debris and microplastics but there is evidence of accurate conceptions also OR • Does not give enough content information to assess this concept</td>
<td>• Uses misconceptions about marine debris and microplastics in explanations</td>
</tr>
<tr>
<td>Explanation Quality</td>
<td>• Each statement is supported by at least one specific scientific detail</td>
<td>• Explanations are general or rely on personal experience that is not explained</td>
<td>• Explanations are not included or rely on “just knowing” or “making sense”</td>
</tr>
<tr>
<td>Information from curriculum (POST ONLY)</td>
<td>• Incorporates facts or vocabulary from the curriculum consistently • Uses facts or vocabulary correctly and appropriately</td>
<td>• Incorporates facts or vocabulary from the curriculum inconsistently • Uses of facts or vocabulary may be limited or not quite correct</td>
<td>• Does not incorporate facts or vocabulary from the curriculum • Uses facts or vocabulary incorrectly</td>
</tr>
</tbody>
</table>
13. What is one possible problem with microplastics that was not mentioned in this lesson?
- This item was coded using in vivo (bottom up) methods to identify common problems perceived by the students and teachers.
- After initial analysis of this item, it was determined not to add substantially to the study and was not coded further.

14. Courtney went on a field trip with her 7th grade class. They went on a boat in the ocean to collect plankton for the class to look at under a microscope. They brought a net to catch the plankton. Courtney’s group put the net in the water and then pulled it up. When they looked closely at the water they had collected, they saw small, colorful pieces floating in the water. Her group had several ideas about the small pieces.

Courtney: “I think those pieces are phytoplankton because they are floating at the surface of the water.”
Jonathan: “I think those pieces are plastic pieces that floated up from the bottom of the ocean.”
Tricia: “I think those pieces are little animals that live in the water.”
Samara: “I think those pieces are plastics that were carried here by the wind.”
Daniel: “I think those are plastic pieces that washed into the ocean from land.”

Which student do you most agree with?
Explain your thinking about what these pieces are and where they came from.

This item was coded in the same way and scored on the same rubric as item #12.
1. **What is marine debris?**
   - This item was coded numerically
     - Correct (1)
     - Incorrect (0)
   Correct answers included:
   - Marine debris originates from people
   - Marine debris is in the ocean

2. **If all of the following items were found floating in the ocean, which would be described as microplastics?**
   a. Plastic bag (1)
   b. Seed (2)
   c. Bottle cap (3)
   d. Plastic nurdles (4)
   e. Multiple responses (99)

*Explain your answer.*
- Explanations were coded using combination of axial (top down) coding and in vivo (bottom up) coding. Codes include:
  - Plastic
  - Size
- Responses that did not have a letter circled but clearly indicated in their explanation which answer they chose were included in the multiple choice section.
- After calculating the percentage of students who chose each answer or set of answers, the multiple choice answers were recoded as correct (1) or incorrect (0) in order to contribute to the overall knowledge score for each student.
  a. Plastic bag – incorrect (recoded as 0)
  b. Seed – incorrect (recoded as 0)
  c. Bottle cap – incorrect (recoded as 0)
  d. Plastic nurdles – correct (recoded as 1)
  e. Multiple responses – incorrect (recoded as invalid data)
3. List two possible sources of microplastics.
   - Correct (1)
   - Incorrect (0)
   Correct answers varied, and could have included any plastic item, or small microplastics and larger plastic items.

4. What is one possible source of microplastics in your classroom now?
   - Correct (1)
   - Incorrect (0)
   Correct answers included any plastic item that may have been in a classroom.

5. Circle the statement that accurately describes the abundance of microplastics.
   a. Microplastics are only found near beaches (1)
   b. Microplastics are found all over the world (2)
   c. Microplastics are only found in the middle of the ocean (3)
   d. Microplastics are found only in rivers (4)

Explain your answer.
   - Explanations were coded using a combination of in vivo and axial coding.
     Codes included:
     • Abundance – Where it is (root code)
       ▪ Everywhere
       ▪ Land
       ▪ Ocean
       ▪ Freshwater
     • Abundance – Why it’s there (root code)
       ▪ Global
       ▪ Currents
       ▪ Waste

   - After calculating the percentage of students who chose each answer or set of answers, the multiple choice answers were recoded as correct (1) or incorrect (0) to contribute to the overall knowledge score for each student.
     a. Microplastics are only found near beaches – incorrect (recoded as 0)
     b. Microplastics are found all over the world – correct (recoded as 1)
     c. Microplastics are only found in the middle of the ocean – incorrect (recoded as 0)
     d. Microplastics are found only in rivers – incorrect (recoded as 0)
6. When more surface area is exposed to water, there is more space for toxins or microbes to attach. Does marine debris hold more toxins when it is big or when it is fragmented into microplastics? Why?
   - Correct (1)
     Correct response included: marine debris holds more toxins when it is fragmented into microplastics because there is more surface area.
   - Incorrect (0)
     Incorrect response included: marine debris holds more toxins when it is big because it has more surface area (or any response not the same as “correct”)

7. Can more microbes live on marine debris when it is whole, or when it is broken into small pieces? Why is this true?
   - Correct (1) responses included: more microbes can live on marine debris when it is fragmented because it has a greater surface area.
   - Incorrect (0) responses included: any other response.

NOTE: Knowledge Questions

Every student did not answer the questions about impacts, and the surface area results are from two, very similar questions. The 5th/6th grade classes did not complete the surface area portion of the lesson, and the 8th grade classes did not complete the surface area assessment.

The questions within the student notebook make up the knowledge score for each student. The knowledge score was calculated using the following objectives coded Correct (1) and Incorrect (0):

- What is marine debris
- Definition of microplastics
- Source of microplastics (average)
- Abundance of microplastics
- Surface area

Concepts with multiple questions were averaged to determine a score for that concept. The sum of all the concepts was calculated to determine the total knowledge score.
APPENDIX E. FULL RESULTS

Student Attitudes and Beliefs

Table E.1. Means for student beliefs and attitudes

<table>
<thead>
<tr>
<th>Beliefs</th>
<th>Pre</th>
<th></th>
<th>Post</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean (M)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Std. dev. (SD)</td>
<td>N</td>
</tr>
<tr>
<td>My behaviors do not make a difference in the amount of microplastics in the ocean&lt;sup&gt;2&lt;/sup&gt;</td>
<td>108</td>
<td>3.70</td>
<td>.99</td>
<td>106</td>
</tr>
<tr>
<td>I can make a difference in the amount of microplastics in the ocean</td>
<td>108</td>
<td>3.83</td>
<td>.84</td>
<td>106</td>
</tr>
<tr>
<td>My actions affect the amount of microplastics in the ocean</td>
<td>108</td>
<td>3.82</td>
<td>.91</td>
<td>107</td>
</tr>
</tbody>
</table>

Attitudes

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th></th>
<th>Post</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean (M)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Std. dev. (SD)</td>
<td>N</td>
</tr>
<tr>
<td>I do not need to worry about microplastics&lt;sup&gt;2&lt;/sup&gt;</td>
<td>108</td>
<td>3.87</td>
<td>.95</td>
<td>107</td>
</tr>
<tr>
<td>Microplastics cause a problem for people</td>
<td>108</td>
<td>3.67</td>
<td>.87</td>
<td>107</td>
</tr>
<tr>
<td>Microplastics cause a problem in the ocean all over the world</td>
<td>108</td>
<td>4.29</td>
<td>.77</td>
<td>106</td>
</tr>
<tr>
<td>Microplastics is an easy problem to solve&lt;sup&gt;2&lt;/sup&gt;</td>
<td>108</td>
<td>3.85</td>
<td>.93</td>
<td>104</td>
</tr>
<tr>
<td>Microplastics cause a problem for life in the ocean</td>
<td>108</td>
<td>4.42</td>
<td>.74</td>
<td>107</td>
</tr>
</tbody>
</table>

<sup>1</sup>Entries are means measured on a 5-point scale of 1 “strongly disagree” to 5 “strongly agree”

<sup>2</sup>Items were reverse coded

* Indicates a significant difference between pre and post survey responses at the <i>p</i> < .05 level.

All student responses on beliefs and attitude statements increased between the pre and post surveys (Table E.1). The largest increase was “I do not need to worry about
microplastics” (.33), and the smallest increase was “microplastics cause a problem for people” and “microplastics cause a problem for the ocean” (.03). “Microplastics cause a problem for life in the ocean” had the highest mean on both the pre (4.42 “agree”) and post (4.45 “agree”) survey. A Wilcoxon Sign Rank test was used to determine any differences between responses on student pre and post surveys. Responses to “I do not need to worry about microplastics” increased significantly ($p < .001$, $Z = 3.43$) between the pre and post survey. The mean for this statement increased from 3.87 (between “neither agree nor disagree” and “agree”) to 4.20 (between “agree” and “strongly agree”). This indicates that students felt more worried about the issue of microplastics after participating in the curriculum.

**Attitudes**

Although the mean response to the statement “microplastics cause a problem for life in the ocean” did not change much between the pre and post survey, students came into the curriculum already believing that microplastics caused a problem for life in the ocean, between “agree” and “strongly agree.” The statement “microplastics cause a problem for people,” however, started with a mean of 3.67 (between “neither agree nor disagree” and “agree”), and then did not increase much after participating in the curriculum.

While students did not change their attitude that microplastics harm marine life, they were still unsure about its impacts on people. In the curriculum, there is discussion of impacts of microplastics. Scientific studies included in the curriculum mention impacts on animals, particularly ingestion of microplastics. The impacts on humans are largely unknown, which is reflected in the content of the curriculum. This may have been reflected in students’ responses remaining between “neither agree nor disagree” and “agree” for the attitude that microplastics causes a problem for people. Even though researchers may not understand all the impacts of microplastics on people, there is evidence for potential links between microplastics and people. For example,
oysters are an important seafood resource and have been shown that they not only take up microplastics (Ward & Kach, 2009), but that their ingestion of microplastics reduces their fertility and negatively impacts larval development (Sussarellu et al., 2016).

Students’ demonstrated lack of clarity around the impacts on people may be an opportunity to include more explicit statements in the curriculum to address this issue.

The statement “microplastics cause a problem in the ocean all over the world” is broad in scope and abstract. Student responses remained between “agree” and “strongly agree” from the pre to the post survey with an increase in means of .13. Although this increase is slight, students felt that microplastics were a global issue before beginning the curriculum. The idea that microplastics is a difficult issue to solve also increased between the pre (3.85 between “neither agree nor disagree” and “agree”) and post (4.09 “agree”) survey. This may be reflecting the more detailed knowledge and understanding of the microplastics topic.

**Beliefs**

The three variables measuring beliefs, “my behaviors do not make a difference in the amount of microplastics in the ocean,” “I can make a difference in the amount of microplastics in the ocean,” and “my actions affect the amount of microplastics in the ocean” were combined into a mean index on both the pre and post surveys. The overall reliability using Cronbach alpha was .78 for pre survey beliefs items and .73 for post survey beliefs items (Table E.2). Because these Cronbach alpha values were high, all variables were included in the mean index. In the pre survey, none of the items raised the overall alpha when deleted, so each was included. In the post survey removing “I can make a difference in the amount of microplastics in the ocean” increased the Cronbach alpha to .77, but was included to be consistent between the two surveys. An exploratory factor analysis grouped all three beliefs items together on both the pre and post survey, which further justified calculating a beliefs index. Attitudes items did not
group consistently in the exploratory factor analysis, and therefore attitudes items were analyzed separately.

Table E.2. Reliability analysis of computed beliefs variable pre and post participation in the curriculum

<table>
<thead>
<tr>
<th></th>
<th>Mean (M)</th>
<th>Std. dev. (SD)</th>
<th>Item total correlation</th>
<th>Alpha (α) if deleted</th>
<th>Cronbach alpha (α)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beliefs (Pre)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can make a difference in the amount of microplastics in the ocean</td>
<td>3.83</td>
<td>.84</td>
<td>.61</td>
<td>.71</td>
<td>.78</td>
</tr>
<tr>
<td>My actions affect the amount of microplastics in the ocean</td>
<td>3.82</td>
<td>.91</td>
<td>.61</td>
<td>.69</td>
<td></td>
</tr>
<tr>
<td>My behaviors do not make a difference in the amount of microplastics in the ocean</td>
<td>3.70</td>
<td>.99</td>
<td>.62</td>
<td>.69</td>
<td></td>
</tr>
<tr>
<td><strong>Beliefs (Post)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can make a difference in the amount of microplastics in the ocean</td>
<td>3.96</td>
<td>.62</td>
<td>.44</td>
<td>.77</td>
<td>.73</td>
</tr>
<tr>
<td>My actions affect the amount of microplastics in the ocean</td>
<td>3.96</td>
<td>.82</td>
<td>.66</td>
<td>.52</td>
<td></td>
</tr>
<tr>
<td>My behaviors do not make a difference in the amount of microplastics in the ocean</td>
<td>3.90</td>
<td>.98</td>
<td>.63</td>
<td>.57</td>
<td></td>
</tr>
</tbody>
</table>

1Variables measured on a 5-point scale of 1 “strongly disagree” to 5 “strongly agree”
2Items were reverse coded

Mean student beliefs increased between the pre survey (3.79 “between neither agree nor disagree” and “agree”) and post survey (3.93 “agree”). A Wilcoxon Sign Rank test was used to determine any differences between student beliefs measured in the pre and post survey. This increase was not significant ($p = .153, Z = 3.93$). An increasing trend in student beliefs indicates that students felt more strongly that they were able to take action that made a difference in the issue of microplastics. This was also high before beginning the curriculum, suggesting that student self-efficacy was generally high and students believed that they were able to create change.
These results show that after participating in the curriculum, students tended to feel more strongly that they could make a difference in the issue of microplastics. Students were significantly more worried and tended to believe the problem to be more challenging after participating in the curriculum. Although students did not seem to think microplastics caused a problem for people, their feelings of worry, which may indicate feelings of personal responsibility, increased after participating. Worry may also relate to holding the attitude that the problem is challenging after learning more specific details and gaining increased awareness of the problem.

**Student Awareness**

Table E.3. Percentages of students reporting awareness of microplastics

<table>
<thead>
<tr>
<th>Have you heard of microplastics before today?</th>
<th>5th/6th (N = 24)</th>
<th>8th (N = 84)</th>
<th>Total (N = 106)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>42</td>
<td>48</td>
<td>47</td>
</tr>
<tr>
<td>No</td>
<td>58</td>
<td>52</td>
<td>53</td>
</tr>
</tbody>
</table>

Entries are percentages of students responding “yes” or “no”

More than half (53%) of students had not heard of microplastics before participating in the curriculum (Table E.3). This differed slightly between grade levels, with more fifth and sixth grade students (58%) reporting that they had not heard of microplastics. One possible influencing factor on these results is that teachers were recruited to participate with their classes in this study based on their previous participation in a teacher workshop focused on marine debris. While teachers may not have taught their classes specifically about microplastics, they had received some training in marine debris issues and were asked to pilot at least one marine debris lesson with their class. Teachers who had participated in the marine debris workshop may also have a greater interest in the topic of marine debris and microplastics. Lincoln
County School District emphasizes Ocean Literacy, which also increases the possibility of students learning about issues such as microplastics.

Awareness of microplastics after participating in the curriculum was inferred from student knowledge scores. Students’ ability to define marine debris and microplastics, identify sources, and describe the abundance of microplastics is dependent on their awareness of the issue. Students scored over 80% correct on each knowledge objective (Table E.5) requiring awareness of microplastics, including defining marine debris and microplastics, identifying sources of microplastics, and describing its abundance. This indicates an increase in overall awareness after participating in the curriculum.

![Student Behaviors](image)

Figure E.1. Mean number of behaviors listed per student. Each grade level shows the mean number of behaviors listed per student on the pre survey (solid bar) and post survey (striped bar).

3Means represent the average number of behaviors listed per student. Number of behaviors ranged between 1 and 5. Fifth and sixth grade N = 21, eighth grade N = 83.
On the pre survey, four students did not respond to the behaviors item and one indicated that he or she did not know. On the post survey, three students did not respond to the behaviors item and one indicated that he or she did not know. Of the students who did respond with at least one behavior, the number of behaviors listed per student was compared between the pre and post survey. On both surveys, the number of behaviors listed per student ranged between 1 and 5 (the total number of spaces provided on the survey). The mean number of behaviors to reduce microplastics listed per student shows an increasing trend from the pre to the post survey (Figure E.1). This difference is greatest for eighth grade students, where the mean number of behaviors increased from 3.54 (pre) to 3.92 (post).

Table E.4. Number of behaviors to reduce microplastics listed per student, a comparison of pre and post surveys

<table>
<thead>
<tr>
<th></th>
<th>Median¹</th>
<th>N</th>
<th>Pre</th>
<th>Post</th>
<th>Z-value</th>
<th>p-value</th>
<th>Effect size (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th/6th</td>
<td></td>
<td>21</td>
<td>3.00</td>
<td>3.50</td>
<td>.29</td>
<td>.774</td>
<td>.04</td>
</tr>
<tr>
<td>8th</td>
<td></td>
<td>78</td>
<td>4.00</td>
<td>4.00</td>
<td>2.53</td>
<td>.012*</td>
<td>.20</td>
</tr>
<tr>
<td>All students</td>
<td></td>
<td>99</td>
<td>4.00</td>
<td>4.00</td>
<td>2.31</td>
<td>.021*</td>
<td>.16</td>
</tr>
</tbody>
</table>

¹Entries are median values of the number of behaviors listed per student
* Indicates a significant p-value at the p<.05 level.

A Wilcoxon Sign Rank test was used to determine any differences in the number of behaviors listed per student between the pre and post surveys. Overall, the number of behaviors listed per student increased. Table E.4 shows the results of these tests and includes the median values for each group. The increase in number of behaviors listed per student was significant (p = .021) and the effect size (.16) was between small and medium (Cohen, 1988) or between minimal and typical (Vaske, 2008). This trend remained the same when students were grouped by grade level. Eighth grade students also showed a significant (p = .012) increase in the number of behaviors listed per student with an effect size (.20) also between small and medium (Cohen, 1988) or
between minimal and typical (Vaske, 2008). Fifth and sixth grade students showed an increase in the number of behaviors listed per student, but the increase was not significant \((p = .774)\), and the effect size (.04) is less than small (Cohen, 1988) or minimal (Vaske, 2008). This increase in the number of behaviors listed per student indicates that students are able to generate more ideas about what behaviors might help reduce microplastics in the ocean. This data does not speak to changes in behavior or intended behavior, but to the expanded knowledge of microplastics-reducing behaviors.

The types of behaviors listed by students revealed students’ specific knowledge of actions that would reduce microplastics in the ocean and also suggests certain understandings about the larger issue of microplastics. Both the number and types of behaviors listed by students tended to shift after participating in the curriculum.

Managing waste was a strong theme within the behaviors listed by students in the pre-survey. Managing waste tended to be discussed most often as preventing trash from entering the ocean by “not littering” or “recycl[ing] instead of throwing away plastics.” Managing waste was also frequently identified as a reactive activity (taking place after waste had become marine debris) such as “cleaning the beach,” or “If you go out to pick sea shells, get some microplastics too.” Almost half of the students who mentioned cleaning up trash mentioned it specifically at the beach. A less prevalent theme in student responses included individual consumption such as “use non-plastic water bottles.” The theme of collective awareness and action was the weakest theme, with responses like “spread the word on microplastics” or “talk to parents about using other things than plastic” present but infrequent among student responses.

Student responses identifying behaviors to reduce microplastics in the post-survey tended to focus on consumption behaviors. Choosing products without plastics or reducing the amount of plastic in our daily lives (“limit plastic use”) was a theme among student responses. Students identified personal care products as an item containing microbeads (“do not use products containing polyethylene/micro-beads”), but also other products (“buy more cotton,” “stop wearing fleece”). Some students
were able to explain how to identify products with microplastics, for example, to “try and look at the ingredients soap and toothpaste have.” Responses describing individual consumption behaviors also often used the term “polyethylene” from the curriculum.

The theme of managing waste with preventive and reactive behaviors was also present in the post survey, but less overwhelming than in the pre survey. Of the students who mentioned picking up trash, the proportion of students specifically mentioning the beach was similar to the pre survey results. Responses stating collective actions and raising awareness were not more frequent in the post survey, but tended to include additional ideas not in the pre survey like “banning the dumping of trash.”

Using vocabulary from the curriculum indicates specific knowledge gained from the curriculum and students’ ability to use it in this context. The increase in the number of behaviors listed per student on the post survey suggests that students gained knowledge of additional behaviors that might have an impact on the issue of microplastics. A shift in the types of behaviors listed from managing waste to individual consumption suggests a more subtle understanding of sources of microplastics and ways to address the larger issue of microplastics. Their expanded knowledge of microplastics-reducing behaviors, knowledge of more specific behaviors, and tendency to identify personal consumption of plastics, suggests that students gained more specific, detailed knowledge about microplastics and the broader issue of plastic in the ocean. Knowing which behaviors might be effective could influence students’ actions, however student actions were not measured in this study.

**Student Knowledge Scores**

Each objective was measured using one question in the student notebooks except identifying sources of microplastics. Identifying sources of microplastics was measured using three items, then a mean index was calculated for each student. Overall knowledge scores (shown in Table E.5 and Figure E.2) were calculated as a mean index of the five curriculum objectives. Students who did not respond to two or more of the
items were not included in the calculation. Students’ mean overall knowledge score was 86% correct responses (Table E.6). When grouped by grade, eighth grade students had a higher overall knowledge score (89%) than fifth and sixth grade students (79%).

Table E.5. Mean student knowledge scores for each objective by grade

<table>
<thead>
<tr>
<th>Objective</th>
<th>5th/6th Grade</th>
<th>8th Grade</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean (M)³</td>
<td>N</td>
</tr>
<tr>
<td>Overall knowledge score</td>
<td>24</td>
<td>79</td>
<td>82</td>
</tr>
<tr>
<td>Define marine debris</td>
<td>24</td>
<td>71</td>
<td>82</td>
</tr>
<tr>
<td>Define microplastics</td>
<td>21</td>
<td>90</td>
<td>65</td>
</tr>
<tr>
<td>Identify sources of microplastics</td>
<td>24</td>
<td>93</td>
<td>82</td>
</tr>
<tr>
<td>Articulate the abundance of microplastics</td>
<td>23</td>
<td>87</td>
<td>78</td>
</tr>
<tr>
<td>Explain how surface area changes when an object fragments</td>
<td>25</td>
<td>60</td>
<td>66</td>
</tr>
</tbody>
</table>

³Entries are mean percentages of correct responses
³Means do not include students who chose multiple answers
Objectives are listed in the order in which they appear in the curriculum

Figure E.2. Mean knowledge scores (percentages of correct responses) shown by objective and grade. The N values are shown in Table E.5.
Table E.6. Student willingness to respond to knowledge objectives

<table>
<thead>
<tr>
<th>Knowledge Objective</th>
<th>Grade¹</th>
<th>5th/6th⁻⁻⁻⁻ (N = 24)</th>
<th>8th⁻⁻⁻⁻ (N = 86)</th>
<th>Total⁻⁻⁻⁻ (N = 110)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define marine debris</td>
<td>93</td>
<td>98</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>Define microplastics²</td>
<td>96</td>
<td>96</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>Identify sources of microplastics</td>
<td>92</td>
<td>98</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>Articulate the abundance of microplastics</td>
<td>89</td>
<td>93</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>Explain how surface area changes when an object fragments</td>
<td>96</td>
<td>79</td>
<td>83</td>
<td></td>
</tr>
</tbody>
</table>

¹Entries are percentages of students who did respond on each knowledge objective
²Percentage includes students who chose multiple answers

Eighth grade students were generally the same or slightly more willing to respond to questions than fifth and sixth grade students except for questions about surface area (Table E.6). Willingness to respond to questions may indicate students’ confidence in answering correctly. Most differences between grade levels in their willingness to respond were small, however, this difference was larger for questions about surface area (17% fewer eighth grade students responded to these questions).

Table E.7. Comparison of knowledge scores by grade

<table>
<thead>
<tr>
<th>Knowledge Objective</th>
<th>Grade¹</th>
<th>5th/6th⁻⁻⁻⁻</th>
<th>8th⁻⁻⁻⁻</th>
<th>Total⁻⁻⁻⁻</th>
<th>χ² value</th>
<th>p-value</th>
<th>φ value</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define marine debris</td>
<td>71</td>
<td>85</td>
<td>82</td>
<td>2.44</td>
<td>.118</td>
<td>.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Define microplastics</td>
<td>90</td>
<td>95</td>
<td>94</td>
<td>.63</td>
<td>.427</td>
<td>.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Articulate the abundance of microplastics</td>
<td>87</td>
<td>100</td>
<td>93</td>
<td>9.20</td>
<td>.002*</td>
<td>.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explain how surface area changes when an object fragments</td>
<td>60</td>
<td>67</td>
<td>65</td>
<td>.35</td>
<td>.554</td>
<td>.06</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹Cell entries are mean knowledge scores, which represent the percentage of correct responses. N values are shown in Table E.5.
* Indicates a significant p-value at the p<.05 level.
Eighth grade students scored higher on every objective except identifying sources of microplastics (Table E.7). The greatest difference in scores between fifth and sixth grade students (87%) and eighth grade students (100%) was present in the “articulating the abundance of microplastics” objective. Articulating the abundance of microplastics is the only objective where eighth graders scored significantly higher than fifth and sixth graders ($p = .002$), with effect size of medium (Cohen, 1988) or typical (Vaske, 2008). Differences between grades in identifying sources of microplastics was measured using a Mann-Whitney U test. The test showed no difference between grades ($N = 106$) for the objective “identify sources of microplastics” ($p = .694$, $Z = .39$) and had an effect size (.04) less than small (Cohen, 1988) or minimal (Vaske, 2008). Each of the objectives are discussed separately below.

Definition of Microplastics

Table E.8. Student responses to multiple choice item defining microplastics

<table>
<thead>
<tr>
<th>If all of the following items were found floating in the ocean, which would be described as microplastics?</th>
<th>Grade&lt;sup&gt;1&lt;/sup&gt;</th>
<th>5&lt;sup&gt;th&lt;/sup&gt;/6&lt;sup&gt;th&lt;/sup&gt; ($N = 25$)</th>
<th>8&lt;sup&gt;th&lt;/sup&gt; ($N = 81$)</th>
<th>Total ($N = 106$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Plastic Bag</td>
<td>8</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>b. Seed</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>c. Bottle Cap</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>d. Plastic Nurdles</td>
<td>76</td>
<td>77</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>Multiple Responses</td>
<td>16</td>
<td>20</td>
<td>19</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup>Cell entries represent percentages of students who chose each possible response or who chose multiple responses.

The mean knowledge score for defining microplastics, calculated as an average of all students’ responses coded 1 “correct” or 0 “incorrect,” was 82% (Table E.5). As shown in Table E.8, almost 20% of students responded with multiple answers, indicating that they believed more than one of the possible answers would be considered microplastics. When students chose multiple responses, none of them chose “seed.” All responses were a combination of the plastic bag, bottle, cap, and plastic nurdles.
Explanations mostly justified their choice by stating that each answer chosen was made of plastic, with multiple students explaining that the plastic bag or bottle cap had the potential to become microplastics. For example, “[plastic bag, bottle cap, plastic nurdles] these things contain plastic and eventually are broken down into smaller pieces.”

Only a few students chose one incorrect answer, and each of these students chose “plastic bag.” Their explanations indicated the belief that plastic bags are a significant source of microplastics. None of the students chose “seed” or “bottle cap” as a single response, even though a bottle cap was identified as a potential source of microplastics by students who chose multiple responses. The bottle cap is the only answer choice that is made of plastic but does not have the word plastic in its description. This may have influenced the way students responded to this question.

Most students (76% of the students who responded) gave the correct answer: plastic nurdle. However, explanations varied. Common patterns among correct responses included identifying the size and composition of the nurdle. Most explanations included both size and composition, such as “plastic nurdles are the only option because the other two pieces of marine debris (the plastic bag and bottle cap) are too large to qualify as microplastics. The seed isn't even plastic!” or “plastic nurdles would be considered microplastics because they are smaller than 5mm and are plastic.” If students only included one of these aspects in their explanation, they most often used size, and less frequently that it is made of plastic. Incorrect explanations for choosing nurdles were infrequent, but incorrect explanations included the idea that nurdles were easy for a fish to eat and that nurdles are fragmented pieces of larger plastic debris. Size and plastic composition are the two aspects that define microplastics, which students seemed to have learned. Such a high percentage of multiple responses may be due to the lesson focusing on sources of microplastics, which includes larger plastic items.
Sources

Table E.9. Frequencies of student responses to “list possible sources of microplastics”

<table>
<thead>
<tr>
<th>Category</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal care products</td>
<td>103</td>
</tr>
<tr>
<td>Toothpaste</td>
<td>37</td>
</tr>
<tr>
<td>Face wash</td>
<td>32</td>
</tr>
<tr>
<td>Soap</td>
<td>31</td>
</tr>
<tr>
<td>Large plastic debris</td>
<td>28</td>
</tr>
<tr>
<td>Industry/nurdles</td>
<td>22</td>
</tr>
<tr>
<td>Fibers</td>
<td>22</td>
</tr>
<tr>
<td>Trash</td>
<td>17</td>
</tr>
</tbody>
</table>

Students were asked to name three possible sources of microplastics. Correct student responses were generally described by five categories: personal care products, industry, large plastic debris, fibers, and trash. Common responses and the frequency they occurred are shown in Table E.9. The most common response was personal care products. The most frequently mentioned personal care products included “toothpaste” (37), “face wash” (32), and “soap” (31). The remaining categories were much less common than personal care products and similar to each other in frequency, with large plastic debris (28) being the next most common. Trash is a major source of marine debris and microplastics, although it was not frequently mentioned by students. This may indicate the need to emphasize the idea that most marine debris is land-based (although it does not necessarily come from the beach).

The curriculum contains an activity devoted to investigating microbeads in face wash, and briefly mentions in student notes that microplastics also come from toothpaste and clothing fibers. Although face wash and soap was a common response, toothpaste specifically and clothing fibers were also common. Because these two items were given much less time in the lesson but seem to stand out to students, this is possibly a way to make a better connection with students. The Microbead-Free Waters
Act of 2015 placed a ban on personal care products containing plastic microbeads in December 2015. This will reduce this source of microplastics, and will make personal care products like face washes with plastic microbeads inaccessible. Microplastics will continue to be an issue, however, and there are many other sources of microplastics that seem to be even more relevant to middle school students. Focusing on clothing fibers and large plastic debris has the potential to make a difference in two larger sources of microplastics in the ocean.

Abundance

Table E.10. Student responses to multiple choice item “circle the statement that accurately describes the abundance of microplastics”

<table>
<thead>
<tr>
<th>Microplastics are found...</th>
<th>Grade (^1)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5(^{th})/6(^{th})</td>
<td>8(^{th})</td>
<td>Total</td>
</tr>
<tr>
<td>a. only found near beaches</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>b. all over the world</td>
<td>87</td>
<td>100</td>
<td>97</td>
</tr>
<tr>
<td>c. only found in the middle of the ocean</td>
<td>13</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>d. only in rivers</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

\(^1\)Cell entries represent percentages of students who chose each possible response

As shown in Table E.10, most fifth and sixth grade students and all eighth grade students who responded to this question correctly identified the abundance of microplastics. The fifth and sixth grade students who did not choose the correct response all chose “microplastics are only found in the middle of the ocean.” This is possibly a reflection on the activity featuring Angel White’s data, which is comprised of several manta trawl tows in the Pacific Ocean. All students read and completed the questions about Angel’s data, however, not just the fifth and sixth grade students.

When asked to explain their answer, many students who said that microplastics are only found in the middle of the ocean did not explain. The few responses given
tended to be general and state that microplastics could be found in the ocean. These responses might also reflect a more general misconception that all marine debris is part of a large island of trash in the middle of the gyre, or the “Pacific garbage patch.”

Students' explanations for finding microplastics all over the world generally tended to fall into two categories: where microplastics are found, and how microplastics come to be all over the world. Some students’ responses reflected both types of response such as “they’re small, they can travel easily and come from products used all over the world,” while some included one or the other. Within the first category, there were three common locations students used to justify their answer choice: microplastics can be found everywhere, on land, and in fresh water. Student responses that fell into the “how microplastics come to be all over the world” category showed patterns of varying strength. The strongest was the idea that microplastics have global sources and that “plastics come from humans and humans live all over the world.” Other patterns included distribution of microplastics via currents and poor waste management.

A smaller, third category included responses in which students used evidence from the curriculum to justify their answer choice. Some students referenced the lesson generally (“in the reading it says that microplastics are found all over the world”), but more often cited specific scientific studies. “[W]hen scientists did a worldwide test about 92% of tows had plastic” shows a reference to relevant scientific data and uses scientific vocabulary. Overall, students were able to describe the abundance of microplastics. This is consistent with their generally high attitude that marine debris is a problem all over the world.

**Surface Area**

Eighth grade students who responded to surface area questions tended to answer them correctly more often (67%) than fifth and sixth grade students (60%). This may be due in part to the difference in the way this part of the lesson was taught. Fifth and sixth grade students did not have prior knowledge of surface area. Common Core
State Standards for sixth grade include finding the area of flat surfaces and solving real-world problems, but do not include surface area calculation until seventh grade.

To communicate the concepts in the curriculum without leading students through an inappropriately frustrating activity, fifth and sixth grade classes were led in a whole-class demonstration where the connection between surface area and fragmentation was made explicitly by the researcher. In eighth grade classrooms, students were asked to calculate surface area and draw conclusions from their work as a group, with less front-end, explicit instruction from the researcher. There are other factors that may influence student willingness to respond, however, including student confidence and time constraints. More time as well as more explicit, direct instruction may be useful in this lesson to both convey lesson content and give students more confidence in their ability to respond correctly.

### Student Understanding

**Table E.11. Student understanding means from scoring rubric**

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean (M)</td>
</tr>
<tr>
<td>Misconceptions(^1)</td>
<td>102</td>
<td>2.51</td>
</tr>
<tr>
<td>Explanations(^1)</td>
<td>102</td>
<td>2.09</td>
</tr>
<tr>
<td>Information from Curriculum(^2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\)Means are measured on a scale from 1 “low” to 3 “high”  
\(^2\)Means are coded as a dichotomous variable 1 “used information from the curriculum” and 0 “did not use information from the curriculum.” The value here can also be interpreted as “48% of students used information from the curriculum.”

After participating in the curriculum, students tended to score higher in the misconceptions category (Table E.11), indicating the use of fewer misconceptions about marine debris or microplastics. A “low” score in misconceptions means that the student...
response showed evidence of misconceptions about curriculum concepts. “High” scores in the misconceptions category means students did not show evidence of misconceptions related to the curriculum concepts. Students also tended to provide more specific explanations of their responses in the post survey. This not only shows that students incorporated specific details, but is consistent with the idea that concepts learned in school change from more abstract at first to more concrete over time (Howe, 1996). The number of misconceptions ranged between zero and two per student in both the pre and post survey, with the mean misconceptions decreasing from .51 ($N = 102$) in the pre survey to .35 ($N = 103$) in the post survey.

In the pre survey, misconceptions tended to include sources of microplastics and the mechanism by which microplastics are produced. Strong themes that emerged from student misconceptions included plastics originating from natural sources such as rocks, beach litter as the main source of microplastics (“people littering on the beach. I think this because that is where most debri [sic] comes from”), and marine debris decomposing in the ocean, such as “plastic trash that was left that decomposed into smaller pieces of plastic” and “plastic goes into the water and dissolves.” Misconceptions about the impacts of microplastics in the ocean also emerged, generally that microplastics kill all marine life.

The most common misconceptions after participating in the lessons were that all “plastic floats on the top of the water,” most debris comes from the beach, and that all animals die when they eat plastic. “All plastic floats” is most likely a function of the first lesson in which students investigated microbeads and differentiated plastic from natural exfoliators by watching their behavior in water (floating or sinking). The idea that “most plastic debree [sic] comes from the beach” and that “animals can eat it and then they would die” are both persistent misconceptions that were not changed by the lessons.

Some student responses in the post survey showed evidence of development of their concept of microplastics. Vygotsky described the development of scientific concepts, or concepts learned in school, as taught in a structured way that moves from
abstract to more concrete. These concepts are developed over time along with everyday concepts that stem from concrete experiences of students (Howe, 1996). All students come to a lesson with prior knowledge of some sort organized in different ways. Structured, taught concepts may be incorporated into students’ existing conceptual structures partially or not at all. Several students wrote responses that contained accurate ideas about microplastics incorporated with misconceptions, showing a partial incorporation of the concept and revealing the process of developing a more concrete understanding.

*When you use plastic products they usually end up down the drain from there they pass through garbage filters because of how small they are. The water pipe then takes them out into the ocean. Or pieces of trash are thrown into the ocean and slowly decompose until they turn into what they are.*

- Student response

This response shows evidence that the student understands microplastics come from land-based sources, particularly garbage, and they travel to the ocean via waterways. The misconception that plastic decomposes in the ocean is still present, and the student seems to be unclear about the products of decomposition. Whether the misconception is new or persistent, it is being incorporated with ideas from the curriculum.

*Those small colorful pieces sound like microplastics. And a common source of microplastics is plastic debris left on the beach or near the water, that has been fragmented in the ocean.*

- Student response

This response also shows the incorporation of curriculum ideas (plastic marine debris becoming small pieces in the ocean and using the vocabulary word “fragment”) with the misconception that most marine debris comes from beach litter.
When people leave plastic on the beach waves get it a carrys [sic] it into the water where it is diluted and become small fragment of plastics.

- Student response

This student has used a vocabulary word from the curriculum (dilute) incorrectly. The student remembered the term, but has substituted it for the correct term (fragment). This response also shows the misconception that most marine debris comes from beach litter.
### Teacher Results

Table E.12. Means for teacher beliefs, attitudes, and teaching considerations

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean (M)(^1)</td>
</tr>
<tr>
<td><strong>Beliefs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My behaviors do not make a difference in the amount of microplastics in the ocean(^2)</td>
<td>3</td>
<td>5.00</td>
</tr>
<tr>
<td>I can make a difference in the amount of microplastics in the ocean</td>
<td>3</td>
<td>4.67</td>
</tr>
<tr>
<td>My actions affect the amount of microplastics in the ocean</td>
<td>3</td>
<td>4.67</td>
</tr>
<tr>
<td><strong>Attitudes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I do not need to worry about microplastics(^2)</td>
<td>3</td>
<td>5.00</td>
</tr>
<tr>
<td>Microplastics cause a problem for people</td>
<td>3</td>
<td>5.00</td>
</tr>
<tr>
<td>Microplastics cause a problem in the ocean all over the world</td>
<td>3</td>
<td>5.00</td>
</tr>
<tr>
<td>Microplastics is an easy problem to solve(^2)</td>
<td>3</td>
<td>5.00</td>
</tr>
<tr>
<td>Microplastics cause a problem for life in the ocean</td>
<td>3</td>
<td>5.00</td>
</tr>
<tr>
<td><strong>Teaching considerations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The microplastics lessons fit well into my existing curriculum</td>
<td>3</td>
<td>5.00</td>
</tr>
<tr>
<td>I am interested in teaching this curriculum in my classroom</td>
<td>3</td>
<td>5.00</td>
</tr>
<tr>
<td>This curriculum is aligned to the standards for my grade level</td>
<td>3</td>
<td>4.67</td>
</tr>
<tr>
<td>The curriculum addresses an important topic</td>
<td>3</td>
<td>5.00</td>
</tr>
<tr>
<td>I would use this curriculum</td>
<td>3</td>
<td>5.00</td>
</tr>
</tbody>
</table>

\(^1\)Entries are means measured on a 5-point scale of 1 “strongly disagree” to 5 “strongly agree”

\(^2\)Items were reverse coded
Three teachers participated in the study and completed the pre and post survey. Teacher mean responses are shown in Table E.13. Because of the small sample size, it is difficult to draw any conclusions, but there were some trends and places where all the participating teachers agreed.

**Beliefs**

Beliefs means were mostly between 4 “agree” and 5 “strongly agree.” Means for both “I can make a difference in the amount of microplastics in the ocean” (4.67 pre and 5.00 post) and “my actions affect the amount of microplastics in the ocean” (4.67 pre and 5.00 post) increased from the pre and the post survey. “My behaviors do not make a difference in the amount of microplastics in the ocean” decreased (5.00 pre to 3.67 post), however this is possibly due to the reverse wording of the item.

**Attitudes**

All teachers responded “strongly agree” for all attitudes statements on the pre and post surveys. This may have been influenced by their strong feelings that microplastics was a problem. This result supports the idea that teachers had a prior interest in the microplastics issue and curriculum, and also believed it was important to teach to students.

**Teaching Considerations**

The group of items listed as “teaching considerations” consisted of a set of statements with the same scale used on other sections of the survey between 1 “strongly disagree” to 5 “strongly agree.” The intention of this section was to gain feedback on the curriculum after the teachers had experienced it in their classrooms. All teachers responded that they “strongly agree” with each of the statements except “the curriculum is aligned to the standards for my grade level,” which was between “agree” and “strongly agree.” This is possibly due to the surface area activity in the curriculum.
The researcher was told that some of the classes had not learned surface area and would not do so until the end of the school year. Aside from timing, teachers showed interest, understood the topic to be an important one, and demonstrated willingness to use the curriculum after having the curriculum taught in their classroom.

**Awareness**

All teachers had heard about microplastics before the start of teaching the curriculum in their classrooms. This is consistent with the facts that teachers had previously participated in a marine debris workshop and curriculum pilot program, and also that they reported high interest and concern for microplastics in the surveys.

**Behaviors**

The mean number of behaviors listed by each teacher decreased from the pre \((M = 4)\) to post survey \((M = 3.67)\). This may be due to time constraints or pressure to generate behaviors that were not listed on the pre survey. The types of behaviors listed by teachers, however, were very similar between the pre and the post surveys. Before and after the curriculum was taught, teachers tended to list consumption behaviors such as "purchase items that do not use plastics." The post survey responses included behaviors like “stop using plastic straws” and “avoid products with microplastics.” Most of the actions listed by teachers were worded in a negative (“don’t buy plastic H\(_2\)O water bottles”) way both on the pre and post survey.

**Understanding**

Teachers tended to understand that microplastics come from several sources and are broken down from larger items and that it is unnatural. There was evidence of the misconception that plastic is fragmented by wave action. There was not much difference between pre and post teacher responses, except that post responses tended to be shorter and more to the point.