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Teaching Marine Debris: A Professional Development Model for Integrating Microplastics Science into Secondary Education

ACTIVITIES AND PROGRAM MODELS

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ABSTRACT

Marine plastics have become one of the most pervasive and complex environmental challenges of our time, impacting ecosystems, wildlife, and human communities across the globe and representing a critical topic for marine science education. This paper describes a place-based professional development workshop for high school teachers held at the Wrigley Marine Science Center on Catalina Island centered on microplastics and marine debris. Teachers engaged in a sequence of hands-on learning stations supported by instructional handouts and accessible materials including: (1) examination of plankton and plastic samples collected from the North Pacific Gyre, (2) sink-and-float experiments investigating plastic density and material properties, (3) geospatial tracking of marine debris using mapping by coordinates, (4) sorting of sand into natural versus synthetic components, (5) microfiber detection using phone adapter microscopes, and (6) a nylon polymer chemistry demonstration. Written participant reflections were analyzed using qualitative thematic coding. Emergent themes included increased content understanding of polymer science and microplastic pathways, strengthened confidence in teaching complex and emerging environmental issues, appreciation for the nylon chemistry demonstration as an anchoring phenomenon, and intentions to implement or adapt multiple investigations in high school science courses. Findings suggest that immersive, phenomena-based professional development that integrates polymer chemistry, real-world marine samples, and quantifiable investigation stations can strengthen secondary teachers' ability to connect abstract chemical and environmental principles to large-scale ocean systems. The results further indicate that station-based design, use of authentic field-collected materials, and cross-institutional partnerships create a replicable model for marine education programs seeking to integrate chemistry, environmental science, and student action projects within NGSS-aligned secondary curricula.

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INTRODUCTION

Plastic pollution poses a significant threat to marine ecosystems and human health (Cole et al. 2011; Kushwaha et al. 2024). Plastic is the most common type of marine debris and varies widely in shape and size, with pieces smaller than five millimeters defined as microplastics (Cole et al. 2011; Ghosh et al. 2023). Microplastics originate from primary sources, such as nurdles used in manufacturing and microfibers from textiles, or from secondary sources resulting from the breakdown of larger plastic debris through photodegradation and other physical, biological, and chemical processes (Browne et al. 2007; Ryan et al. 2009; Thompson et al. 2004). Due to their small size, microplastics are difficult to remove from the environment and are often mistaken for food by marine organisms (Moore 2008). Plastics produced and used on land enter oceans via runoff, wastewater, and inadequate management, with rivers contributing an estimated 1.15 to 2.41 million tonnes of plastic debris annually (Lebreton et al. 2017). Once in the ocean, their durability, low density, and buoyancy enable long-range transport by currents and winds, leading to accumulation in "garbage patches" near the center of ocean gyres (Maximenko, Hafner & Niiler 2012). Microplastics exemplify how human decisions in production, consumption, and waste management directly impact ocean health and, ultimately, human well-being.

Curricula that integrate marine debris science with classroom, field, and citizen-science learning activities have been shown to support student understanding of marine plastics causes and solutions while linking scientific knowledge to community action (Hartley et al. 2021). We designed an experiential, place-based teacher training workshop on marine plastics that incorporated tested, standards-aligned curriculum focused on ocean processes and environmental challenges. Participant outcomes were evaluated to examine how access to high-quality professional development and authentic, hands-on materials influences educator preparedness to teach complex environmental topics. Plastic pollution exemplifies Ocean Literacy Principle #6, highlighting the inextricable connections between the ocean and human activities (Halversen et al. 2021; NOAA 2024).

This article describes the design, implementation, and outcomes of a teacher professional development workshop held at Catalina Island, off the coast of southern California, focused on microplastics and marine debris. The workshop aimed to (1) deepen teacher understanding of microplastics in the marine environment, (2) provide hands-on, state standards-aligned lesson plans and supplies developed for immediate classroom implementation, and (3) illustrate Ocean Literacy Principle #6 – that the ocean and humans are inextricably connected – by focusing on marine debris and microplastics.

METHODS

SETTING AND PARTICIPANTS

The one-day teacher professional development workshop took place at the University of Southern California's (USC) Wrigley Marine Science Center on Catalina Island, a long-standing hub for marine research and education, and was hosted in partnership with USC Joint Educational Project (JEP), USC Sea Grant, and Algalita Marine Research and Education. Participants included high school teachers representing diverse teaching contexts spanning general science, environmental science, and interdisciplinary STEAM (science, technology,



Figure 1 Teacher participants and workshop coordinators on Catalina Island. Photo courtesy of Nick Neumann, Wrigley Institute.

engineering, arts, and mathematics) (Figure 1). Teachers who completed the workshop were eligible to receive continuing education credits through USC Rossier School of Education and its partnership with USC JEP.

PROGRAM STRUCTURE AND CURRICULUM COMPONENTS

The workshop was intentionally designed around established, classroom-tested curricular resources developed by Algalita Marine Research and Education. These resources are aligned with the Next Generation Science Standards (NGSS) performance expectations and emphasize inquiry, data analysis, and human–environment interactions. Workshop activities modeled three distinct core investigation kits provided within the teacher supplies: "Plastic Ocean," "Synthetic Sand," and "Microfiber Investigation." All lesson plans and toolkits were developed by Algalita and are freely available to public school educators through their website. View Algalita's toolkits.

The workshop opened with a live polymerization demonstration to make nylon 6,10 by USC Chemistry Professor Dr. Travis Williams, and USC graduate students Lena Williams and Aidan Van Opdorp, which served as an anchoring phenomenon connecting polymer chemistry, synthetic consumer products, and ocean plastic pollution. Teachers were provided with two immiscible liquids that, when added together, form a nylon polymer film that can be lifted and wound like a thread until one of the two liquid reactants is used up (Figure 2). The solid nylon was rinsed with water and teachers were able to take home their sample of synthetic nylon fiber. This activity demonstrated how easily plastic products can be created despite their inherent resistance to degradation in the natural environment.



Figure 2 High school teachers, Rebecca Bonet, Edric Leggett, and Emily Ochoa, performing the nylon experiment led by Dr. Travis Williams outside in the amphitheater with all of the required PPE. Photos by Dieuwertje Kast & Sydney Rilum.

Following the chemistry demonstration, teachers moved inside the lab for a presentation by Algalita's Education Director, Anika Ballent, who provided contextual framing of microplastics and marine debris as well as an overview of Algalita's long-term research and education efforts. This introduction emphasized the relevance of citizen science, real-world data and education samples, and systems thinking in marine education. Teachers then rotated through a sequence of hands-on investigation stations adapted directly from three Algalita lesson plans provided as part of the provided teacher resources:

LESSON PLAN 1 – PLASTIC OCEAN INVESTIGATION

A. Plastic Soup (Sample Observation) Activity: Participants examined preserved ocean surface water samples containing plankton and microplastics collected from the North Pacific Gyre. Using magnification tools, teachers identified microplastic fragments and plankton, discussed trophic transfer, and explored how plastic pollution intersects with ocean food webs (Figure 3).



Figure 3 Using a hand lens, microscope and the naked eye to examine the surface water samples from the North Pacific Gyre. Photos by Dieuwertje Kast.

B. Sink or Float (Plastic Density) Activity: Teachers tested common plastic items, including high-density polyethylene grocery bags, low-density polyethylene ziploc bags, polystyrene drink cups, polypropylene straws, and expanded polystyrene "Styrofoam" peanuts in water-filled beakers to investigate density, buoyancy, and vertical distribution of plastics throughout the water column (Figure 4). This activity reinforced core physical science concepts while connecting material properties to ecological impact.

An optional extension of this exercise is to also process a subsample of the collected sediment using a hypersaline solution (e.g., saturated NaCl or Seawater) to float lower-density plastic particles before filtration and microscopic examination. This modification introduces students to a standard laboratory technique used in microplastics research while reinforcing concepts of experimental design, detection efficiency, and methodological limitations. Importantly, students should recognize that saturated NaCl or seawater (density ~1.2 g/cm^3) does not recover all microplastics equally. Lower-density polymers such as polyethylene and polypropylene readily float, whereas denser materials, including polyester, nylon, and PET, may still remain in the sediment. Discussing these limitations provides an opportunity to compare the advantages of NaCl as a safe, inexpensive classroom reagent with the denser flotation solutions (e.g., zinc chloride or sodium iodide) commonly employed in research laboratories to maximize recovery of a broader range of plastic polymers. This extension highlights how methodological choices influence scientific results and interpretation.

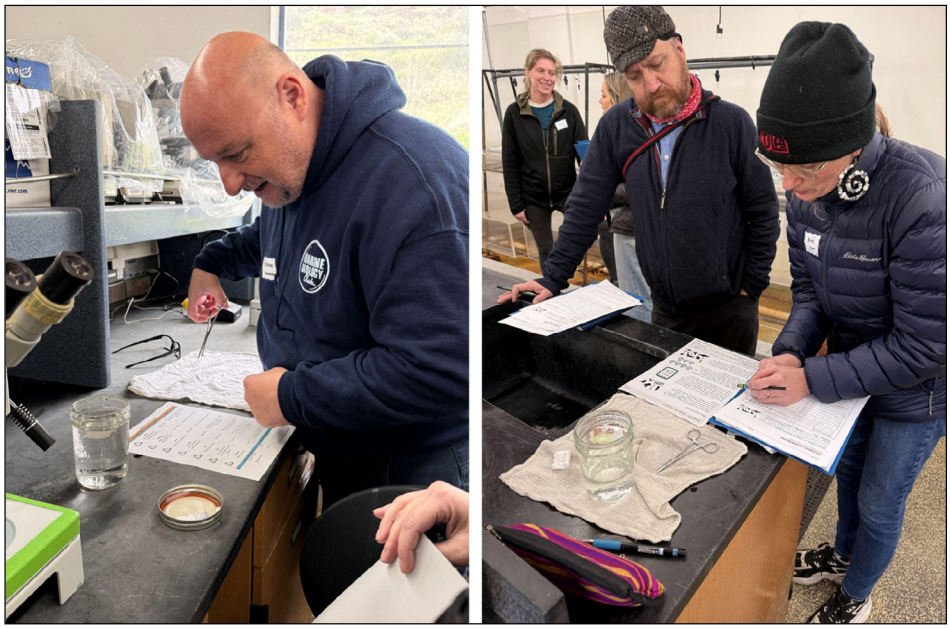

Figure 4 Left - Andreas Vamvakas trying out the sink or float activity. Right – Enzo Loconte and Ariel Climer also performed the experiment near the sink. Photos by Dieuwertje Kast.

C. Tracking Trash (Geospatial Mapping) Activity: Participants used images of real ocean samples and their coordinates to map marine debris accumulation zones, modeling how ocean gyres and surface currents transport plastics across ocean basins (Figure 5). This exercise showed teachers how they could integrate geography, data literacy, and systems thinking.



Figure 5 Edric Leggett and Lori Klein map out the coordinates from the Tracking Trash activity. Photo by Dieuwertje Kast.

LESSON PLAN 2 – SYNTHETIC SAND INVESTIGATION

Teachers analyzed plates of beach sand samples collected from Southern California, sorting materials into natural and synthetic categories using tweezers, magnifiers, and guided worksheets (Figure 6). This activity emphasized sensory observation, quantification, and interpretation of human impacts on coastal ecosystems.



Figure 6 Teachers testing out the synthetic sand activity. Galen Lei and Jessica Heidelberg, Emily Ochoa (in the white scarf), Asmau Benna (in the bonnet), David Chavez (black jacket), Edric Leggett, sort out natural and synthetic components from the sand samples. Photos by Dieuwertje Kast & Sydney Rilum.

LESSON PLAN 3 – MICROFIBER INVESTIGATION

Using clip-on phone microscopes and gridded sampling slides, participants identified and counted microfibers collected from indoor and outdoor locations (Figure 7). Teachers compared deposition patterns and discussed connections to fast fashion, air quality, and emerging research on microfiber pollution.

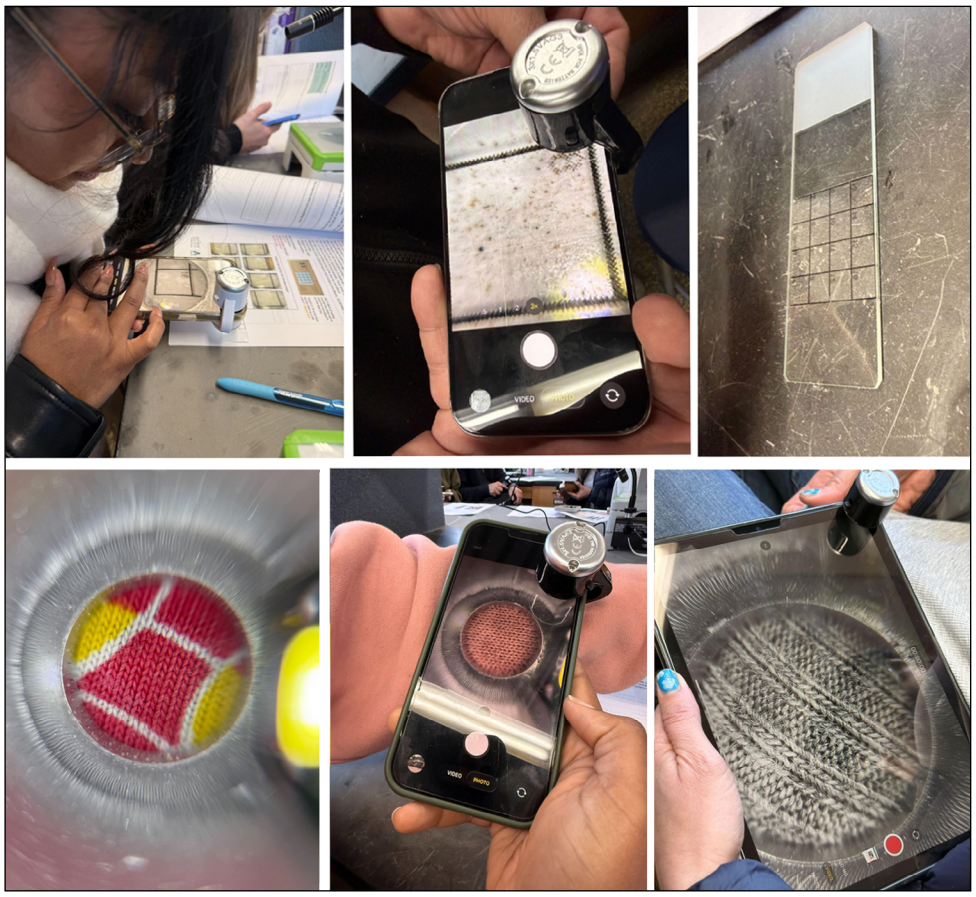

Figure 7 Photos of the fibers on clothes viewed through the clip-on phone microscopes provided. Photos by Dieuwertje Kast.

Throughout the workshop, facilitators highlighted companion resources, including Algalita's instructional videos, downloadable worksheets, and classroom kits. Teachers were encouraged to adapt activities across grade levels and subject areas.

QUALITATIVE ANALYSIS OF OPEN-ENDED SURVEY RESPONSES

DATA COLLECTION

Qualitative data were drawn from open-ended responses submitted through a post-workshop evaluation administered to grade 6–12 and postsecondary educators who participated in the professional development workshop focused on microplastics and marine pollution. Open-ended questions prompted participants to reflect on (a) what they learned during the workshop, (b) the perceived usefulness of individual lessons, (c) planned classroom implementation, and (d) suggestions for future workshops and lesson content. All responses were anonymized prior to analysis.

CODEBOOK DEVELOPMENT AND PROCEDURE

An **inductive thematic analysis** approach was used to analyze open-ended survey responses. A preliminary set of codes was generated and iteratively refined through repeated readings of the dataset. Codes were defined to capture both cognitive outcomes (e.g., content knowledge gains) and pedagogical considerations (e.g., student engagement, curricular integration), as well as affective responses and future instructional needs. The final codebook consisted of **eleven codes**, each with a clear definition, inclusion criteria, and representative examples drawn from the data (Table 1). Codes included, but were not limited to, *Content Knowledge Gain*, *Hands-On/Experiential Learning*, *Student Engagement*, *Curricular Applicability*, *Authentic*

Science Practices, *Interdisciplinary Connections*, *Desire for Deeper Data*, and *Solution-Oriented Thinking*. The complete codebook was used consistently across all open-ended responses.

All open-ended responses were systematically coded using the finalized codebook. Responses were examined line by line, and codes were applied to segments of text that reflected the defined criteria for each code. Multiple codes could be applied to a single response when teachers described overlapping ideas (e.g., hands-on learning that supported both student engagement and authentic science practices). Throughout the coding process, codes were continuously compared across responses to ensure consistent application and to refine thematic boundaries.

THEME GENERATION

Following coding, codes were examined for patterns and relationships and were grouped into **higher-order themes** that represented broader dimensions of teacher experience. These themes reflected (a) teachers' perceived learning outcomes, (b) instructional and pedagogical value of the workshop lessons, (c) anticipated classroom implementation, and (d) identified needs for future professional learning. Representative quotations were selected to illustrate each theme and to preserve participant voice.

RESULTS

CODE NAME	DEFINITION	INCLUSION CRITERIA	EXAMPLE QUOTE
Content Knowledge Gain	Teacher describes learning new scientific concepts related to plastics or microplastics	Mentions of learning facts, processes, impacts, or terminology	"Each of the different resin codes of plastic have different densities…"
Real-World Relevance	Connection to everyday life, society, or human impact	Clothing, fast fashion, beaches, food, human health	"Increase use of plastic in our clothing…"
Student Engagement	Perceived student interest, motivation, or excitement	Hands-on, visual, microscopes, discovery	"Kids get to see the issue for themselves…"
Hands-On/ Experiential Learning	Emphasis on tactile, observational, or inquiry-based activities	Sampling, microscopes, data collection	"Students collect data!"
Curricular Applicability	Ease of integrating lessons into existing curriculum	Units, standards, courses, grade levels	"I can apply this to a unit very easily."
Interdisciplinary Connections	Links to other subjects or scientific domains	Chemistry, math, air pollution, biology	"Connect units with how mathematics can support analysis…"
Authentic Science Practices	Engagement in real scientific methods	Data collection, analysis, sampling	"Authentic samples!! Students do data collection!"
Teacher Confidence/ Comfort	Increased confidence in teaching content	Comfort, preparedness, ability	"Made me feel more comfortable teaching…"
Desire for Deeper Data	Requests for more data, research, or evidence	Data tables, recent research, species impacts	"More recent data tables…"
Solution-Oriented Thinking	Interest in mitigation, solutions, or action	Solutions, addressing the issue, what can be done	"I'd love to spend more time on solutions…"
Positive Affect/ Appreciation	Expressions of gratitude or satisfaction	Thank you, excellent, great opportunity	"Everything was excellent!"

Table 1 Codebook summary table of all eleven codes used to analyze all open-ended survey responses, including each code definition, inclusion criteria, and representative examples drawn from the survey response data.

DISCUSSION

Analysis and coding of open-ended survey responses revealed various themes of teacher experiences from the professional development workshop. Five interrelated themes emerged: content knowledge development, experiential engagement, curricular applicability, desire for deeper data and solutions, and positive affective response.

One central theme that emerged from the data was *curricular applicability* (Table 1). Teachers described integrating lessons into full instructional units, multiple courses (e.g., marine biology, AP Environmental Science), and even extracurricular clubs. This finding aligns with literature emphasizing that professional development must support not only content acquisition but also instructional transfer (Desimone 2009).

The *Interdisciplinary Connections* code—which particularly references chemistry, mathematics, and air pollution—also reflects broader trends in marine education toward integrated STEM approaches (Bybee 2013). Microplastics, by their nature, sit at the intersection of chemistry, ecology, materials science, and public health. Teachers' ability to identify cross-disciplinary applications suggests that the workshop design supported integration rather than siloed content delivery. Additionally, 84.6% (n = 11) of teachers said the workshop made them feel more comfortable teaching microplastic concepts to their students, further supporting the importance of teacher training workshops for building teacher confidence in teaching students new lessons.

Such integration is particularly relevant to Next Generation Science Standards (NGSS Lead States 2013), which emphasize crosscutting concepts and science practices. Teachers' reflections indicate that the workshop's design naturally supported alignment with these standards, enhancing the likelihood of sustained classroom implementation. After completing the workshop, 92.3% (n = 12) of participants said they plan to use these lesson plans in their classroom.

Additionally, teachers' responses reveal a connection between the following codes: *authentic science practices*, *hands-on experiential learning*, *real-world relevance*, and *student engagement*. Teachers' explanations of each resource's usefulness suggest that observing real samples (whether provided with the lesson or collected by students), and using physical, hand-held scientific tools, such as microscopes, magnifiers, and tweezers to collect data from those samples collectively increase student engagement and strengthen personal connection to the environmental issue at hand. Responses like the following all support this connection:

- "gives students a clear picture of what the problem looks like,"
- "It's much easier to have hands-on activities that show where the plastics go,"
- "relevant and relatable to the students,"
- "easy to see the plastics/damage,"
- "students do data collection,"
- "timely and relevant," and
- "small microscope will motivate and engage students."

LIMITATIONS

Several limitations should be considered when interpreting these findings. First, the data were derived from post-workshop self-reported survey responses. As such, findings reflect teachers' perceptions of learning, engagement, and intended classroom implementation rather than direct observations of instructional practice or student outcomes. Self-report data may be influenced by social desirability bias, particularly in the context of a professional development experience that participants may have valued positively.

Second, the qualitative data were collected immediately following the workshop. While teachers articulated clear plans for curricular integration, this study does not examine the extent to which lessons were ultimately implemented or sustained over time. Longitudinal follow-up would provide stronger evidence of instructional transfer and durability of professional learning effects.

Third, although the study sample included educators across grade levels and subject areas, it represents a specific cohort of teachers who elected to participate in a marine debris-focused workshop. Participants may therefore have had pre-existing interest in environmental or marine topics, which may limit the generalizability of findings to broader teacher populations.

Finally, while a systematic inductive coding process was used to analyze responses, the analysis reflects interpretation within a specific research context. As with all qualitative research, themes represent patterns within the dataset rather than statistically generalizable outcomes. Future research could strengthen trustworthiness through triangulation with classroom observations, artifact analysis, or student data. Despite these limitations, the findings provide meaningful insight into how educators experience and interpret marine-focused professional development, particularly in relation to emerging environmental issues such as microplastics.

IMPLICATIONS FOR MARINE EDUCATION PROFESSIONAL DEVELOPMENT

Based on the findings of this study, marine-focused professional development programs may consider the following design principles:

- **Embed Ocean Literacy explicitly:**
  - Frame workshop content around National Oceanographic and Atmospheric Administration (NOAA) Ocean Literacy Principles specifically related to human impact on the ocean to strengthen conceptual coherence and alignment with national marine education standards (NOAA 2024).
- **Prioritize experiential inquiry:**
  - Incorporate authentic scientific tools (e.g., microscopes, sampling protocols, data analysis) and real samples to support visible and tangible engagement with otherwise abstract marine issues.
- **Support interdisciplinary integration:**
  - Provide explicit connections to chemistry, mathematics, and environmental science standards (such as NGSS) to facilitate cross-curricular implementation.
  - Provide example standard and subject applications: Include guidelines and encourage discussion of ways that the workshop content connects to teachers' teaching areas and curriculum goals to highlight relevance and applicability
- **Include current data and emerging research:**
  - Equip teachers with up-to-date scientific resources to address student questions related to biomagnification, human health impacts, and mitigation strategies.
- **Integrate solution-oriented pathways:**
  - Move beyond awareness toward actionable responses, empowering teachers to guide students in systems thinking and stewardship.

By aligning professional development with Ocean Literacy Principles and authentic scientific practices, marine education initiatives can better support teachers in translating emerging ocean science into meaningful classroom instruction.

CONCLUSION

This article examined teacher reflections following a professional development workshop centered on microplastics and marine pollution. Through inductive thematic analysis grounded in a structured codebook, five interrelated themes emerged: content knowledge development, experiential engagement, curricular applicability, desire for deeper data and solutions, and positive affective response.

The findings suggest that marine science professional development can effectively deepen teacher understanding while simultaneously supporting interdisciplinary integration and authentic science practices. Teachers not only described enhanced knowledge of microplastics and marine systems, but also articulated concrete plans to embed lessons within existing curricula across grade levels and disciplines. Importantly, participants further expressed interest in extending learning toward data literacy, chemical analysis, human health impacts, and solution-oriented approaches, indicating readiness to engage students in more complex and action-focused marine issues. These results reinforce the importance of experiential, inquiry-based, and contextually grounded professional development in marine education. As marine

environmental challenges grow increasingly complex and visible in public discourse, supporting teachers with current scientific knowledge, authentic practices, and interdisciplinary tools is essential for preparing students to understand and respond to these issues.

APPENDICES

Algalita's lessons – Google Doc Versions:

- Plastic in the Ocean Lesson Plan
- Synthetic Sand Lesson Plan
- Microfiber Lesson Plan

Algalita's online resources, including videos and lesson kit request forms:

- Slides on Algalita's Classroom Toolkits
- Plastic in the Ocean Toolkit
- Synthetic Sand Toolkit
- Investigate Microfibers Toolkit
- Student Mini-Grant
- Teacher Mini-Grant

Nylon chemistry demonstration details from USC's Dr. Travis Williams, Lena Williams and Aidan Van Opdorp:

- https://archive.org/details/chemicaldemonstr0000shak_d8x2/page/214/mode/2up?q=nylon. Nylon 6,10 protocol.
- Note: If pre-making quantities of solutions for the demo, we strongly recommend purging the sebacoyl chloride/hexane solution with N_2 and storing in the fridge to reduce any degradation. The HMDA solution is fine.

Social Media Post from the Teacher Training Workshop with all the partners involved - USC JEP, USC Sea Grant, USC Wrigley, and Algalita (We'd love it if you would like and share the post):

- Instagram
- Facebook
- LinkedIn

Check out our programs' websites and social media to stay updated on current projects and activities:

- USC Sea Grant: @uscseagrant
- USC JEP STEM Programs: @jep_stem
- Algalita: @algalita

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COMPETING INTERESTS

The authors have no competing interests to declare.

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- Sydney Rilum
    - Sydney Rilum is a Marine Debris Extension Specialist with the University of Southern California Sea Grant Program. She leads research and policy development on marine microplastics and collaborates with communities across Southern California to develop improved technologies, outreach initiatives, and educational programs aimed at reducing marine debris and microplastics in coastal systems. Sydney has worked across education, habitat and species monitoring, research, and environmental data science in a variety of environmental and sustainability sectors, including non-profit organizations (Laguna Ocean Foundation, Aquarium of the Pacific, OC Habitats), state agencies (California Department of Fish and Wildlife, State Water Resources Control Board), and industry (Ocean Rainforest). She holds a Master of Environmental Science and Management (MESM) from the University of California, Santa Barbara Bren School, with specializations in Coastal Marine Resources Management and Environmental Data Science, and a Bachelor's degree in Environmental and Ocean Sciences with a focus in Marine Ecology from the University of San Diego.
- Karla Heidelberg
    - Dr. Heidelberg earned her Ph.D. in Biological Oceanography from the University of Maryland and is a Professor of Biology and Environmental Studies. After a postdoc, she became a Science Policy Fellow at the U.S. State Department in the Office of Oceans

Affairs and then joined the J. Craig Venter Institute to coordinate an around-the-world research expedition to evaluate ocean biodiversity. She came to USC in 2006, initially as resident faculty at the USC Wrigley Marine Science Center on Catalina Island. Her research examines factors affecting marine biodiversity and has taken her to Antarctica, deep-sea hydrothermal vents, and coastal areas worldwide. In 2017, she received the USC Associates Award for Teaching – the highest teaching award offered by USC. Between 2019–2022, she detailed at the National Science Foundation, helping lead the U.S. Antarctic Science Program. Now back at USC, she serves as Director of USC Sea Grant, a NOAA-funded program that connects research with communities and industry while giving students hands-on opportunities to build skills and launch meaningful careers.

- Anika Ballent
    - Since joining Algalita in 2012, Anika has been leading their educational programs, designing and facilitating transformative experiences that stay true to Algalita's values of investigation, experiential learning, imagination, and balance. With a Master's degree in Geology from Western University—where she investigated microplastic pollution in Lake Ontario—and a BSc in Earth and Space Sciences from Jacobs University Bremen (now Constructor University), she brings both scientific expertise and creative vision to Algalita's work. Anika is an active educator, engaging directly with students and teachers to ensure every experience is meaningful and impactful. With over 12 years of experience in the plastic pollution movement, Anika aims to share her curiosity and insights into both the challenges of teaching environmental science and the solutions that drive real impact with the educators, students and community members in Algalita's programming. She strives to bridge complex scientific concepts with engaging, accessible learning experiences to make Algalita's programming stronger, more relevant, and more inspiring.

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