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ACTIVITIES AND PROGRAM MODEL

Planktonic Relationships! Authentic STEM Connections Through Partnership Between University of Southern California's Marine Researchers and Los Angeles Unified Elementary School Students

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Plankton here, plankton there, phytoplankton everywhere! This was the messaging behind the pleasantly planktonic programming that sought to introduce fifth grade students to the work of marine and environmental biology researchers at the University of Southern California. A classroom of 29 fifth grade students from Lenicia B. Weemes Elementary toured the research labs on campus. They learned more about how research is conducted at the university level, and what specifically these labs focus on within the study of marine phytoplankton and cnidarians (corals and anemones), which students were able to view under the microscope and in aquariums. These lab tours provided the students with valuable context for conducting scientific research in the real world, bridging the gap between the information they learn in school and where this research data is generated.

Keywords: Plankton; Marine Education; STEM; Partnerships; Expanding Audiences

Introduction: Ocean Literacy

Take 10 breaths. Out of those 10 breaths, five depend on the photosynthetic activity of phytoplankton in the ocean. Phytoplankton are crucially important to the global ecosystem: they are the primary producers of 50% of the oxygen we breathe and serve as the base of the marine food web (Field et al. 1998; Brierley 2017). However, these organisms are greatly underappreciated, and there are few available curricula that feature the role of plankton in photosynthetic energy production.

Program Overview

The Marine Biology and Biological Oceanography (MBBO) program at the University of Southern California (USC) researches the important ecological role that plankton play in the ocean. The first author of this paper, Kyla Kelly, is a graduate student in the MBBO program; she has found a way to use her knowledge of and passion for phytoplankton to educate children in her community as a volunteer for the Joint Educational Project's (JEP) Young Scientists Program (YSP). YSP is an inquiry-based, hands-on science, technology, engineering, arts and mathematics (STEAM) educational outreach program that aims to strengthen science literacy and promote interest in scientific careers by bringing authentic laboratory experiences directly to K-5 students and their teachers in seven partner schools within the Los Angeles Unified School District (LAUSD). YSP's engaging science curriculum, taught by USC undergraduate and graduate students, helps K-5 students apply what they learn in the classroom to their own lives. To achieve these goals, YSP also brings 'real world' scientists into these elementary schools to facilitate workshops related to their research specialties. These workshops have been successful in engaging students and enhancing both their appreciation for and understanding of various careers in science. One of these workshops held in the spring 2019 semester included hosting marine biology lab tours for Mr. Craig Hinkel's fifth grade class from Lenicia B. Weemes Elementary School. The elementary school students were given tours of two MBBO labs and performed a phytoplankton experiment to learn more about the research that occurs at the university level. Kyla leveraged her academic understanding of marine phytoplankton to write a curriculum addressing their importance in the ocean community, which the fifth grade students were able to experiment with in a controlled, laboratory setting.

Lesson Overview: Planktonic Relationships

Twenty-nine fifth grade students participated in a field trip to USC's University Park Campus and were given a tour of the campus and two MBBO labs. Having previously worked with JEP/YSP, Mr. Hinkel contacted us seeking out a unique experience for his students to visit a college campus in order to learn about higher STEM education and research. He hoped that this exposure to higher education might one day encourage his students to strive for continuing their educational pursuits at the college or university level. We, the authors of this article, strongly encourage teachers (especially those serving areas with large populations of underrepresented minorities) to reach out to local higher education institutions; faculty and students alike are often thrilled by the opportunity to share their research and experience with the broader community.

In the two MBBO labs, students rotated through three stations designed to expose them to a snapshot of some of the marine research methods that are currently utilized at USC. In Dr. Carly Kenkel's lab, students learned about corals, sea anemones, and sea urchins with the guidance of graduate students Nico Lorenzen, Yingqi Zhang, and Maria Rugeri. At this station, students learned that not only are phytoplankton intracellular symbionts of these organisms (e.g. photosynthetic dinoflagellates), but they also contribute to the transfer of organic matter to higher trophic levels in marine food webs (Davy et al. 2012; Brierley 2017). Students were also able to view these organisms in aquariums that are maintained in the lab for research. In addition to having the opportunity to take a look around some of the spaces where research is conducted, the students discussed with the researchers the impacts of climate change and ocean acidification on natural coral populations, as well as the ongoing research and conservation efforts that aim to preserve them.

Emily Eggleston, from Dr. David Caron's and Dr. Eric Webb's labs, talked about the importance of phytoplankton in the context of energy production, and encouraged students to take a look at a few different types of phytoplankton (e.g. cyanobacteria, dinoflagellates, and diatoms) under the microscope. In Mr. Hinkel's classroom, students had recently learned about photosynthesis in land plants. This lab visit helped to expand the students' body of knowledge on this topic by teaching students that half of the photosynthesis on Earth occurs in the ocean, a concept that is equally important but often overlooked. The concept of photosynthesis in the ocean can be very difficult for students to conceptualize: trees are large, tangible objects that we see every day, while phytoplankton are aquatic organisms that are invisible to the naked eye. Therefore, it can be hard for students to fully grasp the contribution of microscopic phytoplankton to primary productivity, relative to that of macroscopic land plants. Viewing phytoplankton under the microscope greatly aided students in visualizing the other 50% of the photosynthesizers that exist and produce the oxygen that we breathe.

Kyla Kelly, a member of Dr. David Hutchins' lab, performed a plankton collection experiment with students and talked to the class about doing research, both in the field and in more controlled laboratory settings. The objective was to help students understand the importance of collecting phytoplankton samples from the environment and what research experiments can be done once these samples are brought back to the lab. Reiterating just how small phytoplankton are helped the students comprehend the difficulties in "catching" these microscopic organisms. Students were first asked what they thought the biggest animal in the ocean was, to which most answered whales and sharks. When students were asked what the smallest organisms in the ocean are, the answers they gave included numerous creatures, ranging from starfish and crabs to baby fish. Students were surprised to learn about the existence of microscopic organisms that inhabit our oceans in incredibly high concentrations, yet remain unseen. This informal assessment showed that at this grade-level, most students have not yet been made aware of the extremely important microorganisms that reside in the ocean: the phytoplankton.

Students were told that to "catch" phytoplankton cells, scientists use nets, similar to how a fisherman would use a net to catch fish. However, just like a fish net needs to have holes that are smaller than the fish so that they do not fall through and escape capture, a phytoplankton net needs to have holes that are smaller than the phytoplankton cells. Students were shown a real plankton net that is used in the field by scientists and were allowed to examine just how small the holes really are (**Figure 1**).

Figure 1: Students were shown a real phytoplankton net before using the makeshift ones to catch their own phytoplankton. They looked very closely at the net mesh to try and see how tiny the holes were. Photo: Dieuwertje Kast. Reproduced with permission of the photographer.

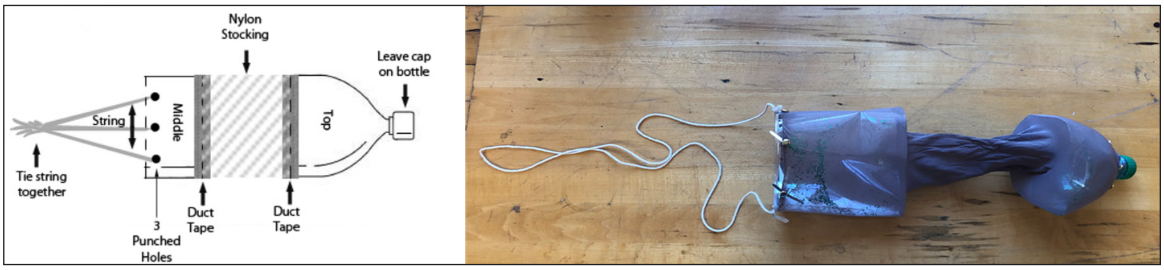

Figure 2: Diagram of how to construct a makeshift plankton tow (left; from NJ Sea Grant Consortium), and a photograph of the assembled phytoplankton tows used by Mr. Hinkel's fifth grade class (right). Photo: Kyla Kelly. Reproduced with permission of the photographer.

The students used makeshift nets, known as phytoplankton tows, to collect their own water samples and phytoplankton. The plankton tows, constructed from plastic soda bottles and pantyhose, were assembled prior to the lesson according to instructions adapted from the New Jersey Sea Grant Consortium's "How to Construct a Soda Bottle Plankton Net" (New Jersey Sea Grant Consortium; **Figure 2**). Large tote bins were filled halfway with water, and green glitter was sprinkled on the surface to represent phytoplankton (chlorophyll-containing) cells. We recommend using a biodegradable form of glitter, as it promotes the value of marine ecosystem protection and sustainability. Students then collected the "phytoplankton" by dragging their nets through the water, which allowed the "cells" to accumulate in the collection bottle as the water flowed through. When the tow was complete, the nets were removed from the water and the cap at the end of the soda bottle was unscrewed, allowing the contents of the net to be released into a sample bottle. Students enjoyed trying to see how much phytoplankton they were able to collect (**Figure 3**).

Figure 3: Students performed their own plankton tows with makeshift nets, collecting "phytoplankton" (represented by green glitter) from the "ocean" and putting them in a sample bottle to take back to the lab. Photo: Dieuwertje Kast. Reproduced with permission of the photographer.

Once the students had collected their phytoplankton cells from the ocean, they were asked what they thought the next steps were in the process of conducting scientific research. This part of the lesson aimed to inform students about what scientists, such as the graduate students working in research labs at USC, do in a lab environment. Many students said that they knew experiments were done in the lab but did not know what exactly these experiments consisted of. Students were told that researchers grow phytoplankton under different environmental conditions and measure how this affects their growth and survival. It was helpful to first connect this concept back to land plants: what do they need to grow? Sunlight, soil full of nutrients, water, and carbon dioxide. Phytoplankton, the plants of the sea, have similar requirements for growth. Scientists try to figure out what happens when these requirements for growth are attenuated or missing altogether. For example, what happens if there is insufficient sunlight to support photosynthesis? Plants and phytoplankton cannot harness the energy they need to photosynthesize and grow, ultimately causing a deficit in energy at the base of the ocean food web. Putting this research in the context of climate change, a topic that is currently being studied by many MBBO labs at USC, students were asked to consider what happens to the atmosphere in situations of excess carbon dioxide, a key chemical player in the equation of photosynthesis. On one hand, phytoplankton and plants may have more of the reactants they need to perform photosynthesis and could theoretically grow at higher rates with more carbon dioxide available. On the other hand, the excess carbon dioxide causes ocean acidification, which can be detrimental to phytoplankton and other marine organisms (Kroeker et al. 2010). Describing the uncertainty of how plankton will react to climate change helped the students walk through the thought process that goes into addressing these important research questions and to understand why scientists do these experiments with phytoplankton samples collected from the field.

Mr. Hinkel's class enjoyed exploring the labs, learning about the process of conducting scientific research, and viewing the marine organisms in the aquarium and under the microscope. These lab tours provided the students with valuable context for conducting scientific research in the real world, bridging the gap between the information they learn in school and where this research data is generated. This experience also enabled students to expand on what they had learned about in the classroom pertaining to photosynthesis on land; their knowledge of this topic was greatly enhanced by incorporating information about phytoplankton, creating a more complete and holistic picture of this globally important process. Furthermore, visiting the campus and interacting with scientists in the university environment exposed students to potential careers in STEAM-related fields and to an average day in the life of a researcher in these fields. In this way, the lab tours were a valuable experience for students, and enhanced their understanding of how knowledge gained in the classroom can be relevant to their own lives.

In order to gauge how this activity enhanced students' understanding of phytoplankton's role in photosynthesis, educators could have students draw a diagram of the photosynthetic processes on the Earth, incorporating elements from both terrestrial and aquatic ecosystems. Examples of what we expected to be included in the diagrams or descriptions include the uptake of carbon dioxide by both land plants and phytoplankton, with the release of equal amounts of oxygen from both sources. Alternatively, a simpler pre- and post- test with a rubric could also be used to quantify a change in students' understanding of marine phytoplankton. Younger age groups could be asked to draw phytoplankton before and after the lesson, while older grade levels could be asked questions such as the following: what is a plankton? What are the different kinds of plankton? What roles do phytoplankton play on the planet? The rubric will be based on a scale of 1 to 3, with 1 meaning the student has little to no knowledge of the subject, 2 being some knowledge, and 3 meaning that that student has a great deal of background information about the subject. An example of this assessment can be found with the supplemental materials.

The phytoplankton tow activity has been written up as a lesson plan and includes step-by-step instructions for constructing the makeshift net tow (see resources). Our lesson plans have been aligned to fifth grade NGSS standards. Specifically, we addressed standards 5-PS3-1 and 5-LS1-1 by incorporating information about how phytoplankton photosynthesis is driven by energy derived from the sun, carbon dioxide, and nutrients that are obtained from the water. By talking about the role of phytoplankton in marine food webs and their key role in ecosystem function, we also addressed standard 5-LS2-1.We hope that this will serve as a helpful resource for educators at schools and other marine education outreach events, allowing us to reach a broader audience.

Resources

Phytoplankton Lesson Plan
https://www.google.com/url?q=https://docs.google.com/document/d/1UxjUKdde2eJEoLXo3REcsiVwNeYHi_X1zB30YRiBpFk/edit%23heading%3Dh.xx8x11ugilmp&sa=D&ust=1558032178647000&usg=AFQjCNH_hliMyXCSq7EBszeDvrjXt7XapA

"How to Construct a Soda Bottle Plankton Net" (New Jersey Sea Grant Consortium) http://njseagrant.org/wp-content/uploads/2014/03/Plankton-How_to_Construct_a_Soda_Bottle_Plankton_Net.pdf

Additional File

The additional file for this article can be found as follows:

- **Plankton Supplementary Assessment.** Plankton knowledge assessment for the participating students. DOI: https://doi.org/10.5334/cjme.28.s1

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Competing Interests

The authors have no competing interests to declare.

Author Contributions

Both authors contributed equally to article writing and educational activity creation.

Author Information

Kyla Kelly is a graduate student at the University of Southern California pursuing a Ph.D. in Marine Biology and Biological Oceanography. Her passion for phytoplankton began during her undergraduate career at the University of New Haven and with the National Oceanographic and Atmospheric Administration. At USC she now studies the combined effects of changing environmental conditions (such as carbon dioxide concentrations, temperature, and nutrient concentrations) in order to predict the occurrence of toxic harmful algal blooms in the context of climate change. At USC she became interested in ocean outreach and education, leading her to start volunteering for JEP's YSP, where she has used her knowledge of and passion for marine phytoplankton to write marine science-based curriculum and teach lessons on the importance of phytoplankton in various LAUSD classrooms.

Dr. Dieuwertje Kast focuses her work on creating STEM programs, providing professional development and mentorship, and supporting integrated STEM education throughout California. Through her efforts, she has provided STEM instruction to over 26,000 underrepresented minority students, 500 educators, 20 school principals, and countless members of the community. Kast has not only revitalized the Young Scientists Program (YSP), but also doubled the number of students and teachers served through the program.

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