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Message in a (Plastic) Bottle

ACTIVITIES AND PROGRAM MODEL

SAVANNAH M. GEIGER
MARY CARLA CURRAN
SUE C. EBANKS
*Author affiliations can be found in the back matter of this article

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ABSTRACT

Microplastics are plastic pieces less than 5 mm in diameter and are a widespread contaminant in waterways worldwide. Microplastics can be split into four categories: beads, fragments, thin films, or fibers. In this activity, students learn about microplastics in the environment and as hazards to marine life. Students create a "MicroGlobe" that mimics real-world microplastic contamination in marine environments. Students calculate the percentages of different types of microplastics and generate pie charts of the collected data. They are challenged to think about ways they can be better stewards of the Earth and their answers in the math exercise are used to answer questions about how their "MicroGlobes" differ from real-world data in the provided Activity Packet. This activity has modifications for students with visual impairments.

CORRESPONDING AUTHOR:
Sue C. Ebanks
Marine Sciences Program, Savannah State University, Box 20467, Savannah, GA 31404, USA
ebankss@savannahstate.edu

KEYWORDS:
microplastics; plastic; plastic debris; recycling; pie charts; visually impaired

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BACKGROUND

Mass production of plastic began in the 1950s because it was cost-effective, usable at a wide range of temperatures, lightweight compared to its strength, and was durable (Andrady & Neal, 2009). However, complete plastic degradation is estimated to take hundreds to thousands of years; thus, nearly all historically created plastics still exist (Cozar et al., 2014). Plastic waste has been found in almost all aquatic environments including rivers, coastal waterways, the open ocean, and even the polar and deep seas. Despite recycling efforts being made worldwide, there was an estimated 4.8–12.7 million tons of plastic waste that entered the environment in 2010 from the 20 countries analyzed (Jambeck et al., 2015). Some ways to decrease plastic prevalence include using biodegradable materials, reducing the production of plastics, recycling, and redesigning filtration systems at wastewater treatment plants to remove plastics (Wu et al., 2017). Additionally, people can participate in beach or river cleanups, contact city officials, or reuse and upcycle their own plastics, finding a secondary use for an item (e.g., reusing a milk jug to water flowers in a garden).

Microplastics are plastic pieces that are less than 5 mm in diameter and can be formed by breakdown of larger plastic debris. (Andrady, 2011). Wave energy and solar energy cause the degradation of pieces of plastic debris in surface waters (Gregory & Andrady, 2003). Microplastics can be divided into categories based on their shapes: fiber (e.g., from clothing), fiber bundles (e.g., many fibers of clothing aggregate into clumps), films (e.g., from cellophane packaging), filaments (e.g., from fishing gear), and fragments (e.g., from weathered water bottles) (Hidalgo-Ruz et al., 2012). Fibers and fragments are the most common types of microplastics in the ocean, comprising up to 91% of all microplastics (Lusher et al., 2014).

Not all plastics exhibit the same properties in the marine environment. The density of seawater relative to plastic has the potential to affect where microplastics concentrate in the water column (Andrady, 2011). Plastics with densities less than seawater (approximately <1.02 g/cm^3) float at the surface of the water, similar to plastics floating within the Great Pacific Garbage Patch (NOAA). Plastics with densities greater than the seawater (approximately >1.02 g/cm^3) often sink to the bottom or remain suspended in the water column at or near the depth that corresponds to the density of the plastic particles. Additionally, physical forces such as storms, currents, and waves also transport or resuspend sinking particles (Li et al., 2020). Microplastics are present throughout the water column, which means that many organisms can be exposed to them (Galloway et al., 2017). Harmful effects to wildlife include bioaccumulation, decreased growth, reduced feeding, a decline in energy storage, and death (Galloway et al., 2017). Also, large plastic debris can entangle marine life including sea birds, sea turtles, fish, whales, and dolphins (Laist, 1997).

The present activity was created by a student at Savannah State University and these real-world data were obtained as part of the thesis requirement (Geiger, 2021). The field sampling portion of this research took place in spring 2019 within coastal waters near Savannah, Georgia. One strength of this activity is that reused material is used, emphasizing how ubiquitous plastics are in our homes while minimizing the wastefulness associated with using new items. There are also modifications for the visually impaired. The objectives of the present activity are to:

(1) teach students about the different types of microplastic pollution and ways to decrease its prevalence;

(2) determine the types of plastic particles a master's student found in coastal waterways of Savannah, Georgia and graph relative percentages on a pie chart;

(3) guide students in constructing a "MicroGlobe" after they select the numbers and types of repurposed plastic items from those provided by the teacher and compare these values to real-world data.

STUDENT GLOSSARY

Degradation – the process by which a larger object breaks into smaller pieces, a decrease in size or change to a damaged shape

Fiber bundles – a shape of microplastic most commonly described as many fibers of clothing aggregate into clumps (Hidalgo-Ruz et al., 2012)

Fibers – a shape of microplastic that most commonly derives from clothing (Hidalgo-Ruz et al., 2012)

Filaments – a shape of microplastic that most commonly derives from fishing gear (Hidalgo-Ruz et al., 2012)

Film – a shape of microplastic that originates most commonly from cellophane packaging (Hidalgo-Ruz et al., 2012)

Fragments – shape of microplastic created from weathered water bottles and other plastic debris (Hidalgo-Ruz et al., 2012)

Microplastics – pieces of plastic that are less than 5 mm in diameter (Andrady, 2011)

STANDARDS

This activity is designed for middle school students (grades 6-8) using the standards below:

Next Generation Science Standards (NGSS Lead States, 2013):

> MS-ESS3-3 Earth and Human Activity
>
> Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
>
> 5-PS1-3 Matter and Its Interactions
>
> Make observations and measurements to identify materials based on their properties.

Common Core Math Standards (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010):

> CCSS.MATH.CONTENT.6.RP.A.3
>
> Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.
>
> CCSS.MATH.CONTENT.6.RP.A.3.A
>
> Make tables of equivalent ratios relating quantities with whole-number measurements, find missing values in the tables, and plot the pairs of values on the coordinate plane. Use tables to compare ratios.

Ocean Literacy Principle (National Marine Educators Association, 2021):

> Principle 6: The ocean and humans are inextricably interconnected.
>
> 6d. Humans affect the ocean in a variety of ways. Laws, regulations, and resource management affect what is taken out of and put into the ocean. Human development and activity lead to pollution (point source, non-point source, and noise pollution), changes to ocean chemistry (ocean acidification) and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
>
> 6g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Safety:

Students use small materials that are potential choking hazards. Materials in this activity (e.g., cut pieces of plastic) have sharp edges. Supervise students during the activity. The teacher evaluates whether materials are cut in advance or if students can safely use scissors themselves. Additionally, glass jars used in this activity are breakable.

Materials List (for a class of 20 students):

- 20 clear/transparent glass jars, with lids that do not leak and a volume no larger than 1 L (34 oz) but no smaller than 0.18 L (6 oz) (e.g., pickle jar, pasta sauce jar)
- Pieces of either cut household plastic materials such as ribbon (this floats) and/or individual sequins (for suspension in the "MicroGlobe") for a total of 180 pieces that are small enough to fit in jars. Note that the teacher could prepare these items prior to the activity.
- 180 pieces of plastic bottles that are small enough to fit in jars (these float). Note that the teacher could prepare these items prior to the activity.
- 180 puff balls (pom-pom size, approximately 2.54 cm (1 in.) diameter) (these sink)
- Permanent markers
- Colored pencils or markers
- Tap water (enough to fill jars)
- Timers or stopwatches
- Calculators
- Ocean animal figurine/s (optional)
- "MicroGlobe" Activity Packet (one per student)

Modifications:

The teacher could easily substitute different items for the ones that we indicate in this activity. Some other materials that could be used are pieces of rubber bands (these float), pieces of straws (these float), glitter (this suspends in the "MicroGlobe"), and buttons (these sink). Students with visual impairments can utilize the modified activity packet with larger, darker text found in Supplementary File 3. The teacher can also trace the pie charts with puff paint prior to the activity and use textured paper or felt, which allows students to feel the different types of materials that represent the types of microplastics.

Time Requirement:

Estimated time to complete the activity is 2 class periods (approximately 90 min) one to complete the tables on page 1 and 2 of the Activity Packet and the other to build the "MicroGlobes" and answer discussion questions.

Procedure:

The teacher provides some background information about microplastic pollution in the environment. Pre-activity questions include:

What kind of plastics might be found in the ocean?

How do they get there?

Are all plastics the same?

What plastic items do you use?

What are some negative impacts on marine organisms?

1. Students begin by working on Part 1 of the Activity Packet.
    a. Students calculate the percents of the different types of microplastics from the real-world research project.
    b. Students round these values to the nearest 5%. There are 10 pie slices on the pie chart, so students can divide the slices in half, if needed.
        i. Example: On page 1 of the Activity Packet, there are 28 fragments out of 309 microplastics total. Students divide 28 by 309 to get 0.09 or 9%, and then round to 10%. An example of a student pie graph is in Figure 1. An answer key to the table with the real-world data is in Supplementary File 2.

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c. If time permits, there are further discussion questions in Part 4 (page 4) of the Activity Packet to answer as a class or in small groups. Alternatively, the teacher assigns these questions for homework. For students who finish early or for an additional activity, there is an extension activity in Supplementary File 4 about the density of plastics.

Figure 1 A student displaying his completed "MicroGlobe" pie chart using the real-world data. Photo courtesy of Ben Wells.

2. Making a "MicroGlobe:"

   Students are making a keepsake art piece out of recycled plastic unless the teacher or some of the students want to upcycle the material to leave for a future class.

   a. Students begin by choosing 15, 20, or 25 pieces of each type of plastic to put in the "MicroGlobes"

      i. Choices can be made from cut household plastic materials such as the ribbon, plastic bottle pieces, and small puff balls as pictured in Figure 2.

Figure 2 Microplastic pieces that were used to create a "MicroGlobe." These are recycled household materials including ribbon, plastic bottle pieces, and small puff balls. Photo courtesy of Savannah Geiger.

b. Students record those data on page 2 of the Activity Packet to complete the table and calculate percents as they did for the real-world data.

   i. Example: If a student chooses to include 5 puff balls in the "MicroGlobe," the student will divide 5 by the total number of pieces in the "MicroGlobe" (15, 20, or 25) and convert that number into a percent. Next, the student will round the percent value to the nearest 5% and fill in the pie chart as demonstrated by the student pictured in Figure 3.

   ii. Note that the entire table should be completed, ensuring that the rounded percent abundance column adds up to 100% before coloring in the pie chart.

   iii. Students must use the same colors for both the real-world data pie chart and their own pie charts.

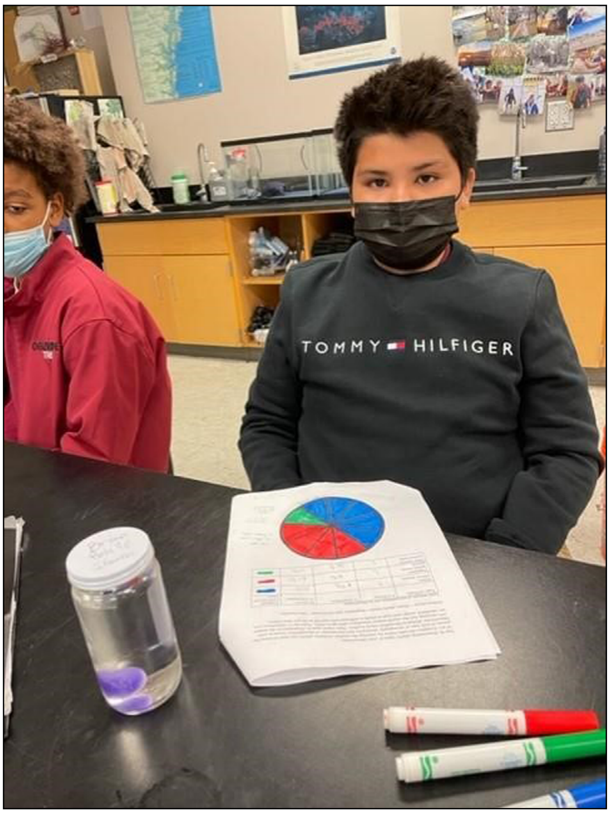

Figure 3 A student with his completed "MicroGlobe" pie chart, representing the contents of his "MicroGlobe." Photo courtesy of Ben Wells.

c. Once the table and pie chart are complete, students should begin building their "MicroGlobes." Each student should fill the jar with the number of pieces recorded on page 2 of the Activity Packet.

   i. Example: In Figure 4, students are pictured with their "MicroGlobes" filled with plastic pieces and water.

d. Once all of the pieces are in the "MicroGlobe," students should put their names on the lids of the jars using masking tape or permanent marker.

   i. Note that rubbing alcohol easily removes permanent marker once the activity is complete so that jars are reusable for this activity again or for another purpose.

   ii. Note that names should go only on lids and not on sides, so that students may clearly view the contents inside the jars.

e. Students have the option to select an organism figurine/s, if provided. Figurines represent the potential for organisms to be impacted by plastic.

f. Once all items are in the jar, students fill the jars approximately ¾ full with tap water before tightly securing the lids on the jars.

g. Students may invert the jar to gently mix the contents and then answer the questions about density in the Activity Packet.

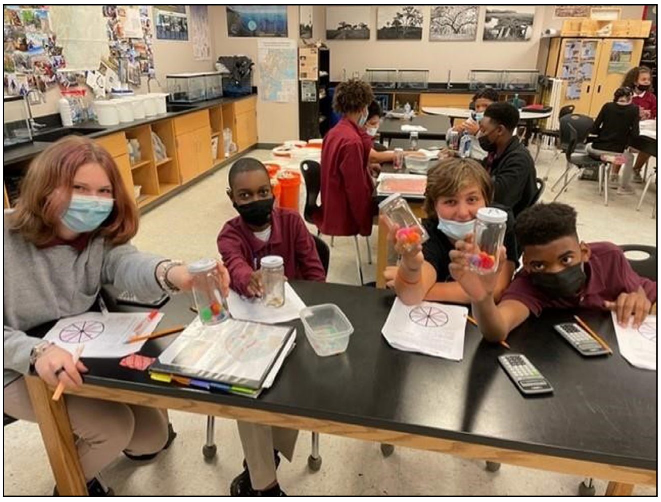

Figure 4 Students proudly displaying the contents of their "MicroGlobes." Photo courtesy of Ben Wells.

REFLECTIONS AND RECOMMENDATIONS

We tested this activity with 15 students in a 6th grade class. Students enjoyed the different aspects of the activity. Some preferred the math portion, and one student even said that calculating percentages was her favorite math exercise to do, which was surprising to us. Other students enjoyed the creativity of constructing the "MicroGlobe" and liked watching the objects swirling in the water. They saw that it tied into lessons in which they had been learning about the impacts of pollution (e.g., animals get hurt or sick, turtles get stuck, eating plastic is not good for the stomach, it impacts the ocean).

Students were also honest and insightful when listing what plastic items they had used recently (water bottle, cookie packaging, keyboard, phone, notebook cover, even the trash can) and what they could use instead (reusable cup/water bottle, biodegradable material, metal, leather, wood, paper bags). They knew that their teacher used alternatives to plastic when packing his lunch every day. They also knew that they could help by recycling and by not burning plastic, throwing trash in the ocean, littering, or leaving things at the beach. They knew that sewers carry waste to rivers, estuaries, and the ocean.

It was clear while assisting and after discussion with the teacher that some students initially had trouble calculating percents (multiplying by 100) after determining the ratio of a particular microplastic type with respect to the total number of microplastic pieces. Sometimes instead of multiplying by 100 (moving the decimal two places to the right) they moved it to the left. Sometimes they guessed wildly or had a total sum of percents other than 100 and they had to then go back and determine which value was incorrect. However, once we went through one or two examples, they were able to master the exercise. Some even called it "straightforward." They seemed to have no difficulty rounding their percents to the nearest 5, coloring the appropriate number of pie slices, or dividing a pie slice in half (such as a pie with 45% fibers, 10% fragments, and 45% fiber bundles).

We allowed the students to vote on what color to assign the various components. In hindsight, we should have avoided picking red and green to accommodate students who might be colorblind and we should have picked a color other than orange if red was also chosen to enhance contrast between categories. When we tested the activity, the teacher had an unusually large class size to accommodate another teacher's absence so he used the colors for which he had the most crayons (red and orange). One recommended color palette is blue, yellow, and pink. In an advanced class or a class for which the focus is also graphing, students could have selected their own color palate, which would have created the opportunity for the class to discuss the benefits of contrast in visualizing data.

Additionally, this activity could be applied within the 5E lesson plan model of Engage, Explore, Explain, Elaborate, and Evaluate. Students are engaged from the beginning of this activity with a class discussion on plastics in the ocean. Students can explore their classroom together to determine single-use plastic items. They are then challenged to explain the differences in their data and real-world data using pie charts and calculating percents. Completion of the Activity Packet gives students the opportunity to elaborate on their findings through prompted questions. To conclude this activity, students evaluate their use of plastic and then challenge themselves to make positive changes in their lives to reduce plastic waste.

ADDITIONAL FILES

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

- **Supplementary File 1.** Activity packet. DOI: https://doi.org/10.5334/cjme.98.s1
- **Supplementary File 2.** Answer key. DOI: https://doi.org/10.5334/cjme.98.s2
- **Supplementary File 3.** Visually-impaired packet - larger, bolder text of the "MicroGlobe" Activity Packet. DOI: https://doi.org/10.5334/cjme.98.s3
- **Supplementary File 4.** Extension activity. DOI: https://doi.org/10.5334/cjme.98.s4

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHORS' CONTRIBUTIONS

Savannah M. Geiger collected the original real-world data, helped design the activity, conceptualized the "MicroGlobe," tested the activity in the classroom, and co-wrote the manuscript.

Mary Carla Curran helped design the activity, helped test the activity in classrooms, and co-wrote the manuscript.

Sue C. Ebanks mentored the original research that laid the foundation for the "MicroGlobe," helped test the activity in a classroom, and co-wrote the manuscript.

AUTHOR INFORMATION

Savannah M. Geiger is a graduate of Savannah State University's Master of Science in Marine Sciences program. She is interested in the transportation of microplastics in the ocean and how marine organisms are affected by plastic ingestion. She enjoys bringing her science to life through classroom activities and hopes that her work can inspire the next generation of scientists.

Mary Carla Curran retired as a Full Professor in the Department of Marine and Environmental Sciences at Savannah State University and is now professor emerita. She is an active member of the National Marine Educators Association and has extensive experience translating scientific research into peer-reviewed K-12 activities often with modifications for the visually impaired. She is passionate about outreach activities and hopes to encourage students to remain interested in the sciences. Her areas of research include fish biology, parasite-host interactions, and estuarine ecology.

Sue C. Ebanks is a Full Professor in the Department of Marine and Environmental Sciences at Savannah State University. She is actively involved in the National Association of Geoscience Teachers. She collaborates with the Historically Black Colleges & Universities (HBCU) Geosciences Working Group and the Science Education Resource Center (SERC) at Carleton College to develop resources to support training of pre-service teachers and professional development of in-service teachers for the geosciences. Her primary areas of research are invertebrate physiology and toxicology.

AUTHOR AFFILIATIONS

Savannah M. Geiger
Marine Sciences Program, Savannah State University, Box 20467, Savannah, GA 31404, USA
Mary Carla Curran orcid.org/0009-0007-0423-0785
Marine Sciences Program, Savannah State University, Box 20467, Savannah, GA 31404, USA
Sue C. Ebanks orcid.org/0000-0001-8886-7730
Marine Sciences Program, Savannah State University, Box 20467, Savannah, GA 31404, USA

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