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# Microscopic Communities: Interdisciplinary Exploration of Microbes in the Classroom†

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**Children are aware of microbes from a young age and are rightly encouraged to wash their hands to prevent illness. However, myriad microbes live in, on, and around us, most of which are benign or beneficial. Our goal was to teach elementary students about microbiota by leveraging familiar literacy practices, social studies themes, and the arts to advance students' knowledge and reasoning skills in science. With this perspective in mind, we developed and implemented an interdisciplinary unit targeted at second grade, in which students learned about microbes and microbial communities. Our goal was to further students' conceptual knowledge of the microbes that surround them by purposefully integrating microbial communities within the second grade curriculum. Throughout the unit, students engaged in hands-on, inquiry-based science experiences and used multimodal communication (through a combination of linguistic, visual, audio, gestural, and spatial modes): they sampled microbes from their own bodies and/or environments and applied their knowledge and imagination to create their own microbes through art and story-telling, generating a class microbial community—both literal and artistic. At the end of the unit, students demonstrated knowledge of microbes and of the diversity and ubiquity of microbial communities and habitats.**

## INTRODUCTION

Microbes are all around us, on us, and within us. The term microbiota refers to diverse communities of microbes that live in different habitats. It is often used interchangeably with the word microbiome, a term that is defined in different ways depending on the context. In genomic terms, it refers specifically to the genomes, or genetic material, of all microbes within a community (1, 2). It also refers to the sum of microbes and their genetic material in a given community or habitat (2, 3). For clarity, we will use the term microbiota to describe microbial communities that perform different functions, interacting, cooperating, and conflicting with one another. Balance and diversity within microbiota is important for the health and function of the entire community, just like our own human communities. Microbes communicate with each other by releasing and sensing signals from each other that can lead to changes in behavior, morphology, and/or functions of other microbes (1, 2, 4, 5). Microbiota include bacteria, viruses, fungi, and protists.

Children are conceptually aware of microbes; they hear about "germs" from a young age, with exhortations to wash their hands to prevent illness. In practical terms, though, microbes can be difficult to visualize. Nonetheless, microbes

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are fundamental to who we are and how our bodies and environments function. To facilitate an understanding of the microscopic, we developed a three-day, interdisciplinary unit for second grade students that focuses on microbes, building on familiar social studies concepts, the arts, and literacy practices. In particular, this unit drew upon disciplinary core ideas in the Next Generation Science Standards (NGSS) (6) and the Common Core State Learning Standards (7) that relate to biodiversity and interdependent relationships in ecosystems, noticing patterns and structure/function relationships, and processes involved with scientific investigations, while supporting literacy and math skill development. We developed strong university–school partnerships to bring this unit into the classroom (8).

Microbes are invisible to the naked eye, they live in, on, and around us, and they are different shapes, sizes, and even colors. They are everywhere, including extreme conditions such as tundras, volcanoes, deserts, icebergs, and the ocean floor. Microbes in the soil help plants grow by providing nutrients that the plants have trouble making themselves. They can create natural chemicals that act as pesticides so that crops do not have to be sprayed. Some microbes even use oil as food, converting the oil into byproducts that are less harmful to the environment; others break down plastics (5).

Microbes form communities in and on our bodies. The human body is home to millions of microbes, with most living in our guts and on our skin. Some microbes cause illness, but the vast majority are benign and many keep us healthy. They can affect our mood and prime our immune system. The microbial communities that live in our stomach help us digest our food. They also help fight off bacteria that make us sick. The communities on the dry habitat of our skin are composed of different microbes than those on the slightly oily habitat of our scalp. Our armpit forms a nice, moist habitat where many microbes can grow, but there is far more microbial diversity on the dry skin of our knees. In fact, our bodies provide many different habitats that suit different types of bacteria, and every person has their own set of microbiota that is somewhat unique to them (2, 4, 5).

In this unit, we took an interdisciplinary approach to underscore the fact that most microbes are beneficial and essential for our survival. We strategically connected new and prior knowledge with multiple opportunities to learn about microbes through reading, discussion, observation, movement, and composition (9). Microbes live in communities, grow rapidly, have different roles in our environment, and are diverse in how they look and move, allowing connections with social studies, art, math, and literacy. This unit's learning goals were to (a) learn about and describe microbes and colonies, (b) know that microbes live in communities and habitats everywhere, including on our bodies, (c) dispel the myth that all microbes are bad "germs," and, perhaps most important, (d) encourage a sense of curiosity and excitement about microbes and how they impact our world. This approach marks a paradigm shift in our thinking about the role of microbes in our lives.

## Intended audience

This unit was used in first to third grade classrooms, special education classes, and was expanded for high school biology. Individual teachers may emphasize different aspects of the exploration of microbiota with their students (e.g., comparing indoor and outdoor microbiota, storytelling, and categorizing and counting) (see Appendix 1). This unit was developed through university–elementary school partnerships. As a university entity, we engaged elementary teachers in several area schools to implement and improve this unit. The unit may be taught with any scientific partner with knowledge of microbial safety and access to an autoclave, which is required to safely carry out this lesson. Universities and colleges interested in implementing this unit should reach out to school district science directors or school principals. Teachers interested in finding a scientific partner may survey their classroom parents, contact university or college biology, microbiology, and biomedical sciences departments or biology-focused student clubs at postsecondary institutions. We trained undergraduate and graduate college students to provide instruction and/or support; this could be offered as an independent study or service-learning experience for college or high school.

## Learning time

This unit was designed for implementation over the course of three 45-minute class periods. The timing can be customized, depending on individual class needs and schedules.

## Prerequisite student knowledge

None required.

## Learning objectives

Essential question: Are all microbial communities the same?

1. Upon completion of this activity, students will know that microbes are living organisms all around us and exist in diverse communities. This objective is assessed by the Microbiota Lab Notes, where:
   a. Students will observe their microbial plates and complete the data table in their Microbiota Lab Notes, comparing and contrasting the physical attributes of the microbial colonies from different habitats and within the same habitat/community, including color, size, and texture.
   b. Students will conclude that different habitats support different microbes, using evidence from their data table to support their written explanations in the Microbiota Lab Notes.
2. Upon completion of this activity, students will know how the jobs of different microbes affect our health

and life on earth. This objective is assessed through a KWL chart, class discussions, and microbe art project. (A KWL chart is used by students to represent what they already know, want to know, and ultimately learn.)

a. Students will be able to explain how some of the roles that microbes have affect our health and life.
b. Students will create an art microbe, using their new knowledge of where microbes are found, what they do, what they look like, and how they move.
c. Students will tell a story about their art microbe.

## PROCEDURE

### Materials

- *Tiny Creatures: The World of Microbes* by Nicola Davies
- Chart paper and markers
- Agar plates with growth medium (Appendix 1)
- Petri dishes
- Sterile swabs
- Parafilm
- Microbiota Lab Notes
- Open-ended art supplies and construction paper
- Internet access (see Internet Resources in Appendix 1)

### Student instructions

Students will practice good lab safety, described and modeled by the teacher, on Days 1 and 2 and engage higher-order thinking skills through discussions, completion of a KWL chart, Microbiota Lab Notes and an art project (see Appendices)

### Teacher instructions

Agar plates need to be made or purchased prior to the first lesson. These can be ordered, made using scientific reagents, or made using gelatin and beef broth (Appendix 1). Teachers lead the students through three lessons of inquiry-based learning, beginning with a KWL chart about microbes.

**Day 1:** The lesson begins with a class KWL chart (Appendix 2) about microbes, which elicits students' prior knowledge and serves as a pre-assessment. Upon completion of the "know" and "want to know" columns, the teacher leads an interactive read-aloud of *Tiny Creatures: The World of Microbes* by Nicola Davies (10). This text provides exceptional comparisons and illustrations to assist students in visualizing microbes and understanding that (a) microbes exist everywhere, (b) they are essential to our world, (c) microbes and microbial communities are diverse, and (d) their growth and survival are based on microbial habitats. In addition to serving as valuable formative assessment tools, the KWL, read-aloud, and discussions provide opportunities for students to build background knowledge about microbes and microbiota, resulting in increased conceptual knowledge of microbes while developing vocabulary (11). During the read-aloud, terms from social studies like community and habitat are strategically connected to students' learning of microbiota. Following the interactive read-aloud and class discussion, students complete the "what you learned" column of the KWL chart, individually or as a group.

Conceptual knowledge of microbes and microbiota is further developed through inquiry experiences. To become familiar with what microbes are and how they may look, the scientific partner may bring a microscope for students to observe live yeast cells (see Appendix 1). Alternatively, students may view pictures and videos of microbes moving, e.g. paramecia and amoeba (see Internet Resources in Appendix 1). Students engage in physical movement that embodies microbial movement. These opportunities for bodily-kinesthetic movement and imagination open up varied forms of participation and support students' learning (12).

The teacher leads students through the development of their own experiments to grow microbial communities from different habitats. To personalize their understanding of microbial communities and habitats, students sample the microbiota in their own environments. Students are also introduced to the essential question, "Are all microbial communities the same?" The students develop scientific hypotheses about microbial communities from two different habitats on their bodies (e.g., head, armpit) or the classroom (e.g., keyboard, desk).

Teachers should cultivate a culture of lab safety with their students throughout this unit. In preparation for the lab experiment, desks are cleared of all food and drink, including water bottles, and students wash their hands. Teachers guide students' use of sterile cotton swabs to sample the habitats and streak the samples onto agar plates containing nutrient-rich agar (Fig. 1), moving the swab gently back and forth across the plate to separate the microbes. Teachers tell students that rich media is great food for many microbes, so it is important to only touch the swab to the plate. Teachers seal the agar plates with parafilm and explain that this will keep the moisture in during incubation and that it also protects them. Although most microbes are benign, some harmful microbes may grow on the plates. The plates are placed in a warm spot in the classroom for up to one week. After completing their experiments, students clean their desks with disinfecting wipes and wash their hands with soap and water.

**Day 2 (1 week later):** The teacher begins the unit's second lesson with a discussion that elicits what students have learned about microbes and microbiota and adds this information to the KWL chart. Students then review the experiments and their hypotheses. Prior to distributing their agar plates, the teacher reminds the students that, while most microbes are good, some are bad and explains that some bad microbes may have grown on the agar plates.

For that reason, the teacher instructs students to use only their sense of sight to make their observations and states that the agar plates are not to be opened nor taken out of the classroom. As on Day 1, the students clear their work spaces of everything, including water bottles and wash their hands before their sealed plates are distributed. The plates must remain sealed for the observation. Students use the Microbiota Lab Notes (Appendix 3) as a guide for making observations and drawing conclusions, based on the number, size, texture, and color of the colonies.

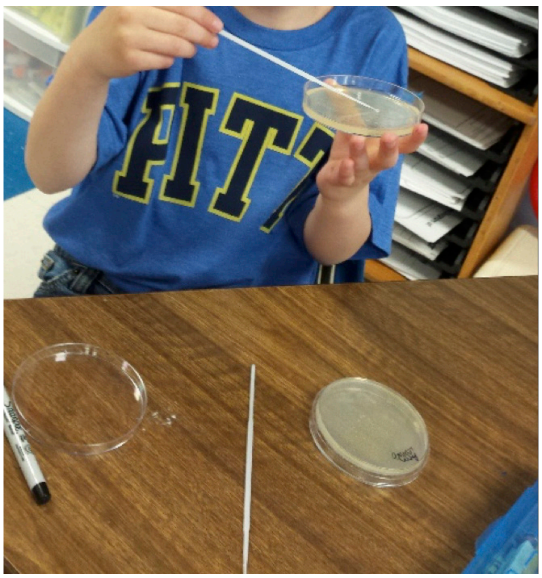

FIGURE 1. Student streaking sample onto agar plate.

While working on their Microbiota Lab Notes, students engage in productive talk (13) about the microbial colonies they observe and their similarities and differences. Productive talk promotes science learning through dialogue that allows students to listen, articulate, and build on ideas with and from others. As a formative assessment measure, teachers can listen to student discussions, ask students questions, and record important aspects of their communication in the Anecdotal Records (Appendix 4). Moreover, the Microbiota Lab Notes assess students' abilities to document their observations and interpret a data table (see Appendix 5 for an example rubric, which may be adapted by teachers to meet their students' needs) in order to compare and contrast microbiota. These assessments allow students to share their ideas and what they have learned in various ways. Students must clean their desks with disinfecting wipes and wash their hands when they are finished making their observations. Teachers should seal the plates in bags, and the scientific partner should sterilize them by autoclaving before discarding (see instructions below).

**Day 3 (up to 2 weeks later):** In the third lesson, information about microbes is reviewed, and students apply their knowledge to create their own microbes. In this lesson, students engage in the process of transduction, or moving meaning from one mode of communication to another (14). The goal is to create tangible class microbiota, conceptualize the diversity of microbial communities, and support the imagination and creativity inherent in both science and art. Students consider what their microbe would look like, how it would move, get food, and interact with other microbes. To create their art microbes, students use open-ended construction art supplies. They reference the KWL chart, Microbiota Lab Notes, microbe images, and use their imaginations to create a story about their microbe and its community. When creating and sharing their microbial artwork, students focus on the skills of self-expression, observation, reflection, and exploration, while stretching their imaginations, and making meaning, all key aspects of art education (15).

### Suggestions for determining student learning

Students will be assessed based on the following:

- KWL chart (Appendices 2 and 7)
- Microbiota Lab Notes (Appendices 3 and 5)
- Microbial Art Project (Appendix 6)
- Participation in discussions (Appendix 4)
- Observations (Appendix 4)

### Sample data

Sample data are discussed in the Evidence of Student Learning section.

### Safety issues

Instructors must follow the ASM Biosafety Guidelines regarding sampling of environmental microbes (16). Swabbing environmental samples will result in the collection of unknown microbes, which are typically categorized as biosafety level 2 (BSL-2), and may result in the growth of pathogenic isolates. Therefore, plates MUST remain sealed and safety procedures MUST be followed and communicated clearly to students. Agar plates are sealed with parafilm immediately after inoculation to prevent them from accidentally opening. Students and teachers only observe them with their eyes. Students wash their hands with soap and water and wipe their desks with disinfecting wipes after making their observations. Teachers collect the plates once observations have been made. Plates must be autoclaved before being discarded.

## DISCUSSION

### Field testing

This unit has been modified over several iterations of implementation in various classrooms across schools and school districts. To assess student learning, we had conversations with students throughout the unit, in addition to evalu-

**Fig. 2A**

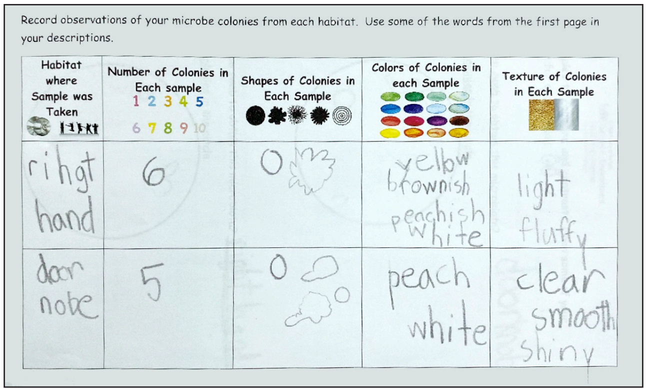


**Fig. 2B**

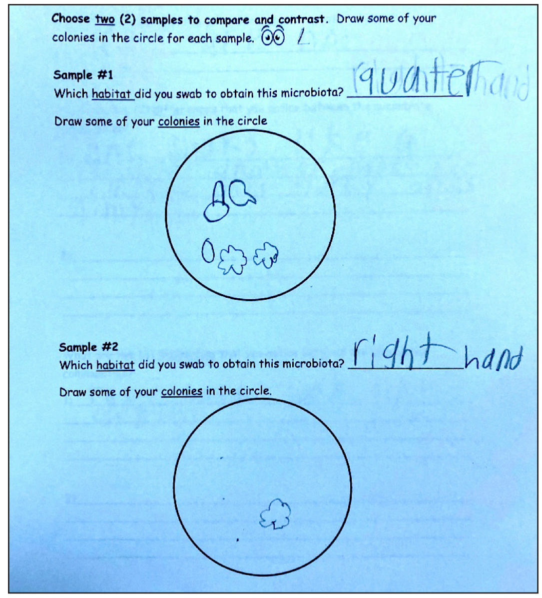


**Fig. 2C**

**Fig. 2D**

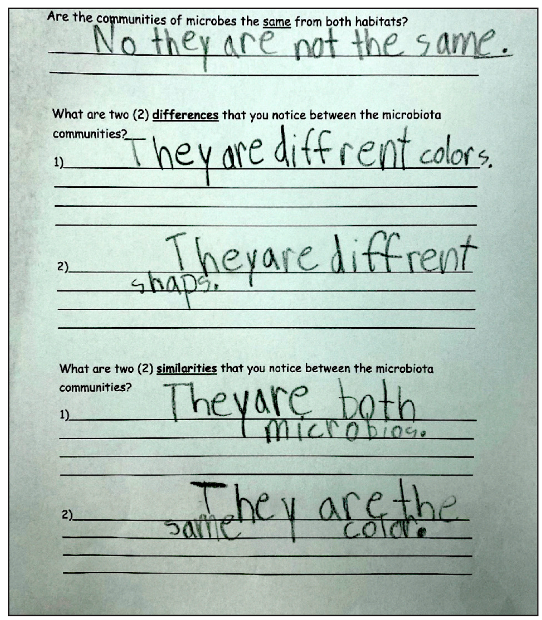


FIGURE 2. (A) This student properly labeled the rows of the table and filled in accurate descriptions of the observations of each plate. (B) This student swabbed a quarter and their right hand. The drawings accurately depict the colony growth that was observed on the plates and show the different colony shapes that grew. (C) Agar plates after incubation gathered together. Student names have been blurred for privacy. (D) This student used the observation chart to draw conclusions about the observed similarities and differences. Color was written as both a similarity and a difference because the student observed that some colonies were the same color but they were not all the same color.

ating lab reports and art projects. Students recognized that the microbial colonies from one habitat typically looked different than those from another habitat and often observed more than one colony type from a single habitat, indicating a community. In some iterations, note-takers listened to the Day 3 conversation. These assessments revealed that students retained and enhanced their knowledge of microbes and microbial communities through the unit.

In field testing, the most significant change was made to the observation and lab notes materials. We realized that some students required more scaffolding to complete the Microbiota Lab Notes. Initially, the lab report contained only open-ended questions for students to record observed similarities and differences between colonies from two habitats. Many students required more guidance, including prompts to observe the colors, shapes, textures and number of colonies. Therefore, we replaced the open-ended questions with a guided data table (Fig. 2a). To assist students in completing the data table, we added a word bank and pictures for the colony shapes and rephrased written and verbal directions. Students were reminded not to touch the colonies to determine texture but to write what the texture looks like (e.g., slimy, goopy, fuzzy, etc.) instead.

Some students misinterpreted the directions for drawing the colonies observed from each habitat. We observed students drawing pictures of the habitats (Fig. 3) or drawing exactly what they saw on their plates, including their labels and names. The initial direction statement included two parts, to write the habitat which was swabbed, and draw the colonies that were observed. This direction was modified to: (1) What habitat did you swab? and (2) Draw the colonies. Following this change, students drew the colonies in each habitat (Fig. 2b).

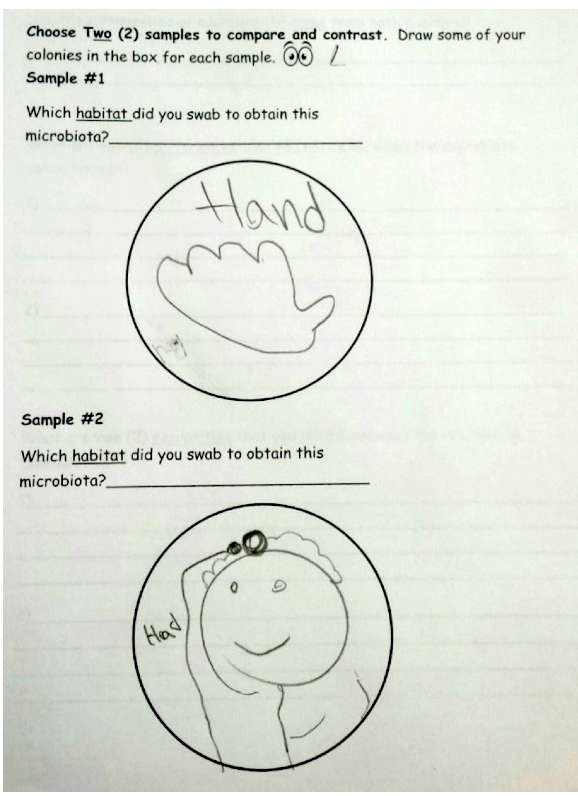


FIGURE 3. A student's misinterpretation of the instructions in an early Microbiota Lab Notes packet.

## Evidence of student learning

The KWL chart, Microbiota Lab Notes, and art project reinforce and assess students' knowledge about microbes and microbiota at each stage of the unit. In line with equitable assessment approaches, various measures are used that allow students to express their learning in multiple, varied ways.

**KWL Chart.** The KWL chart consistently demonstrates that younger children initially do not have robust prior knowledge of what microbes are, where they are found, and what roles they have in our health and wellness. In Appendix 7, we list the most common answers that students give for each column. Students who do have familiarity with "microbes" understand them to only be "bad" germs and know that those germs live in and on us. The students put significantly more content in the "What Do You Want to Know" column than in the "What Do You Know" column, indicating their curiosity about microbes and their interest in learning more. After reading *Tiny Creatures: The World of Microbes*, students are able to answer many of their questions, but as we move through the workshop activities, more questions and answers are added to the chart.

**Microbiota Lab Notes.** Students observe the colonies that grew (Fig. 2c), using the Microbiota Lab Notes as a guide to record observations and draw conclusions. Students first record their observations in a data table (Fig. 2a), noting the quantity, shapes, colors, and textures of the colonies from each habitat, and draw the microbes they observe (Fig. 2b). Using both the data table and drawings as references, the students draw conclusions about the similarities and differences of the microbial colonies from different habitats (Fig. 2d).

**Art Project Assessment.** The art project allows students to express their new knowledge of microbes through a creative process. Students have access to pictures of actual microbes, as well as illustrations from *Tiny Creatures: The World of Microbes*. While the majority of students choose to use the open-ended art supplies to create their own fictitious microbes, some do their best to emulate microbes they see in the illustrations. Students are generally excited about creating a microbe, and it is important to walk around the room and remind students to think about the job their microbe does and what characteristics are important for it to do that job (Appendix 6). Asking questions such as: (1) What job does your microbe do? (2) What characteristics does your microbe have? and (3) Is your microbe good or bad? helps students channel their science knowledge and creativity into this project.

Students are encouraged to write stories about their microbes, which helps them connect the characteristics (good or bad microbes, shape, color, size, and habitat) to their creations. Figures 4a and 4b exemplify students' creative stories and their incorporation of new concepts. In Figure 4a, the student highlighted good microbes: *Patritia*, the microbe that breaks down food and *Strong Sergeant Army Man*, which fights bad microbes. In Figure 4b, the student focuses on the methods used by good microbes to defeat the bad *blob* microbes. When asked why the microbe in the middle of the page was long and skinny, the student responded that its job was to defeat bad microbes by tying, hence being made of yarn (Fig. 4b). Once the students have completed their art projects, the concept of microbiota is reinforced by gathering all of the art projects together to form "class microbiota" (Fig. 5).

**Fig. 4A**


**Fig. 4B**


FIGURE 4. (A) A student's story about the art microbial community she created with Patritia and the Strong Sergeant Army Man. (B) A student's story about the art microbial community he created about good microbes fighting bad microbes..

FIGURE 5. A class art microbiota.

**Possible modifications**

We implemented the unit in inclusion, 6-1-1, and 12-1-1 classes, with differentiation so that all students could participate. One modification is for all students to swab the same habitats, allowing the teacher to give clear instructions and demonstrate each step of the process. Instead of saying "swab two habitats," the teacher may model and explain, "swab your arm, like me." Another option for modification is to inoculate plates as a group. Students may be selected to perform different components of the experiment—labeling the sample location on the plate, swabbing a location, or putting the plate in a warm location. To extend this unit, teachers may emphasize different aspects of the exploration of microbiota (e.g., comparing indoor and outdoor microbiota, exploring exponential growth, engaging in storytelling, and categorizing, measuring, and counting colonies while documenting daily observations).

This lesson has also been modified for use at the high school level. The experimental component remains the same, but students first conduct research to identify microbes that are most commonly found on various body parts and in locations around the school (inside versus outside locations). More sophisticated essential questions can be addressed: (1) How do microbial communities affect the environment, our health, or life on earth? and (2) In what ways are different microbes interdependent? Students can also plan more complex experiments, answering questions like, "Which kills more microbes, hand sanitizer or soap and water?" High school and college students can also be mentored to "teach back" and lead lessons in second grade classrooms within their school districts.

## SUPPLEMENTAL MATERIALS

Appendix 1: Unit plan, including universal design for learning guidelines
Appendix 2: KWL chart
Appendix 3: Microbiota lab notes
Appendix 4: Anecdotal records
Appendix 5: Microbiota lab notes rubric
Appendix 6: Microbe art and writing project checklist
Appendix 7: Completed KWL chart exemplar
Appendix 8: Microbes found on the human body

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