This lesson plan was created by a teacher participating in the Research Experiences for Teachers program from the Precision Microbiome Engineering Research Center. Are you interested in spending part of your summer in a lab getting paid to do microbiome research and create lesson plans?

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Lesson plan by McKenna Martin

Title
Exploring Earth's Hidden Heroes: Unveiling the Secrets of Microbes and Soil

Overview
In this lesson, students will apply prior knowledge from previous lessons (soil, natural resources, pollution, and human health) and apply this knowledge to an introduction into microbiomes. After a brief introduction to microbiomes, students will take a closer look into how microbes affect soil, do some soil analysis of their own, and connect soil health back to human health.

Key Search Words
List relevant search words: Earth/Environmental Science, 9th grade, Microbiomes, Microbiology, Microbial ecology, Microbial diversity, Soil microbiology, Microorganisms, Bacteria, Fungi, Soil composition, Soil types (e.g., sandy, clay, loam), Soil analysis, Soil sampling techniques, Plant-microbe interactions, Microbial biomass measurement, Fungi to bacteria ratio, DNA sequencing (related to soil microbes), Biogeochemical cycles

Learning Objectives
Learning objectives or outcomes are what students are expected to know after completing the lesson.
- Define microbiomes and their composition
- Explain the importance of microbiomes in human health
- Discuss the impact of microbiomes on soil health
- Understand how to collect and prepare soil samples for testing
- Analyze the relationships between microbiomes, human health, and soil health

Curriculum Alignment
Curriculum alignment is the relationship of the lesson to the NGSS or the North Carolina Essential Standards. List specific goals and objectives that this plan addresses (e.g., EEn.2.6.4).
- **ESS.EES.6.1 Analyze and interpret data to infer how use of natural resources impacts ecosystems and human populations, including human health.**

Classroom time required
Classroom time required is the amount of time a teacher will need to schedule for implementation of this lesson plan. If your lesson includes multiple activities, you will want to specify the amount of time (minutes, hours, class periods, or weeks) each activity is projected to take.
- This lesson is meant to take place over two consecutive days on a block schedule, where each block is typically 90 minutes long
- In order to reuse lab materials, and allow for enough time to clean and reset materials, it is recommended that each block staggers this lesson plan by 1 day. (e.g. Block 1 starts lessons on Monday and completes on Tuesday, Block 2 starts lessons on Tuesday and completes on Wednesday, Block 3 starts lessons Wednesday and completes on Thursday.)

Materials & Technology
Materials Needed

- Brain Dump Handout
- Field Journal Handout
- Map Assessment Rubric
- This lesson requires that the students work in groups of 3 so the classroom be arranged to accommodate
- microBIOMETER® Classroom Kit
    - 100 Test cards, 100 Reagent packets, 10 Extraction vials, 10 Pipettes, 10 Soil sampler syringes, 10 Testing platforms, 10 Whiskers, 10 Soil sifters, 10 Capped measurers, 10 Spatulas, 1 Magnet, 1 Test tube rack
    - 3 Test cards, 3 Reagent packets, 1 Extraction vial, 1 Pipette, 1 Soil sampler syringe, 1 Whisker, 1 Soil sifters, 1 Capped measurer, and 1 Spatula **per group of 3 students**.
- Clear, plastic bags to hold soil samples
- Access to a sink to rinse off lab materials
- Access to a refrigerator to store soil samples
- Personal Protective Equipment (PPE)
    - googles, **1 per student**
    - gloves, **at least 3 pairs per student**

Technology Resources

- Internet Connection
- Google Applications (Slides, Docs, Drawings, etc.)
- Projector or SmartBoard to project provided Google Slides Presentation
- Computers or Laptops, **minimum: 1 per group**
- Smartphone (iPhone or Android), **minimum: 1 per group**
- microBIOMETER® App (will be downloaded on Smartphone for soil analysis) ***not yet compatible with the iPhone 15 PRO series***

Safety

This lesson plan will require students to complete soil testing as well as a soil sample analysis. When conducting soil analysis there are several safety issues that the teacher needs to be aware of to ensure the well-being of students and maintain a safe learning environment.

- Chemical Hazards: Soil testing often involves the use of chemicals such as acids, bases, and solvents. Teachers must ensure that students are trained in the safe handling of these chemicals, including wearing appropriate personal protective equipment (PPE) such as gloves, goggles, and lab coats. Chemicals should be stored properly and used in well-ventilated areas to prevent inhalation of fumes.
- Biological Hazards: Soil may contain microorganisms, fungi, and other potentially harmful biological agents. Students should be instructed to wash their hands thoroughly after handling soil samples, especially before eating. Avoiding ingestion of soil and preventing contact with open wounds or cuts is also crucial.
- Physical Hazards: Soil sampling tools can be sharp and pose a risk of injury if not handled properly. Students should be trained in the correct use of these tools and supervised during their use to prevent accidents.
- Environmental Hazards: Soil may contain contaminants such as heavy metals or pesticides, especially in urban or agricultural areas. Teachers should be aware of potential environmental hazards and choose sampling locations carefully. If testing for contaminants, appropriate measures should be taken to prevent exposure and contamination of the testing area.
- Emergency Procedures: Teachers and students should be familiar with emergency procedures in case of accidents, spills, or exposure to hazardous materials. This includes knowing the location of safety equipment such as eyewash stations and fire extinguishers, as well as how to contact emergency services if needed.
- Risk Assessment: Before conducting any soil testing activities, teachers should perform a risk assessment to identify potential hazards and implement appropriate control measures to mitigate risks. This includes planning for safe storage and disposal of chemicals, as well as ensuring adequate supervision and training for students.

Teacher Preparation for Activity

Be sure to look over the provided supplemental materials before the lesson: Lecture Google Slides Presentation, Brain Dump Worksheet, Field Journal, Student Direction Sheet, Class Discussion Questions, and Map Assessment Rubric.

Be sure to purchase the microBIOMETER® Classroom Kit and download the microBIOMETER® App to look through the instructions before class. It may also be helpful to go ahead and separate/organize these materials for the students.

Other suggestions: The materials for the lab activity in this lesson were divided to account for a class of 30 students (3 Test cards, 3 Reagent packets, 1 Extraction vial, 1 Pipette, 1 Soil sampler, 1 Whisker, 1 Soil sifters, 1 Capped measurer, and 1 Spatula per group of 3 students). The idea is that 3 blocks of 30 students will be able to complete this activity with 1 kit. If your class size differs, you may need to adjust group sizes or number of tests available.

Instructors should also consider creating the groups of 3 in advance.

Instructors should also have a plan for storing the soil samples (must be refrigerated after collection.)

Student Preparation for Activity

- Students should already be familiar with Earth's natural resources (oil, coal, natural gas, metals, sunlight, soil, air, and water.)
- Students should already be familiar with the different soil components (sand, silt, clay) and their characteristics.
- Students should already be familiar with various illnesses associated with uses of natural resources and pollution.

Procedure

DAY 1

- As a warm up, the teacher should ask some review questions on soil since the idea is for this lesson to be completed after the students have a prior knowledge of soil. (E.g. What are the three components of soil? What are the steps to determine soil type?). Have students record and share their answers. **(5 min.)**
- Instructor should project the provided Google Slides Presentation
- The first activity is for students to complete a "Brain Dump" on Soil, Natural Resources, and Pollution-associated Illnesses. Teachers should monitor the room and help prompt struggling students. Give about 3 minutes for students to write, and 2 minutes for sharing. **(5 min.)**
- After the brain dump, the teacher will draw the students back to the Google Slides Presentation and spend a few minutes lecturing to introduce the idea of microbiomes. After the introduction, continuing through the slides, the instructor will explain that the primary focus of today will be soil. More specifics are available in the lecture slides, but as the teacher is presenting, students should be actively listening. The teacher should be roaming the room, making sure students are actively listening. **(20 min.)**
    - **OPTIONAL:** Instructors have students take notes during the lecture
- The teacher will then explain to students how they are going to take a closer look at microbes in soil. The teacher will distribute the microBIOMETER® Student Direction Sheet as well as the Field Journal. The instructor will provide any site collection-specific instruction, explain the direction sheet and field journal, and distribute materials listed on the instruction sheet. Instructors should also share any necessary information detailed in the "Safety" section of the lesson plan. **(10 min.)**
- The instructor will lead the students to the chosen collection site. Students will follow the instructions on the microBIOMETER® Student Direction Sheet and document their findings in their Field Journal (one direction sheet per student, 1 field journal per group.) The teacher will roam, check in on groups, make sure they are using materials carefully, safely, and correctly. **(30 min.)**
- After the groups finish collecting their soil samples, the instructor will lead the students back to the classroom.
- When back in class, the teacher will collect the soil samples from each group (confirm they are labeled), and store them. Students should remain in their groups, make sure the first 3 columns of their field journals are filled out. **(15 min.)**
- For the few remaining minutes in class, the students will clean up and return the soil sampling materials to the instructor. If finished cleaning with time to spare, the instructor will give students a brief overview of Part 2: Extraction and Part 3: Testing. **(5 min.)**

DAY 2

- Day 2 will begin with a few warm up questions, included in the Google Slides Presentation recapping what was taught during Day 1. Give students a few minutes to read, think of responses, and share. **(5 min.)**
    - What is a microbiome? What are some examples of microbiomes as discussed in class? What do microbes do for soil? Share some details about the soil samples you collected yesterday (color, consistency, components, etc.)
- Next, the instructor will show the video embedded in the Google Slides Presentation reviewing soil as well as a closer look into the role of Bacteria and Fungi in Soil **(11 min.)**
    - **OPTIONAL:** Instructors have students take notes during the lecture
- The teacher will re-distribute the soil samples, instruct the students to get in their groups, and take out their microBIOMETER® Student Direction Sheet as well as their Field Journal.
- The instructor will project the slides explaining Part 2: Extraction and Part 3: Testing as well as go through the rotation schedule. The instructor will then distribute materials outlined in the microBIOMETER® Student Direction Sheet. **(3-5 min.)**
- Students will follow along the directions on the microBIOMETER® Student Direction Sheet to perform the extraction and complete the analysis. The students will rotate through the steps to ensure that each student has an opportunity to complete each of the steps of both the extraction as well as the testing and analysis. It will take students about 20 minutes to complete the extraction and testing per sample. Students should keep track of their analysis results from the app and record them as well as any other necessary details on their Field Journal **(60 min.)**
- For the last 10 minutes of class, students will participate in a class discussion. This discussion can be as formal or informal as the instructor would like. Attached in the Exploring Earth's Hidden Heroes Discussion Questions,

includes a starter question (How do microbiomes in soil contribute to soil health? What roles do bacteria, fungi, and other microorganisms play in maintaining soil?) and the big question of the lesson (How does use of natural resources (in our case, SOIL) impact ecosystems and human populations, including human health?) **(10 min.)**
    - The document includes accepted/predicted student responses as well as some additional information to share with students to tie the lesson together.
    - **EXTENSION OR EXTRA CREDIT OPPORTUNITY**: The instructor could print the starter & big question and collect the student written responses.
- As for the assessment (which could be completed in class if the instructor would like to spend additional class time, or outside of class) the students will use their microBIOMETER® app results and Field Journal to create their own map showcasing where their soil samples were taken, microbial biomass concentration for each sample, and fungi to bacteria ratio. The Map Assessment Rubric includes specific details of what should be included. Instructors can show the "Mallard Creek Study" slide from the Google Slides Presentation to show an example of a sample map.

Differentiation

- Students with Learning Disabilities:
    - During the class discussion, provide a list of simplified questions for the students to read over during the discussion
    - During the "Create Your Own Map" assessment, provide varied format options – offer options for how students can present their maps, such as digital maps using online tools like Google Maps or physical maps using drawing materials. This accommodates students' strengths and preferences.

- Gifted and Talented Students:
    - Challenge Gifted and Talented Students by having them write and submit their responses to "the big question" of the lesson (How does use of natural resources (in our case, SOIL) impact ecosystems and human populations, including human health?)
    - Challenge Gifted and Talented Students by including a response with their map about what the fungi to bacteria ratio means for the health of their soil samples

- English Language Learners:
    - Provide English Language Learner students with a list of relevant vocabulary words with their definition to help them navigate through the lesson
    - During the class discussion, provide a list of simplified questions for the students to read over during the discussion
    - During the "Create Your Own Map" assessment, provide varied format options – offer options for how students can present their maps, such as digital maps using online tools like Google Maps or physical maps using drawing materials. This accommodates students' strengths and preferences.

Assessment/Check for Understanding

The goal of this lesson is based on **ESS.EES.6.1 Analyze and interpret data to infer how use of natural resources impacts ecosystems and human populations, including human health**. The learning objectives or outcomes include: Defining microbiomes and their composition, Explaining the importance of microbiomes in human health, Discussing the impact of microbiomes on soil health, Understanding how to collect and prepare soil samples for testing, and most importantly, being able to analyze the relationships between microbiomes, human health, and soil health.

- Exploring Earth's Hidden Heroes Class Discussion
    - A class discussion will be used as one form of assessment for this lesson. Attached in the Exploring Earth's Hidden Heroes Discussion Questions, includes a starter question (How do microbiomes in soil contribute to soil health? What roles do bacteria, fungi, and other microorganisms play in maintaining soil?) and the big question of the lesson (How does use of natural resources (in our case, SOIL) impact ecosystems and human populations, including human health?) Class discussions are useful assessment tools to assist in:
        - Gauge understanding among students
        - Identifying misconceptions
        - Encourage peer learning
        - Provide immediate feedback to students
    - The document includes accepted/predicted student responses as well as some additional information to share with students to tie the lesson together.
        - **MODIFICATION**: Provide a list of simplified questions for students who may struggle with a strictly verbal discussion. A list of relevant vocabulary and definitions would also be helpful.

- Exploring Earth's Hidden Heroes "Create Your Own Map" Assessment & Rubric

- The second form of assessment in this lesson will be for students to create their own map showcasing where their soil samples were taken, microbial biomass concentration for each sample, and fungi to bacteria ratio.
- The rubric outlines what should be included in their map and prospective point values.
    - **MODIFICATION**: Varied Formats – offer options for how students can present their maps, such as digital maps using online tools like Google Maps or physical maps using drawing materials. This accommodates students' strengths and preferences.

Required resources

Exploring Earth's Hidden Heroes PowerPoint, https://docs.google.com/presentation/d/1Q_Ig46IFLlst6bdLaF0fYL-CQYVuBtnxmQqLMvb_Dcg/edit?usp=sharing, This is the link to the Google Slides Presentation to go along with this 2 day lesson plan. Relevant images and videos are embedded into this PowerPoint.

Exploring Earth's Hidden Heroes Discussion Questions, https://docs.google.com/document/d/153hzfzVxkaEe7YpPxUTfTpJ-pzsbE9naFn8MdF5UkBE/edit?usp=sharing, This is the link to the suggested class discussion/reflection questions for the teacher to pose to students near the end of the lesson.

microBIOMETER®, https://microbiometer.com/, This is the website used to purchase the microBIOMETER® as well as instructions, demonstration materials, FAQs, and additional important information on the kit.

Supplemental resources

Nadeu, E., van Dijk, R., & Hiller, N. (2023, December). The Soil Microbiome. Institute for European Environmental Policy.

https://ieep.eu/wp-content/uploads/2023/12/The-Soil-Microbiome-ESAD-IEEP-2023.pdf

Author comments

- This lesson plan was developed through a research experience conducted at the University of North Carolina at Charlotte in their Department of Bioinformatics & Genomics.
- As mentioned above, in the “Teacher Preparation” section, the materials provided in the kit were divided based on a class of 30 students with 3 students in each group. You may need to adjust this.
- Time Constraints
    - This lesson was designed so that each group of 3 students collects, tests, and analyzes 3 soil samples. If this is going to take too long since only one sample can be analyzed and tested at a time due to a material count limitation, you may lower the number of samples being tested per group.
    - The class discussion can be as formal or informal as the instructor would like. The Exploring Earth's Hidden Heroes Discussion Questions are simply a guide and not a necessity for this lesson.
    - The Map Assessment with included Rubric can be completed outside of class if the instructor does not want to spend more time in class on this topic.
- Extension Opportunities
    - Collecting written responses to the “big” question

Sources

Microbial Biomass Soil Testing Kits & Equipment USA | microBIOMETER®. (2024, July 17). MicroBIOMETER.

https://microbiometer.com/

OpenAI. (2024). *ChatGPT* (July 17 version) [Large language model]. https://chat.openai.com

Appendices

Brain Dump Worksheet
Field Journal
microBIOMETER® Student Direction Sheet
Map Assessment Rubric