OUR WATERY WORLD

TEACHING MIDDLE SCHOOL STUDENTS ABOUT BIODIVERSITY

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Most biologists have had a pivotal experience during which they fell in love with the natural world, whether it was a trip to the woods, the desert, or the ocean. Experiences with nature—especially when accompanied by a knowledgeable guide—can be transformative for young science students. Our goal for the lesson described here was to introduce inner-city, middle school students to local natural areas while teaching them about the scientific inquiry process and the importance of water to life on Earth.

Without water, our planet would be lifeless and barren. Due to its incredible chemistry, water is crucial for sustaining all life on this planet. This chemistry includes cohesion and adhesion—water's ability to stick to itself and other surfaces. Plants harness these properties, at times pulling water against gravity tens of meters from roots to peripheral stems. Water-strider insects and fishing spiders also use cohesion to walk across water. Because water has a high specific heat capacity (a lot of heat is required to change its temperature), it is an excellent thermal buffer that moderates global climate. Without water, our planet would heat to scorching temperatures during the day and cool to freezing temperatures at night, killing most life-forms. Lastly, photosynthesis, respiration, and DNA replication require water. Simply put, water is a crucial molecule for life on Earth, and where there is more water, there is usually higher biodiversity.

We developed an inquiry-based activity that highlights water's influence on biodiversity and provides students with a positive experience with nature. Our 5E activity (Engage, Explore, Explain, Expand, Evaluate; see Bybee 1997) spans two 80-minute sessions, one at a natural site and one inside the classroom. Though we designed this module for an after-school program, it could be adapted to a regular classroom, with or without the field component (see Exploring Inside the Classroom, below). This lesson includes three of the eight core categories for the National Science Education Standards: unifying concepts and processes in science, science as inquiry, and life sciences (NRC 1996). As such, it works well following a taxonomic module or as a precursor to an in-depth life-science or ecology module of the curriculum, as it provides a basic understanding of the distribution of living things.

At the beginning of the lesson, the class as a whole (or in focus groups) can be asked to discuss biodiversity and what affects biodiversity. This discussion enables an initial assessment of students' preconceived notions, and it acts as a good transition into the student-led formation of related hypotheses and predictions about the relationship between the environment and biodiversity.

While we carried out this module at a local river restoration site, it can be performed at any neighborhood park with a water source. Additionally, this activity can be modified to take place within the classroom using photographs or looking at microorganisms in mud samples from different locations. With an hour or two of budgeted time, you can nurture your students' appreciation for the fascinating patterns within the natural world.

Engage: What factors lead to greater biodiversity?

Due to our tight schedule as an after-school program, we could not conduct a separate pre-assessment, so we coupled the pre-assessment with the Engage portion of the lesson. If time allows for an independent pre-assessment, we suggest introducing biodiversity through an inquiry exercise where students see photos of different habitats with obvious differences in biodiversity. The Activity Worksheet has guiding questions to lead students through the process of understanding the concept of biodiversity. This is also a good time to introduce the difference between abiotic (nonliving) and biotic (living) factors. Then, for several of the factors listed, discuss the role each factor plays in biology in general, and ask students if (and why) the factors may be important to biodiversity.

Before the field trip, please plan accordingly to ensure the safety of everyone included (see Bigelow 2011). Make sure to travel to the site ahead of time to assess feasibility, and check with your institution for any required paperwork or set guidelines you should follow. Also, there are several dangerous arthropod species throughout the United States, so be certain to inform students to be cautious when touching an animal to make sure that it is not a scorpion, black widow spider, or stinging insect.

We began our activity on the bus ride to the restoration site by showing students pictures of different environments. This exercise is easily implemented in the classroom if a field trip is not possible. One photograph was the skyline of Phoenix, while the other was a desert habitat (Figures 1 and 2). This is the ideal time to give students the Activity Worksheet, as it asks student to compare the two different habitats and introduces biodiversity. We encourage you to select photos that are relatable to your students and adapt the Activity Worksheet to them, as well. Do not worry if your class is not located in the desert; in fact, you will more easily be able to find water nearby! If your students are from a temperate area, we suggest including photos of a coniferous forest and a lake. If your class is near the coast, your students have an excellent opportunity to learn about marine environments and biodiversity. Lastly, if your class is in a cold climate, this activity should be conducted during early fall or mid-spring. We chose to show a desert and a cityscape to illustrate a wide variety of different influences on biodiversity, including temperature, water sources, and humans.

After studying the photos, students predicted which environment had more diversity. Most students predicted that the city setting would have higher plant and animal diversity (which we defined as biodiversity). Then we asked students to name factors that affect biodiversity. Students quickly shouted, "Pollution! Space! Buildings! Food!" Though they voiced many appropriate ideas, we were surprised that no one said water. We then asked a guided question, "Which environment has more water, and how might this affect its biodiversity?" Students discussed the presence of water and its importance in biodiversity, with many students stating that the

FIGURE 1 Phoenix, Arizona

FIGURE 2 Death Valley, California

city environment had more water sources and might therefore have greater biodiversity. This lesson was ideal because it exposed a lack of understanding about the importance of water for life and allowed students to discover it for themselves.

Once we arrived at the restoration site, a graduate-student mentor teamed up with each group of five or six middle school students. We had a high teacher-to-student ratio, but this activity is still feasible with one teacher and a full class of students as long as preparation is done to keep them focused. If you have a full classroom, we suggest having a list of additional factors in addition to water proximity that can be easily measured within the same area to keep students involved. Proximity to roads and buildings, along with other abiotic factors such as temperature and sunlight, are just a few factors that might influence biodiversity and are easy to measure.

Our goal was to guide students into forming realistic hypotheses and predictions that tested the following causal question: How does proximity to water affect biodiversity? Students' hypotheses ranged from water having a positive effect on biodiversity to water having a negative effect on biodiversity. These hypotheses led to a broad range of predictions, from a greater number of species found in dry areas to a greater number of species found near water. Rather than correcting any predictions, we allowed students to test their own. We wanted students to understand that the process of science includes forming hypotheses, whether or not they are correct, and as long as hypotheses are tested critically, science will progress. Again, if you have a large class, the Engage portion, including hypothesis and prediction development, can be introduced during class. You can deliver the Engage and the beginning of the Explore sections in the classroom using the Activity Worksheet. If you are not taking a field trip, this is where different photos and collected mud will be used (see Exploring Inside the Classroom). Regardless of whether you are traveling or not, be sure to have students write their hypotheses and testable predictions in their notebooks along with a data table for recording the number of different species and total individuals of each species found.

Explore: Water and biodiversity

In this part of the activity, students got their hands dirty by counting creatures.

Materials

The class can be one group or divided into several groups. Several groups of students are ideal, as teachers can discuss the importance of replication in experiments. If your class has 30 students, three groups of 10 would be optimal. Each group of 10 individuals can be divided into two 5-person groups that each measure one transect, which will engender high participation and quick measurements. Regardless of group size, each group will need the materials listed below. If you are unable to travel to a water source, your materials will be different (see Exploring Inside the Classroom).

- 3 m length of string
- Field guide of local area (regional Audubon guides work well)
- Clipboard with paper and writing utensils
- 4 flag markers (or sticks or rocks to mark a measured area)

Have students work together to design an experiment to test their predictions. After a few minutes, if

Activity Worksheet: Our Watery World

Photograph	Predicted difference in animals	Predicted difference in plants	Other different characteristics	Amount of life
Phoenix				
Death Valley				

Through this activity, we will go through the different steps of the scientific inquiry process. These steps are (1) observe, (2) ask a question, (3) hypothesize (make an educated explanation to answer the proposed question), (4) predict what will happen if your hypothesis is correct, (5) devise methods to test the predictions with an experiment, (6) gather data and determine if the hypothesis is supported or not, (7) conclude whether the hypothesis is supported or not, and (8) repeat the process with a new question. As a class, you will now work through the scientific inquiry process.

Engage

Do all areas have the same amount of animals, plants, and other life? Compare the amount of animals and plants in the photographs of Phoenix and Death Valley (Figures 1 and 2).

Observation:

• What factors do you think lead to the differences in these two habitats?

• *Biodiversity* is the amount of organisms and species within a given area. Why is biodiversity important?

• What factors lead to high biodiversity? What factors lead to low biodiversity?

We are now going to test what effect one of the factors has on biodiversity. Your teacher will tell you now which factor to test. The factor is _________________.
Write one sentence about why this factor causes high or low biodiversity.

Question:
Which area do you think will have the most biodiversity?

Hypothesis:
Explain why you think one area will have higher biodiversity than the other.

Predictions:
Based on your above hypothesis, which transect should have more biodiversity? What kinds of organisms do you expect to find in each transect? Do you predict any other differences between your transects?

Explore

Experimental methods:
Devise a way to test the predictions.

Gather data:
Transect near water
Transect away from water

Data analysis:
What did you find?

Conclusions:
Did your findings/results support your hypothesis?

Explain

Give three reasons why water important and necessary for all life.
1.
2.
3.

Expand

An *ecoscape* is a form of landscape architecture that includes an understanding of the sciences involved with biology and the environment. When you go to a nature park, you are in an ecoscape designed by architects.

Imagine you are an architect hired by the city to design an ecoscape for a local park that must have high biodiversity. The goal is to increase biodiversity in the city. Be sure to label the components that will increase biodiversity.

students have not come up with a usable method, we suggest asking leading questions to introduce students to the idea of transects. For example, you could ask, “How large of an area should you compare?” or “How would you make sure the sites you use at each location are similar in size?”

After students have discussed these ideas, you can introduce them to the idea of using transects. *Transects*, or specified paths or areas in an environment, are used as part of an ecological approach to measure parameters in different environments while controlling for size and area. Our transects were circular and created by two students working together. One student (center student) held one end of a 3 m string, while another student pulled the string tight and walked around the center student. This method created a circular transect that had a diameter of 6 m. Students designed one transect within 15 m of the river and another transect on a line perpendicular to the river, at least 100 m from the other transect (see Figure 3). If you have a large class, introducing the methods of the activity during the Engage section may help with students’ understanding of transects. The exact sites of the transects should be randomly chosen, otherwise students may simply pick the spot that looks like the most enjoyable location to count plant and animals, as opposed to the most ecologically relevant site. The sites can easily be randomized by having a student with closed eyes throw a small ball or similar object in the general vicinity of where the transect should be located. Once transects were determined, students counted all organisms within each transect. Our students quickly realized that they should specialize—some students worked together to count plant diversity, while other students focused on arthropod diversity. To make things more interesting, we challenged everyone to use field guides to identify the organisms that they were counting (though most groups only identified a few).

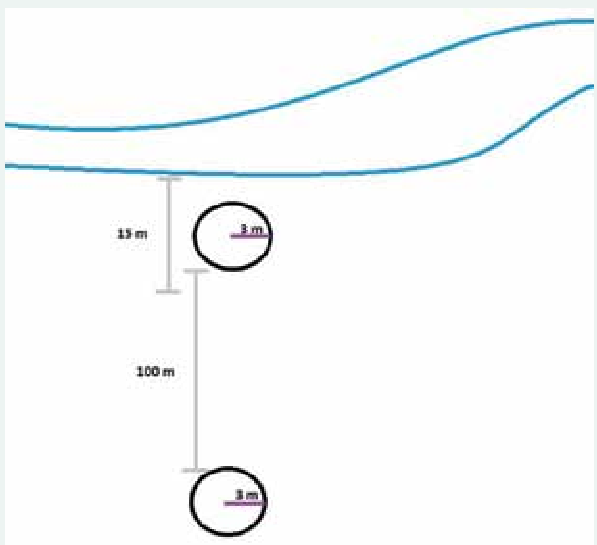
Students and mentors were surprised to see high diversity within our modest transects (some students wanted to include the people in a plane flying overhead in their diversity count). Most of the diversity was composed of plants, although there were plenty of ground-dwelling creatures: spiders, centipedes, millipedes, crickets, grasshoppers, and lots of ants.

To capitalize on access to an outdoor field site and maximize student engagement, we took students on a short hike after they finished biodiversity measurements. This hike was a great opportunity to introduce students to animals that would have been scared away from the transects, such as birds, reptiles, and mammals. The hike also provided an opportunity to engage students in a discussion of other factors that contribute to biodiversity. We had extra time while waiting for the bus, so mentors quickly recapped the scientific inquiry process with their group members, working another factor into the hypotheses, such as temperature, soil, or pollution, and discussing potential experimental designs. Given more time, teachers could use this discussion to elaborate more on the Explore portion of the 5E model, designing other experiments, or measuring other factors (e.g., temperature) that may contribute to findings.

Exploring inside the classroom

We realize that not all classes can travel to an area with water. If you cannot take your students to the field, bring the field to them. With little preparation you can find many photos of areas near and far from water and treat each photo as a transect that students will use to count organisms. Another approach to introducing school-bound students to this lesson is to bring in samples of dirt or mud that you have collected. (**Safety Note**: Samples should only be collected at sites free of toxis, dangerous debris, and bacteria/mold/microbe contamination. Students must wear gloves when handling samples and avoid exposure to and dust gener-

FIGURE 3 Experimental setup



ated. For disposal, samples should be heated or frozen to kill microbes, and then bagged in placed in the trash that same day.) You should still find more organisms in mud that you have collected from near water than soil away from water. After you dig up several buckets of substrate from both near and away from water, have students look through the substrate the next day, or you can have students build simple Berlese funnel traps for invertebrates (see How to Make a Berlese Funnel in Resources). Two additional options include (1) providing varied amounts of water to transects outside the school over time and comparing biodiversity among transects, or (2) having students plant the same mix of seeds in separate pots but water the pots differently and compare the amount of species in each pot. If you follow these alternatives, your students can still explore the methods of science while receiving an introduction to biodiversity and water.

Explain: Water is crucial for life

We used the bus ride back to the school to discuss the fundamentals of water's importance to life. We asked students to explain why water is important for living entities and then discussed how all known forms of life depend on water. The Activity Worksheet asks students to give three reasons why water is important for life. There are many reasons that you can discuss, including water's role as a climate buffer; its importance as a medium for biological reactions to occur, including photosynthesis, metabolism, and DNA replication; and its cohesion and adhesion, which enable it to be used by plants and animals. We urge you to compile all the answers that students suggest and work through each one with the class. This will drive home the point that water is important for vital life processes and therefore in areas with more water, an increased diversity of organisms may be able to survive.

Expand: Design an ecoscape for high diversity

We started our second day of the lesson by having students design ecoscapes that would increase biodiversity (see Activity Worksheet for details pertaining to ecoscapes). Students used colored pencils to draw parks and courtyards that incorporated creative waterfalls and pools for promoting higher organismal diversity. Though we did not have the foresight to include a discussion of the importance of water conservation, this would be a good lead-in to introduce this concept.

Evaluate

We focused most of the second day of the module on the assessment. Although our lesson spotlights water and biodiversity, our program focuses on the process of scientific investigation. So we evaluated students in a way that was conducive to reiterating a component of professional science—presentations of their experiments. We used the presentation to assess students' understanding of the core principles of water and biodiversity by requiring that their introduction and discussion slides incorporate fundamentals of water and biodiversity. Additionally, this process helped students relate their methods to the goals of the learning activity, which helped us gauge their understanding of the interrelation of steps of a scientific investigation.

Groups of students analyzed the data collected the previous week using simple bar graphs and pie charts to depict the difference in diversity between the two transects. Then they created five-minute PowerPoint presentations about their experiments. We stressed the importance of having an introduction that starts with background information about water and biodiversity and ends with stating the causal question, hypothesis, and predictions. Students then led us through their methods (with any special observations regarding transects) and data, with an emphasis on explaining the graphical representations of the data. Lastly, students created conclusions that reiterated the importance of the experiment and which design issues could be strengthened. Each group then presented its PowerPoint to the rest of the class.

In hindsight, a more formal assessment in the form of a short quiz taken before and after our lesson would have been beneficial. Figure 4 is an assessment that would have worked well with our students, but you may wish to create your own personalized assesssment.

FIGURE 4 Assessment

1. What is biodiversity?
2. What factors influence the amount of animals in an area?
3. Compare the biodiversity of two different areas.
4. Draw two parks, one that you think will have high biodiversity and one that you think will have low biodiversity, and label important components (e.g., buildings, rivers).

Further direction and expansion

Further expansion could include using Berlese funnel traps as outlined in the Exploring Inside the Classroom section to compare biodiversity of soil organisms from areas of different water exposure. Soil samples could also be collected from the water source to complement the samples taken near water and far from water. Students can refine their hypotheses and predictions based on conclusions from this lesson and work through the scientific inquiry process again with their new ideas.

Additionally, students could compare biodiversity in different parts of the world and correlate this to precipitation. Using a global map of biodiversity hot spots (see Resources), along with an interactive map of precipitation levels, such as those provided on the National Geographic education website (see Resources), students can determine if biodiversity hot spots are more likely to occur in water-rich areas. This extension gives students a global perspective on water availability, water's relationship to biodiversity, and interactive technology in the classroom.

Conclusion

By organizing a short visit to a natural site and implementing an educational ecology module that stresses scientific investigation, we introduced some students to nature for the first time and provided all of our students with a hands-on experience of science. Despite our concerns that students would not want to gather bugs or dig through the dirt, by the end of the module, students were clamoring to go back outside. Many of our students designed experiments at the restoration site for the Arizona Science and Engineering Fair, affirming the positive influence this experience had on their interest in nature and science. Teachers looking to implement a simple yet effective ecology module that expands the curriculum of a science class are encouraged to use our lesson plan and take a walk outside with the future scientists who may be among their students.

Standards

This lesson focuses on the nature of science as laid out in the *Next Generation Science Standards*. The Nature of Science Framework states: "Students need to understand what is meant by an observation, a hypothesis, an inference, a model, a theory, or a claim and be able to distinguish amongst them" (NRC 2012, p. 79). This lesson enforces the methodologies of the scientific inquiry process, data acquisition, and analysis. ■

References

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Resources

Conservation International biodiversity hot-spots map—*www.conservation.org/where/priority_areas/hotspots/Pages/hotspots_main.aspx*

Field trip safety preparation—*www.nsta.org/elementaryschool/connections/201204SafetyTips.pdf*

The great outdoors (from *Exploring safely: A guide for elementary teachers*)—*http://learningcenter.nsta.org/files/PB166X1-9.pdf*

How to make a Berlese funnel—*www.archbold-station.org/discoveringflscrub/unit3/unit3b1part2.html*

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National Geographic Education's mapmaker interactive—*http://education.nationalgeographic.com/education/mapping/interactive-map/?ar_a=1*

Saul, J.D. 1993. Ready, set, let's go! Using field trips in your curriculum. *Day Care & Early Education* 21 (1): 27–29.

Water resources

USGS Water Science School—*http://ga.water.usgs.gov/edu/mwater.html*

Water and life—*www.lsbu.ac.uk/water/life.html*

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