HAVING pHun WITH SOILS

by Sharon Gilman and Cynthia Lilly

Through many different iterations of national science standards, teachers have been encouraged to allow their students to learn science by doing their own exploration or inquiry (Achieve 2012; NRC 1996, 2012). Many studies have provided evidence that this approach results in students having a better understanding of the content and processes of science. For example, in a survey of 138 different studies of inquiry-based learning in the classroom, Minner, Levy, and Century (2010) demonstrate a trend favoring inquiry-based instructional practices and found that "teaching strategies that actively engage students in the learning process through scientific investigations are more likely to increase conceptual understanding than are strategies that rely on more passive techniques." In a study directly comparing student learning using active versus more traditional passive learning, Taraban et al. (2007) found test data showing "students gained significantly more content knowledge and knowledge of process skills using the labs compared to traditional instruction." Similar results are found in other studies (e.g., Schroeder et al. 2007; Geier et al. 2008).

These results are convincing enough that the new *Framework for K–12 Science Education* (NRC 2012) and the Next Generation Science Standards (NGSS) (Achieve 2012) give science process skills at least equal ranking with content. "Science and Engineering Practices" in the NGSS cut across all content and grade levels; these "practices" are as follows:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

The previous National Science Education Standards (NRC 1996) included this type of "Science as Inquiry," however, it was listed as the first standard for each grade level, and teachers tend to teach it first, separating inquiry (specified as science and engineering practices in the new Framework [NRC 2012]) from the content standards that followed, as if inquiry and the science and engineering practices themselves were content to be learned rather than the way science works.

The lesson described here aims to address this issue by using the practice of science to teach science. Students explore how soil pH varies and how this affects what can grow in those soils, and in this way come to learn about pH. This classroom-tested lesson plan, and others like it, can be found online (see Resources).

pHun with soils

This was done as an inquiry lesson that was followed with a lesson about soil quality and a lab on permeability, texture, and particle size. As a warm-up to the lab, we discussed the pH scale and what the numbers mean (0–6.9 is acidic, 7 is neutral, and 7.1–14 is basic). This lesson plan

FIGURE 1 Materials

Teacher demonstration

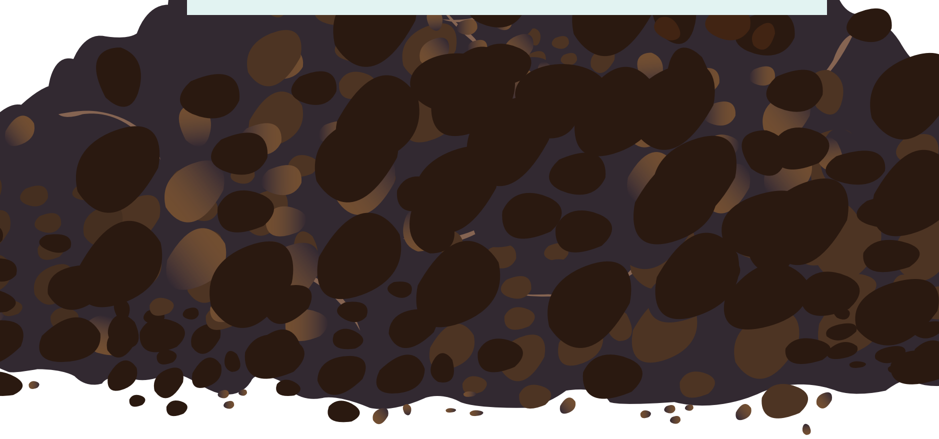
- 1 acid. (see "Engage: Teacher Demonstration" section for possible acids and bases.) Using an eyedropper, apply 1 to 2 drops to the pH paper.
- 1 base
- pH paper
- chemical-splash safety goggles

Student activity

Each lab station gets two of the same soil sample and needs the following supplies:

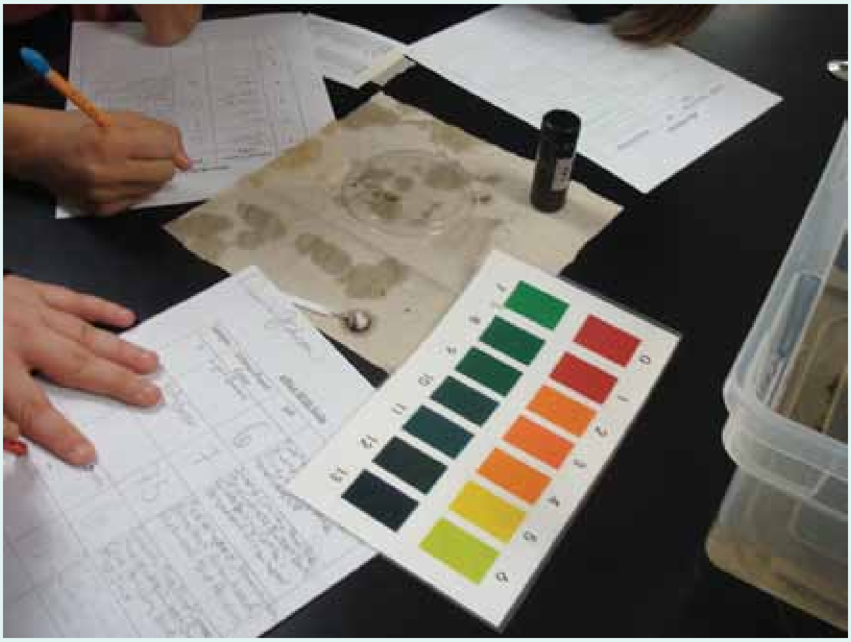
- 2 containers of soil (we used small glass jars with 1–2 teaspoons of soil)
- 2 small lab scoops or small measuring spoons
- 2 petri dishes
- 2 small strips (approximately 3 cm each) of Universal pH paper (range 1–14)
- pH reference chart (this will come with your pH paper, or can be found online)
- Beaker of water
- 2 eyedroppers
- Plant reference chart (Figure 4)
- Chemical splash goggles
- Gloves (check for latex allergies)

Students work in teams of two at a lab table of four, so there are two lab setups for each pair of students (one soil type) at each lab table. Provide a bucket or tub in the middle for soiled petri dishes and cover tables with butcher paper or newspaper for easy cleanup. Refresh soil samples for each class if needed.



was adapted from "Investing in Nature: Soil pH and Plants" from Botanic Gardens Conservation International. It fits into the 5E model of inquiry and was used in seventh-grade classrooms. In previous years, the soil pH concept had been one of the most missed questions on our benchmark testing, so we developed a specific lab addressing the role of pH and plants, and why it is critical for plants to have the correct level to ensure productive growth and survival. This lab gives students a hands-on learning experience and addresses the following science concepts:

FIGURE 2 Lab setup for pH soil analysis



- Explain the effects of soil quality (pH) on the characteristics of an ecosystem.
- Infer what might happen in an ecosystem if a particular quality (pH) should change.
- Identify methods for observing or measuring soil quality (pH).
- Recognize a soil quality (pH) based on its description.

Teacher preparation

Collect six different local, contaminant-free soil samples; use gloves when obtaining samples. Sanitize samples with heat when necessary. Where we live, there are various types of wetlands, and soil was collected from six different locations. You could use other kinds of sites, or soils could be selected from under different types of plants; this activity could also be incorporated into a plant-identification hike around the school. If you are not able to collect your own soil, a garden center should have a variety of soils available (worm castings, clay, sand, compost, topsoil, and potting soils would work). To collect samples from under plants, dig 10–15 cm down into the soil under the plants and place the sample in a small container labeled with the name of the associated plant or site (this information is for teacher reference only and should not be shared with students prior to their investigation). Examples would be soil from under an azalea bush, tomato plant, or pine tree. You will need approximately 1–2 teaspoons of soil for each class (we used very small lab scoops so groups used a very small amount when testing; the number of classes you teach will determine how much soil you need). Soil keeps well, so there no need to use it immediately, and it can be reused. See Figure 1 for a complete materials list.

Engage (teacher demonstration)

Students are told that they are being asked to plan and develop a wetland restoration (the science club at the school was actually doing this, so it was especially relevant for students in the club, but as all of the samples were local, everyone had a connection) and given the following scenario:

> There are six different wetlands in the community that have been heavily affected by humans—county developers have attempted to fill in the wetlands and create gardens in front of some newly developed

land, but the land is still too wet, and all of the plants died. New plants need to be put into place, but first the soil must be tested to determine that the plants selected are appropriate for each environment.

This story can be adjusted to your own location (forest, farmland, stream-side, desert). Inform students that selecting an appropriate plant for a soil's pH is vital to the plant's survival, so students will be testing soil to determine its pH and then choosing plants (each student group will test one type of soil and then results will be shared among the class).

Discuss that pH paper is an indicator, explain how to use a pH reference chart (a chart should be included with your pH kit; if not, they can be easily found online), and have students predict in their science journal what colors will appear when pH paper is dipped in solutions of various pH (basic: laundry detergent, ammonia; acidic: lemon juice, vinegar, hydrochloric acid). The teacher tests the solutions so students can determine the accuracy of their predictions and categorize the results. Display the pH scale: acidic, basic, and neutral. Have students reflect on their predictions and the results in their science journals and what pH means to them at this point. As a class, discuss students' predictions to check for understanding.

Explore (procedure)

Safety note: Students must wear chemical-splash safety goggles and gloves, properly dispose of the soil as directed, and clean up the area and wash hands afterward. See Figure 2 for the setup at the lab table.

1. Students place a piece of pH paper (approximately 3 cm) in one petri dish and approximately 1/8 teaspoon (just enough to cover the pH paper) of their soil sample on the paper.
2. Using the eyedropper, students moisten the soil until the pH paper becomes wet, leave soil on pH paper for one minute, then brush the soil away and use the side of the pH paper that the soil was not on to match the color to the pH chart.
3. In the appropriate column of the provided table (Figure 3), students record the color of the pH paper and number and whether the soil is acidic, basic, or neutral. Next, students record three or four plants suitable for this pH by matching the pH number to the plant reference chart (Figure 4). This is repeated for all six soil samples.

FIGURE 3 Table for student data

Sample	pH paper color and number	pH: acid, base, or neutral	Restored plants
1			
2			
3			
4			
5			
6			

4. In their work areas, all of the groups display their soil sample (with site or plant names clearly visible) and their table with the results of the pH paper tests. Students circulate through the room, recording the findings for each soil sample. This should take approximately 15 to 20 minutes.
5. After rotating through the stations, students return to their original table and dispose of soiled petri dishes and used pH paper in the trash receptacles at each table.

Explain

After reviewing the data collected from the lab, students individually graph the pH values of the soils from the six sites. During the wrap-up discussion, encourage students to use correct vocabulary (*acid, base, neutral*) as you review the purpose of the pH paper in relation to the data collected. Teachers can show supplemental video clips (see Resources or search YouTube) that reinforce the concepts**.** Students should add the following essential information about pH to their science journal:

- Soils can be basic or acidic and usually measure between 4 and 10 on the pH scale.
- Indicators can be used to measure the pH of soils.
- Most plants grow best in soils with a pH between 5 and 7.
- Regardless of the nutrients present in the soil, if the pH is not suitable, those nutrients will be inaccessible to the organisms.
- Lime is a mineral that alters pH, making the soil nutrients more accessible.

FIGURE 4 Plant reference chart

Species	pH range
Bald cypress	4.5–6
Blue flag iris	5–7
Blue panicum	6–8
Broadleaf arrowhead	5–9
Cattail	5–9
Duckweed	4–9
Elderberry	5–9
Fetterbush	3.5–6
Giant bulrush	5–9
Honeysuckle	6–7.5
Loblolly bay	4.5–6.5
Loblolly pine	4–7
Pickerelweed	5–9
Pond cypress	5–7
Pond pine	5–7
Swamp cyrilla	5–7
Swamp tupelo	4.5–6
Sweet gum	4.5–7

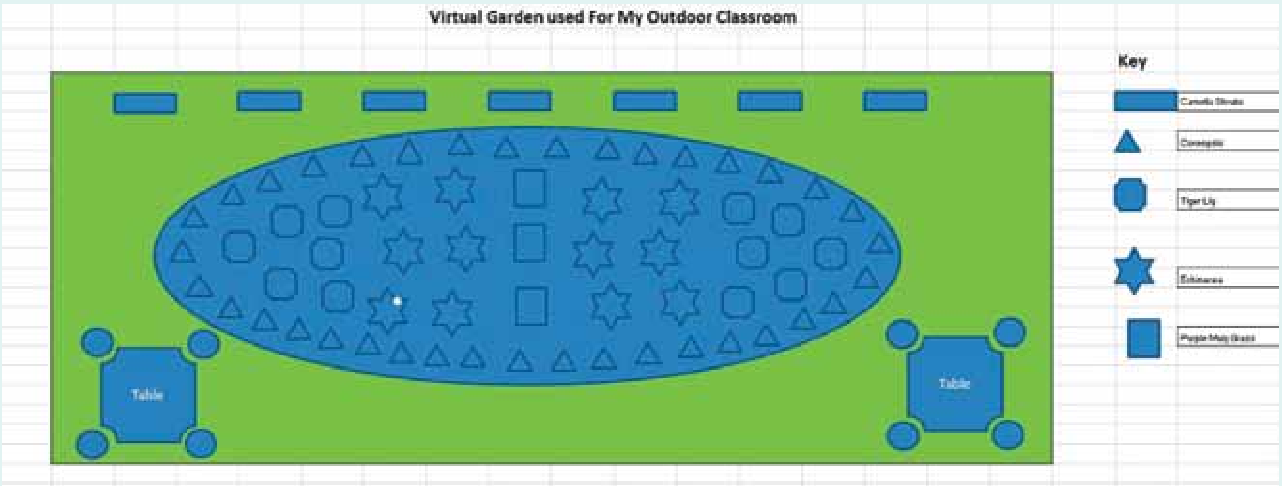
FIGURE 5 Student instructions for diagramming a garden

(We had students diagram a wetland for an actual local wetland restoration project.)

Students are asked to plan a garden that they would like to see at their home or at school. Their challenge is to design a virtual garden, or one on paper if internet access is unavailable. They will draw it to scale. Drawing could be done using various computer programs, or it could simply be done on graph paper with colored pencils. Students can draw the actual plant or make a key denoting the types of plants used, as in Figure 6.

1. Use gardening books or the internet to choose plants as examples of what could be in the virtual or paper garden.
2. Create your own paper or virtual garden and put what would fit best in the garden (based on soil pH and which plants grow best in your area).
3. Use a mix of different varieties of plants.
4. Reflect on the process of designing the virtual or paper garden, and the final actual garden if there is the opportunity to construct one. How did you decide which plants to use? How did you decide where to put them?

FIGURE 6 An example of a virtual garden



Elaborate

Students take what they've learned about plants and pH and apply it by diagramming a restoration for a garden or wetland, or whatever restoration works in your area. This can be done by providing them a list of plants native to your area, along with their pH preferences, which offers a nice connection to plant diversity (see Figure 5 for student instructions); such lists are available online (see Resources).

The science club at the school then took this information and used it to design an actual wetland restoration and assisted with the planting on-site, with the help of a local environmental education outreach program. This information could also be used when planning an herb garden on a windowsill, vegetable garden in a yard, small flower garden at a school, or foliage garden in the front of a house.

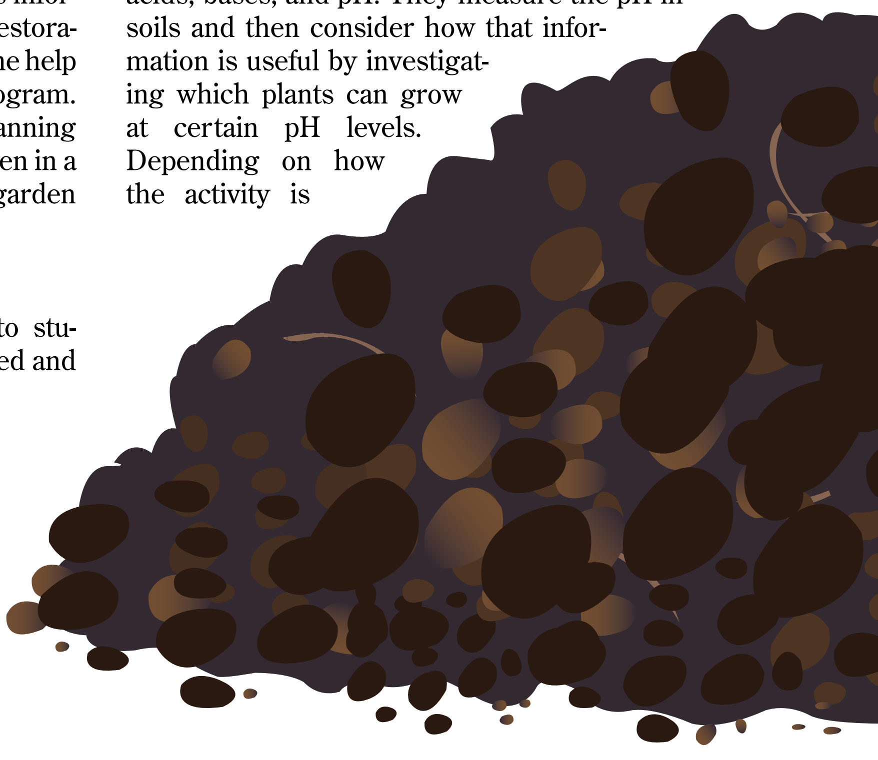
Evaluate

The following analysis questions are given to students at the end of the activity and then collected and graded by the teacher:

1. Review the new plant communities in our wetlands. Do they all look the same? What do our plans for the restored wetland tell us about the relationship between soil pH and plant communities in nature?
2. If we change the pH of a wetland by dumping chemicals into it, what would happen to the plant community?
3. Define *acid*, *base*, and *neutral* in terms of pH.
4. Can you predict whether soil is acidic or alkaline based on the types of plants growing in it? Explain.

Conclusion

This activity allows students to explore the concept of acids, bases, and pH. They measure the pH in soils and then consider how that information is useful by investigating which plants can grow at certain pH levels. Depending on how the activity is



carried out, in some cases students will see that the plants growing in a particular soil are those that can tolerate that pH. If the soil samples are not local, students can explore which types of plants could grow in those soils. In either case, students can apply the rather abstract concept of pH to their world in a real, hands-on way. As an extension, students can then apply this information in the design of a garden. ■

Acknowledgments

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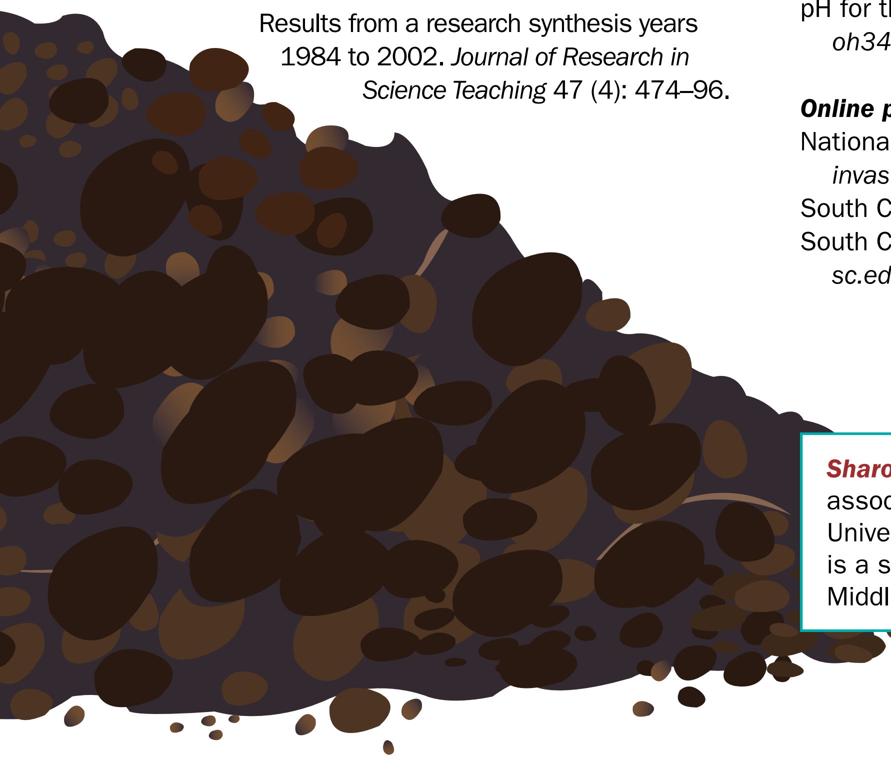

Resources

pHun With Soil and other lesson plans—*http://kingfish.coastal.edu/GK-12/11/home*

The role of acids and bases in soil (video)— *www.cosmeo.com/videoTitle.cfm?&nodeid=&guidAssetId=A244BF25-51D6-47D0-8FA8-AB6EB40B1518*

Information about pH related to gardening

Guide to soil pH and why it's important to the garden—*http://voices.yahoo.com/soil-ph-guide-soil-ph-why-its-important-to-6235422.html*

pH for the garden—*http://pss.uvm.edu/ppp/pubs/oh34.htm*

Online plant lists

National Invasive Species Information Center—*www.invasivespeciesinfo.gov*

South Carolina Native Plant Society—*www.scnps.org*

South Carolina Plant Atlas—*http://herbarium.biol.sc.edu/scplantatlas.html*

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