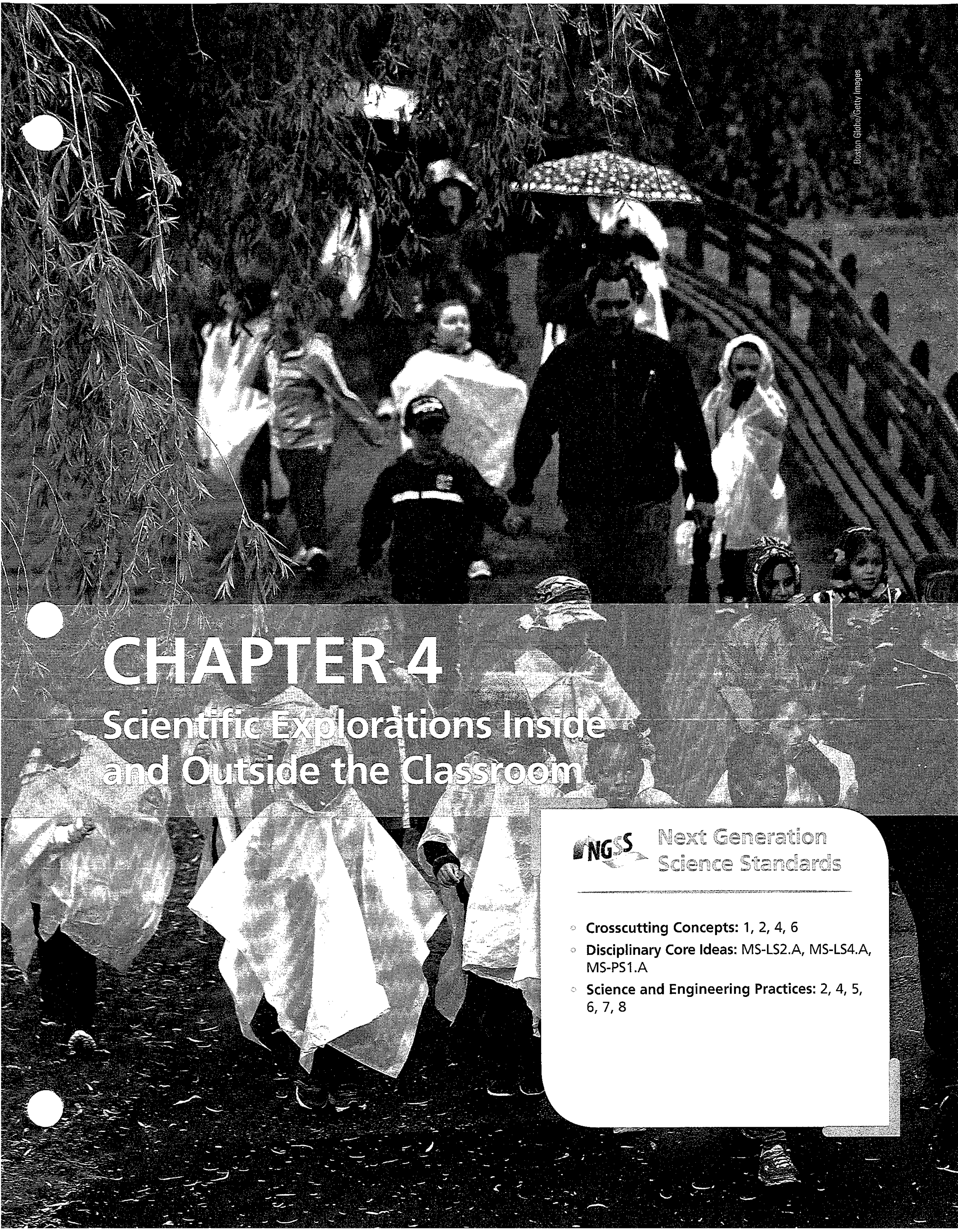

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CHAPTER 4

Scientific Explorations Inside and Outside the Classroom

NGSS Next Generation Science Standards

- **Crosscutting Concepts:** 1, 2, 4, 6
- **Disciplinary Core Ideas:** MS-LS2.A, MS-LS4.A, MS-PS1.A
- **Science and Engineering Practices:** 2, 4, 5, 6, 7, 8

LEARNING OBJECTIVES

After reading this chapter, you should be able to:

- 4-1 Distinguish between the formal and informal science curriculum.
- 4-2 Reflect on the importance of students' experiences with the natural world.
- 4-3 Connect scientific study to the daily life of the classroom.
- 4-4 Understand the distinction between everyday observations and scientific observations.
- 4-5 Discuss how to use scientific data to provide evidence of ecological disruption.
- 4-6 Examine the goals and procedures for science field trips.
- 4-7 Discuss the significance of science centers in the daily life of the classroom.
- 4-8 Discuss how a classroom can reflect the science unit at hand.

Reflection

To Think About:

- How can informal science-learning experiences shape your knowledge of science?
- What natural event has been making headlines recently?
- Why do you think scientific study feels alien to many students?
- How does the region where you live adapt to changing climate conditions?
- How can environmental issues find their way into the elementary and middle school science curriculum?
- What items do you tend to collect? Do they include anything from nature? Can they find their way to a classroom science center?

We are living through a period of time in education when standardized testing and formal curriculum topics dominate the landscape of teaching and learning. Teaching elementary and middle school science is a wonderful way to engage students in creative and personally relevant topics about the natural world. This gives you, the teacher, the opportunity to make the science experience personal and locally relevant; and, depending upon the area in which you live, you can use natural events to promote science in the daily life of the classroom and to make connections to the region in which your school is situated and where your students live. In this chapter, you will see how one middle school does just that.

Two of the stories described in this chapter were made possible through National Science Foundation Research Grants: NSF (Grant# 733269; 0918629) Ecology Disrupted (2009-2014) and (Grant #1221188), Unifying Life: Placing urban tree diversity into an evolutionary context. All views expressed are those of the author and not the NSF.

4-1 Two Types of Science Curricula

formal science curriculum The explicit statement by a school or a school district of the science topics and methodologies to be implemented at each grade level.

Many schools follow a **formal science curriculum** that has been developed at the state or local level or that has been commercially developed and purchased by the school district. These formal curricula have primarily been put together with the guidance of the *National Science Education Standards* (National Research Council, 1996), the American Association for the Advancement of Science (AAAS, 1993) *Benchmarks for Science Literacy*, or state and local frameworks. Sometimes schools and districts adopt a formal science curriculum that has been developed by a commercial publisher. Now, there is a new generation of science and engineering standards that are emerging, and these new standards stress the importance of engaging students in creative experiences that allow them to design solutions to some of our vexing scientific problems.

When teachers use *only* the formal guidelines to design students' science experiences, they limit the topics of study to those addressed in formal curricula. Although those experiences may be good—and may make some topical connections to students' lives—they do not include experiences that are *unique* to a particular class in a specific geographic locale.

Science experiences that are unique and very personal make up what I call the **informal science curriculum**. In this chapter, you will see that this informal curriculum can be extremely important. You can think of it as a way to integrate into the classroom spontaneous natural events from the school's locale and science experiences that the students bring from home. In Chapter 2 you saw the informal science curriculum at work when Mr. Wilson brought icicles into class to teach students about changes in matter. Students can also study local objects from nature and even make collections of the plants they find outside the school.

informal science curriculum Science learning experiences that go beyond the formal science curriculum of the school or school district to include other topics and methodologies that connect to students' daily life outside the school. The topics might arise, for example, from spontaneous natural occurrences, local news events, or materials the students bring from home.

I live in an area that usually receives 18 inches of snow a year. In the 2009 winter season, more than 80 inches of snow fell in my area. It was most certainly a subject for science exploration. When schools reopened from one of the snowstorms, one teacher brought in a huge bucket full of snow to her fourth-grade class and asked students to design a way to measure how much water the snowmelt would yield. This is what I mean by the informal science curriculum. Students designed experiments, used measuring devices, and studied an event in their locale.

This chapter explores a variety of informal science learning experiences and the ways you can develop them by using a classroom science center and field trips. We also see how Web-based materials can help a class explore environmental science issues that affect the students themselves and everyone else in their region. The Internet also makes it possible to explore regions well beyond our own home boundaries. First, however, let's look at some reasons why it is so important to make these connections between science and your students' daily lives *outside the classroom*.

4-2 The Importance of Experiences with Nature

Imagine small groups of students scattered about a natural area adjacent to their school. One group is identifying local plant life using a field guide. They are choosing plants that will be part of their Nature Gallery. Another group has a microphone attached to an iPod and is trying to record the sounds of cicadas for use in a podcast they are creating about how insects communicate. . . . Ultimately these are place based, meaningful, and active learning experiences (Bodzin, Klein, & Weaver, 2010).

Using the outdoors as a way to do science with students creates a classroom culture that values the natural world. This is so important at a time when many youngsters spend more time indoors, online, and playing computer games than they do outside, interacting with nature. Many scientists agree that there are serious health issues associated with spending excessive time indoors. For children and adults, these health problems include obesity, depression, and type 2 diabetes (Jones, 2008).

Thomas Berry, once described in *Newsweek* magazine as part of a new breed of "eco-theologians," said that "teaching children about the natural world should be treated as one of the most important events in their lives" (Berry, 1996). A large body of evidence suggests that immersing students in the local environment enhances their understanding of the natural world and enables them to develop an appreciation for nature that is necessary for stewardship of the planet.

The state of the environment, a controversial topic for many years, is currently receiving a great deal of attention as a result of rising global temperatures, depleted stores of natural resources, and disappearing flora and fauna. "Going green" has come to represent the ways in which individuals may change their daily practices to conserve energy, generate less waste, and understand the effects of their lifestyles on the quality of life on our planet. You can hardly read a newspaper or watch television without some reference to "green practices."

green science
The branch of environmental studies that includes the study of alternative and renewable energy, food webs, conservation, resource distribution, and the changes in world climate.

So what do we mean by green science? **Green science** involves teaching students about conservation, alternative and renewable energy, and sustainable practices that reduce each individual's environmental footprint—that is, the amount of natural resource depletion and waste generation in which we all engage as we go about our daily lives. It also refers to helping students understand the science ideas, or core concepts, that are the underlying causes of an environmental disruption to nature. It is one thing to label an "issue" an environmental problem. It is quite another to address the scientific evidence that tells us that, indeed, there is a problem.

Later in this chapter we will explore ways that elementary and middle school science teaching can help students develop a "greener" approach to everyday events. Just by getting students outside, we can help them develop an appreciation for nature.

4-2a Diversity Within and Without

Wherever your school is located, you will find enormous diversity in the nature around you. Often you can see some of it just by looking out your classroom window. You may find yourself amid the rich deciduous forests of the suburban or rural Northeast, close by the vast cornfields of the Midwest, or near the rocky shores of a coastal community. In the Southwest or Southeast, you may be surrounded by the dramatic flora and fauna of arid or tropical regions. Even at an inner-city school, you may find trees in the planting squares on sidewalks or dandelions breaking through the cracks.

You probably have a great deal of diversity among your students as well. They will notice different things in nature and respond to them in different ways. Consider the little dandelion in the sidewalk, for example. One student may see it as a sign of the stubborn persistence of plant life; a student with relatives in the suburbs may see it as a weed that ought to be exterminated. One student may come from a family who serves dandelion greens at meals; others probably have no idea that people would eat such a thing. One may think the dandelion flower is beautiful; another may think it ugly or not even recognize it as a flower. Whatever their particular reactions, your students' unique ways of experiencing nature provide a rich tapestry of science experiences that can become part of the life of your classroom.

By taking advantage of this diversity inside and outside your class—seizing the opportunities to make interesting connections between students' lives and the natural world around them—you can make your classroom a dynamic, vital place. Moreover, building these links stimulates learning in two major ways:

1. It helps students see the larger picture.
2. It helps students to see science as a way of knowing the natural world.

4-3 Seeing the Larger Picture: Content Plus Context

All students learn better if they can relate their school experiences to their daily lives. Recall what the opening chapter of this book said about the need to fit new concepts into our prior knowledge—a concept that the science stories in previous chapters have already demonstrated. Particularly in science education, however, many adults can recall learning the content without any context to which they could relate it. There was no larger picture, so to speak.

As a result, these students "learned" science by memorizing decontextualized facts to pass tests and then forgot them afterward (as reported in science autobiographies; see Koch, 1990).

Today, even formal science curricula generally strive to find ways for students, especially young children, to relate science ideas to their lives, and the best curricula acknowledge that students' lives encompass a wide variety of activities, cultures, and home environments. By linking science to students' own, individual "larger pictures," we not only help them learn better, but we also help them use science ideas to understand events in their daily lives more fully. As we discussed at the beginning of this book, we are living in an increasingly complex world—one that requires its citizens to be observant, critical, and thoughtful about their immediate environment. Those who understand scientific ideas in the context of their daily lives have a head start in dealing with the issues that their lives present.

There are many ways to integrate scientific study of the environment into the daily life of your classroom. Yet even when learning about subjects critical to the world they live in—the water they drink, the air they breathe—students can be put off by a detached, fact-based approach. In this chapter, you will read about several ways in which teachers in ordinary classrooms integrate scientific understanding into their students' *own* natural environment. You will also see examples in which other branches of science, such as physical science and life science, are linked to students' experiences. We begin with how students in the sixth and seventh grades explored local urban trees as a way to understand biodiversity and common ancestry.

4-4 Making Observations of Local Trees: Understanding Common Ancestry

> "*You see, but you do not observe.*
> —Sherlock Holmes, *"A Scandal in Bohemia"*"

In the last chapter, we invited students to stations where using their senses to make perceptions about the materials was key to taking next steps. But, as many researchers indicate, "on the surface, scientific observation is deceptively simple" (Eberbach & Crowley, 2009). So how do everyday observations become more scientific? Part of the answer lies in the context—the actual disciplinary frameworks that students are provided. The other part of the response is that everyday observers can be taught to observe more scientifically. The following story sets the stage for sixth-grade students to prepare to go outside in a Northeast autumn and observe the trees around the urban neighborhood of their school. As you will see, the teacher begins in the classroom with careful observations of acorns and then uses an iPod app called Leafsnap to go outside to scientifically observe local trees. This type of observation uses the app as a tool to examine attributes of the trees, their leaf structure, leaf arrangement on a stem, bark, fruit, and, depending on the season, their flower. It is autumn in the Northeast. The deciduous trees have not changed color yet, and the students walk by these trees daily and never notice them.

As you read the following story, ask yourself these questions: Why is the teacher engaging students in studying local trees? How is scientific observation different from everyday observation? What types of organizing principles can lead students' observations to a fuller understanding of the common ancestry of all trees?

SCIENCE STORY

Studying Street Trees

I am entering an all-girls urban middle school and upon entering the ninth floor of the building I and the arriving students are warmly greeted by Wanda, the security person engaged to check the students in. Ms. Ellis teaches science to sixth- and seventh-grade students and I am a guest in her first period sixth-grade science class. Walking into her brightly lit science room, there are artifacts from trees everywhere! The back table has leaf presses, seeds, pods, samaras, acorns, dried leaves, and preserved pressed leaves. On each of the six lab tables is a plate of several acorns, all of which come from the same tree. Prior to the lesson, Ms. Ellis explains that she is hoping the students will be curious to locate what they are exploring inside the classroom when they go outside later this week. On the board:

> The Aim: How can careful observations assist us in identifying something?
>
> Do Now: Are there any trees outside the front of the school? Can you describe them? Do you think anyone takes care of the trees here in the city? Do you think anyone should?

I love this room—the students eagerly walk in and notice the acorn piles on the center of the tables. They take their seats and respond in their notebooks to the "Do Now."

Ms. Ellis begins by saying "Before we can go outside with our iPods and Leafsnap apps, we have a lot to explore in class." She asks, "Did anyone go anywhere this weekend where they noticed lots of trees?" Students talked about trees near relatives' houses, trees in the large local park, trees near their church. . . . One student offered that she started noticing trees because they were talking about them in class. There are twenty-five girls in total, all new to the school, several new to science. Girls talk about the trees outside school in vague terms, so Ms. Ellis assigns homework: "How many trees are out front on the street where our school is located? This side of the street? Are they all the same kind? Do you think they look healthy?"

They then discuss tree caretakers in the local park—those who prune and even water the trees. Ms. Ellis remarks that that would be a cool job! They then discuss the acorns on the table and reach consensus that they contain seeds that could grow into a new tree. She instructs the students to select one acorn from the center piles on their tables and record a description of their acorns with great detail. After a few minutes, the girls return their acorns to the center pile and one student mixes them around. They are then instructed to find their acorns. They have ten seconds. Ms. Ellis asks, "How do you know it's your acorn?"

Responses included "Mine was very tiny with a pointy cap," "My acorn had a round dark spot on it," and "The top of my acorn has a piece of stem attached to it."

Students trade notebooks with another student and, based on their acorn description, the student has to find her partner's acorn. Ms. Ellis asks how many found their neighbor's acorn based on the written description; she then solicited good and bad descriptions. She asks, "Do you think these acorns all came from the same kind of tree? Why? Why not?" The students conclude that they came from the same kind of tree because they look very similar.

After the acorns are collected, Ms. Ellis distributes new materials to each table; this time they are artifacts from trees. However, each table receives a different assortment. These include samaras, dried pods, preserved pressed leaves, hairy seeds in a shell, horse chestnut spiky balls, and different simple and compound leaves that were dried. Students use dry erase markers to write descriptions of these artifacts on their desktops (which are dry erase boards). They are asked to be detailed, and they describe the items by size, color, and things they already know. Ms. Ellis says, "Some of you are using magnifying lenses to find tiny details. This is what scientists do; they also compare objects to what they already know." The girls then rotate tables and add descriptions to those already written there. They do this twice and have exposure to three sets of materials. Ms. Ellis then asks them to draw a square in the center of the table and write the responses to this question: What do all the things on your desks have in common? Girls write things like "They were once alive," "They come from plants or trees. . . . "

The students erase their desks as the period closes, and Ms. Ellis will follow up with them the following day. They are scheduled to go outside in two days.

The Next Day: Preparing to Use the Leafsnap App

Upon entering Ms. Ellis's classroom the next day, the SMART Board is on with the following:

> Do Now: How do we use the Leafsnap app?
>
> Do Now: We are going to be using iPods in class today. Working with a partner at your table, come up with three important rules we should follow when using the iPods.

With the class the following emerges:

1. Use caution: Don't damage the screen.
2. Use only for Leafsnap—do not download other apps or play with the iPods.
3. Share the iPod with your partner at all times.
4. Do not take the iPods home; that is, don't steal!
5. Do not delete the Leafsnap app.
6. No food or drink near the iPods.

Students initial their agreement next to the number of their iPod.

Students select one each from four piles of leaves at the front of the room. Ms. Ellis tells the stories of where she found them—waiting for the train near her house, walking across the local park this morning, and on the corner of the street the school is on . . . the girls grin.

Students are instructed to follow the directions that are indicated on the SMART Board:

> Take a picture of one of the leaves and write the name of the tree on the erasable desk surface. Students photograph their leaves and make choices for the tree name based on the generated list.

They label their leaves on their tables: American Elm or Slippery Elm; Ginkgo Biloba; Scarlet Oak or Pin Oak; Sugar Maple or Norway Maple.

Ms. Ellis asks: "How sure are you that the trees match the leaves? How did you make your choice?"

On the SMART Board it states:

> Compare your choice with others at your table—do they match? How confident are YOU that your Leafsnap choice is the correct one?

Starting with the leaf that looks like a fan, everyone had Ginkgo Biloba. Ms. Ellis asks, "What does this tell us about this tree?" They conclude that it is unique, and she tells them where she found the leaves.

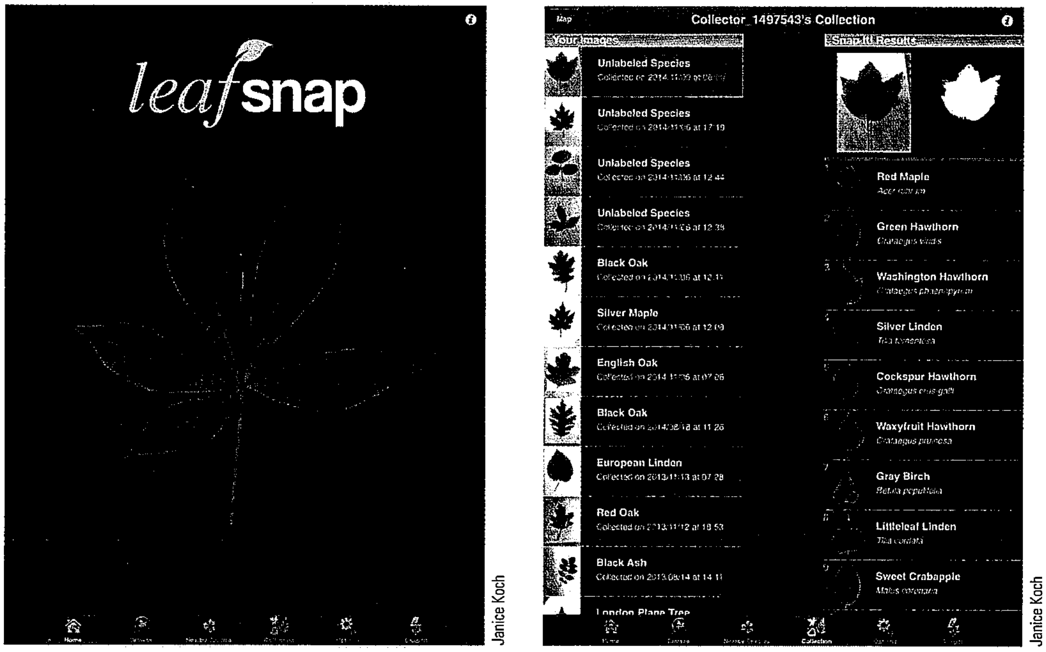
For the Maple leaf, some students had Norway Maple, whereas most had Sugar Maple. She then displays the Leafsnap image on the SMART Board, demonstrates how to label leaves in their collection, and interrogates the duality. They conclude that we need more evidence to say for sure the name of the tree—we need to stand in front of the tree!

Plant blindness: *the inability to see or notice the plants in one's own environment—leading to: (a) the inability to recognize the importance of plants in the biosphere, and in human affairs; (b) the inability to appreciate the aesthetic and unique biological features of the life forms belonging to the Plant Kingdom; and (c) the misguided, anthropocentric ranking of plants as inferior to animals, leading to the erroneous conclusion that they are unworthy of human consideration.* (Wandersee & Schussler, 1998)

They repeated the procedure with the American Elm leaf and the Oak leaf, and then the students were asked: What could you do to confirm that our tree choices were correct? She distributes the first worksheet and invites the students to find a leaf and, using the guide, identify it for homework. The students are engaged and enthusiastic and loving the iPods!

Time to Go Outside

The students are aware that they will take a picture of a leaf from a local tree by gently separating the leaf from the stem and placing it on a white piece of paper. The camera in the Leafsnap app takes the picture and poses several choices for the name of the tree (Figure 4.1). Walking outside with the students and their teacher, I was struck by how excited the girls were to examine the leaves from the local trees. They had already discussed "plant blindness," a phenomenon where so many people (and most students) take no notice of plants, including trees, and now they are venturing outside to specifically study the characteristics and names of the trees. This purposeful observation is fun to watch. After the girls "leafsnap" their tree sample, they decide which one it is and then examine how the leaves are arranged on the stem (opposite one another or alternate); what the bark is like; and what, if anything, other than the leaves is attached to the branches. The students notice acorns from the oak trees and samaras from the maple trees, but they



Collector_1497543's Collection

Unlabeled Species
Unlabeled Species
Unlabeled Species
Unlabeled Species
Black Oak
Silver Maple
English Oak
Black Oak
European Linden
Red Oak
Black Ash
London Plane Tree

Red Maple
Green Hawthorn
Crataegus viridis
Washington Hawthorn
Crataegus phaenopyrum
Silver Linden
Tilia tomentosa
Cockspur Hawthorn
Crataegus crus-galli
Waxyfruit Hawthorn
Crataegus pruinosa
Gray Birch
Betula populifolia
Littleleaf Linden
Tilia cordata
Sweet Crabapple
Malus coronaria

Janice Koch

Janice Koch

FIGURE 4.1 Images from the Leafsnap App

are surprised to find other structures that we call pods or legumes. They are beginning to learn about local biodiversity. When they arrive at a decision about which tree it is, they are asked:

- Does your evidence support your Leafsnap hypothesis? Explain your reasoning. As with any good explanation, make sure that you cite specific evidence!
- If your Leafsnap hypothesis was NOT supported from your evidence, what tree do you think you actually found?
- Examine the other choices and explain why one of the others is a better choice OR explain why you don't think any of the choices actually are supported. Again, make sure that you include necessary evidence!

Students are directed to scientifically observe trees instead of casually observing them or noticing them. The focus here is on using a comparative method, as do scientists, to contrast the features of, in this case, the trees, with the information provided by the handheld technology and the other trees on the block. The hope is that the students will begin scientifically observing the trees like expert biologists. Students spend several days exploring local trees and collecting data about them, recording those data in their notebooks in a format similar to Figure 4.2. They start thinking and talking about their tree observations, and this type of observing in the disciplinary framework of relatedness leads them to understand the centrality of the fruit of the tree (i.e., acorn, samara, legume) and to begin to group trees based on their specific characteristics. The goal is to foster urban middle school student interest in and learning of local biodiversity and the patterns of evolution. This beginning, using the Leafsnap app, is an important step to encourage scientific observation. The context is learning about the common ancestry of

1. Find your target tree! (This will be assigned to your pair.)
2. Remove a leaf from the tree (or if it is very tall, look on the ground and see if there is a leaf from that tree nearby).
3. Use Leafsnap to develop a hypothesis about what type of tree it is. Your Leafsnap hypothesis is the **first** tree that comes up on your list.

   Leafsnap Hypothesis: Our tree is a ____.

4. Provide evidence to determine if the Leafsnap hypothesis is supported. To do this, use the "Name that Characteristic" worksheet to help you identify other characteristics of your tree.
5. Compare **all** tree characteristics to those pictures that are included with Leafsnap.
6. List the characteristics and how they compare in the space below. **You need to include at least four characteristics, such as shape of leaf, back of leaf, edge of leaf, bark of tree, arrangement of leaves on branch, fruits/flowers, and so on.** Make sure that you use proper descriptive language, as provided on the worksheet!

Characteristic	How it is shown in Leafsnap	How it appears on my tree	Check for Leafsnap Tree Match (√)

FIGURE 4.2 A guide for students to record their observations

the trees by studying their identifying characteristics. Shared fruit, leaf, and flower structure is evidence of common descent.

The Teaching Ideas behind This Story

- Notice how Ms. Ellis engages the students with tree-related objects from nature before exploring *Leafsnap and going outside.*
- The contract that the students initialed when taking the iPods to be used in class and outside became a class activity in which all the students had "buy-in."
- The students worked in pairs, making it possible for them to help each other as they used the app to capture photos of the leaves and come up with their hypothesis.
- The outdoors experience extended into the classroom with data recording and sharing.

The Science Ideas behind This Story

- Eighty percent of Americans live in cities or suburbs and are very disconnected from their environment where they are often unknowingly surrounded by many forms of life. Street trees provide an opportunity to engage students in biodiversity.
- The tree characteristics used to determine relatedness and common ancestry are leaf, fruit, and flower structure. Shared fruit, leaf, and flower structure is evidence of common descent.
- Traits are a reflection of ancestry.
- Different plant groups have similar and different traits that are adaptations that help them to survive and reproduce.
- For example, all plants have green leaves for photosynthesis; all flowering trees have fruits to disperse their seed; fruits may take different form in different species groups.
- Plants have different forms for the same function. These forms are shaped by an organism's ancestry. For example, all flowering trees have fruits for seed dispersal, but some plants use samaras (maples and ashes), some use acorns (oaks), and some use pods. All trees have leaves that perform photosynthesis, but leaf form in the same environment varies by species group.
- Traits cannot change based simply on need—there is a limit to how much fruits and leaves can change. For example, animal-dispersed acorns are too heavy to transform into wind-dispersed winged seeds.

Connections to the Next Generation Science Standards

- **NGSS DCI: MS-LS4.A: Evidence of Common Ancestry and Diversity:** Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent.
- **NGSS SEPs:** Students were engaged in *analyzing and interpreting data, constructing explanations,* and *engaging in argument from evidence.* They *obtained, evaluated, and communicated information.*
- **NGSS CCs:** Students recognized *patterns* and *structure and function* when examining the characteristics of trees.

4-5 Scientific Data as Evidence

The following Science Story describes seventh-grade students' experiences as they explore scientific data related to their environment. Along the way, as you will see, the students caught a glimpse into how scientists work on issues affecting changes to ecosystems.

SCIENCE STORY

Ecology Disrupted

Seventh-grade students in an urban area near Baltimore, Maryland, are learning about ecosystems while exploring how scientists work. Their teacher, Ms. Kane, has introduced students to what is meant by an ecosystem. She talks to the students about the snowfall amounts that accumulated in their area the previous winter. The students recall the record-breaking winter in Maryland, where over 80 inches of snow fell in a region ill-equipped to handle it. She asks students to think about what substances were used to help melt the snow and ice. The students recall road salt and sand as a way to help drivers get around. She asks students to think about how these abiotic factors could affect our ecosystem.

Prior knowledge: *These seventh-grade students already understand that an* ***ecosystem*** *is a natural unit, a defined space in which living things (biotic factors) function together with nonliving or abiotic factors in a specific environment. Abiotic factors include all the nonliving chemical or physical factors in an environment, from the quality of the gases in the atmosphere to the types of buildings, roads, and soil that are present.*

The specific abiotic factors that Ms. Kane wants to explore with her seventh graders are the roads in the Eastern United States and the road salt that is used on them in instances of heavy snow and ice. The students are shown satellite images of North America with red lines indicating the roads. Students see that parts of this area are almost totally covered with roads, whereas some parts seem to have few roads. Next, Ms. Kane shows a map image of the Baltimore area and explains that scientists are exploring the area's water supply. Scientists, she says, are exploring the following question:

How do snowy and icy roads put the Baltimore area's water supply at risk?

The students now receive a set of six photographs, one set for each group of four students (Photo 4.1). The photos depict a snowy urban scene, roads with white residue on them, a salt-spreading truck on snowy roads, and rivers and streams near bridges and elevated roadways. The students are asked to make observations about the photos and to suggest how snowy and icy roads may place the water supply in their area at risk. The photos constitute a data set, and Ms. Kane wants the students to relate the data to the study question. Each group of four students arrives at some form of the following hypothesis:

- *Salt spreaders add salt to icy or snowy roads, and when the snow melts, the salty melted water washes off the roads to rivers and streams and sewers.*

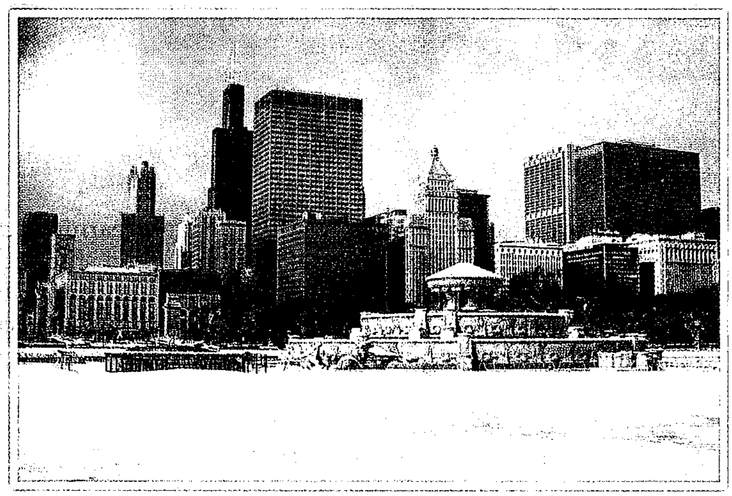
One group goes as far as to say that fish could be harmed by the salty residue.

My thinking: *I am impressed by how well the students work on this challenge. At first, they are unsure why the photo of the salt-spreading truck is in the data set, but then they see the connection. I think, "Would they have thought that salting the roads could harm the environment before this unit?" What do you think?*

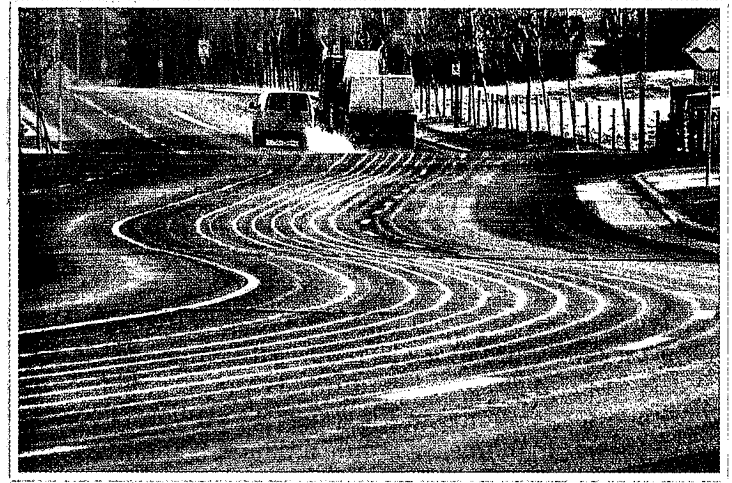
For homework, students are given a fact sheet about salt water, and they are asked why people don't drink salty water (Table 4.1).

My thinking: *The fact sheet and accompanying questions help to scaffold the students' thinking. Now that they have identified salt as the abiotic factor in this ecosystem, they can consider its effects on living things (biotic factors) by exploring these data.*

When students enter Ms. Kane's science class the following day, there are stations with table salt in beakers, lightweight paper cups, and digital scales. At each station, students are asked to weigh a specific amount of salt, ranging from 50 mg to 750 mg. Students are surprised by how small the amounts are; using the numbers without relating them to real quantities is often misleading. After students make the measurements, students are asked to mix the salt into liter bottles of water. After tasting the waters with varying salinities, they understand that even small quantities of salt in a liter of water can affect the quality of the water.



David Lee/Shutterstock.com



Modfos/Thinkstock

PHOTO 4.1 Photos such as these are used as the data set in Ms. Kane's classroom.

A final station has two halves of an eggplant exposed. On one half, Ms. Kane has liberally covered the surface with table salt. After 30 minutes, the eggplant half covered with table salt has water pooling at the surface, demonstrating how salt draws water out from organic matter, dehydrating it. Ms. Kane then explains that scientists have been checking the level of salt in nearby streams and rivers and in the drinking-water supply in the Baltimore area since the 1970s, not long after salt-spreader trucks came into heavy use in the area. She shares with the students the numerical data shown in Table 4.2. She asks, "Why do you suppose scientists began to do this water testing soon after salt-spreading trucks were sent out on snowy and icy roads?"

One student, Mia, answers, "Maybe they were concerned about where all the salt would wind up?"

At this point, Ms. Kane shows a brief video of Dr. Sujay Kaushal, the author of the scientific paper from which the data are taken. In this video, Dr. Kaushal recalls how he and his sister used to walk along the banks of streams in rural Tennessee. He remarks about all the articles of pollution you could see on the banks of these streams and wonders about all the things that were in the water that you could not see. He says, "the water in the streams and rivers are a reflection of all the bad water quality things we do on land." Students could actually see the crystallized road salt on the side of the streams that he studies around where he currently lives, in Maryland. The students get a feeling now for the motivations of this scientist. Ms. Kane remarks, "Whenever we add something to the local ecosystem that does not *naturally* belong there, we want to learn how the system is affected."

TABLE 4.1 The Fact Sheet about Freshwater and Salt Water Given to Ms. Kane's Students

How much salt does salt water have?	▪ Water with salt levels greater than 250–400 milligrams per liter (mg/L) will taste salty. ▪ Water with salt levels under 1,000 mg/L is considered to be freshwater (not salty). ▪ Water with salt levels between 1,000 mg/L and 3,000 mg/L is considered to be slightly salty. ▪ Water with salt levels between 10,000 mg/L and 35,000 mg/L is considered to be very salty. ▪ The salt level in the open ocean is approximately 35,000 mg/L.
How does salt affect freshwater animals and plants?	▪ Some freshwater animals and plants die when salt levels reach 226 mg/L for extended periods of time. Smaller animals that are the basis of the food web are the most sensitive to high salt levels. ▪ Some frogs die when salt levels exceed 400 mg/L. ▪ Freshwater fish like rainbow trout die when salt levels reach 1,000 mg/L for an extended time. ▪ Salt levels as low as 68 mg/L negatively affect roadside plants, such as pine trees. ▪ Large animals like elk, bighorn sheep, and seed-eating birds have all died from eating road salt. ▪ The EPA (Environmental Protection Agency) drinking standard for humans specifies a salt level no higher than 250 mg/L.
Snowmelt runoff	▪ Snowmelt doesn't just sit. It moves. It follows one rule—GRAVITY! Water always flows down. ▪ When water flows over hard surfaces like roads, it carries whatever is loose on the surface with it, such as salt and litter. ▪ Water flows into storm drains, which empty into streams. Streams flow into rivers and lakes. All rivers eventually flow to the lowest point—the ocean. ▪ Some water is collected in reservoirs for people to drink. The process of storing water in reservoirs helps to clean the water naturally. Sometimes water is also filtered and disinfected before it is sent in pipes to the tap. But salt is not filtered out of the water!

Shawn offers, "Just like dumping waste water from factories into the river." Ms. Kane agrees, and suggests that the students can think about other examples of abiotic factors affecting ecosystems.

Now the students begin to examine the data in Table 4.2 in detail. They are also given data sheets that reflect the salinity levels in the *urban, rural,* and *suburban* areas for the last seven years. In each group of four, students select a data sheet to graph, making sure that the scales on each graph are the same. The students understand that one way the scientists make decisions about their data is by representing those data in graphs. They see that in urban areas the water is much saltier than in the area's suburban or forested

TABLE 4.2 Average Salt Levels in Baltimore-Area Streams (mg/L)

	1999	2000	2001	2002	2003	2004	2005
Forested area	2.60	2.54	2.66	2.39	2.69	2.77	2.66
Suburban area	243.79	62.43	68.81	89.08	96.74	115.70	181.23
Urban area	332.22	344.98	235.47	256.34	358.47	454.90	777.73

Source: Institute of Ecosystem Studies, Baltimore Ecosystem Study, www.beslter.org.

regions. The students reason that the more prevalent the roads, the greater the need for salting them on snowy and icy days. They also reason that in 2009, when the Baltimore area had record snowfall, the salt content of the water must have increased rapidly in both urban and suburban settings. They conclude that the data support their hypothesis that salty melted snow washes off the roads and eventually reaches the local streams. Ms. Kane shares the story of the road salt making television news the previous winter. The newscaster reported that "scientists are concerned about the amount of salt we used on the road this winter!" Knowing that Ms. Kane analyzes scientific road salt data, her family was excited to see it on television and called her when they heard the report. This unit is referred to as "Ecology Disrupted" since the abiotic factor introduced to the system disrupts the chemical balance in freshwater streams and rivers.

After the students complete their graphs and study the data that Dr. Kaushal had collected and analyzed, Ms. Kane asks the students which areas were most affected by the salting: urban, suburban, or forested areas? Many students immediately say "urban," since the salinity levels were highest there; however, a large number of students feel that suburban streams also had high salinities, and since there are not as many people in the suburbs as there are in the city, perhaps the suburban streams were most affected when compared to the population. Then the students reach at least one surprising conclusion: Although rural areas seem to be so much less affected by road salting than urban areas, if you analyze the population in relation to the salinity, you find that rural areas have an unwarranted amount of road salting for the level of the population. When Ms. Kane asks what living things were most affected, the students focus on the plight of the fish in local freshwater streams.

Ms. Kane asks the students to brainstorm possible solutions to the crisis of adding massive amounts of road salt to the ecosystem during snowy and icy winters. Students work in groups and brainstorm the question and come up with suggestions that range from using public transportation to manufacturing less harmful materials to help melt snow to finding ways for tires to be coated with substances that melt the snow. Although the ideas sometimes sound extravagant, any idea is better than no idea! I am impressed that brainstorming solutions is part of the science lesson.

As a culminating activity, the students use the Web to access the *Science Bulletins* from the American Museum of Natural History on which these data were based. They also examine a *Science Bulletin* focusing on the urban heat island effect. Although this study was done in the city of Atlanta, these city students could relate to how much hotter it is in the city than in areas that have less brick, mortar, and asphalt. The abiotic factors in this disrupted ecosystem were the construction materials used and the design of the buildings. When Ms. Kane asks for possible solutions, one student mentions the roof gardens that were being developed all over the city. The plants would hold on to less heat energy than the artificial building materials.

The Teaching Ideas behind This Story

- Connecting real scientific data to a locally relevant problem engages the students in authentic science experiences—in this case, in environmental science.
- Ms. Kane made connections to the enormous amounts of snowfall the students experienced the previous winter in their own neighborhood.

- Gathering the data often requires the assistance of the Internet; in this story Ms. Kane used the Web to access two of the *Science Bulletins* from the American Museum of Natural History, "Winter Roads Make Salty Streams" (2006) and "Urban Heat Island Effect" (2004).
- *Science Bulletins* are video and slide programs from the American Museum of Natural History that bring you the latest developments in the fields of astrophysics, earth science, biodiversity, and human biology and evolution through documentary feature stories about scientists in the field and regular brief research updates using scientific visualizations and imagery. Ms. Kane's lessons and the video of Dr. Kaushal, based on these bulletins, were made possible by funding from National Science Foundation Grant #0733269 (2007).
- To help students connect the weather conditions to the addition of salt to the ecosystem, photos were used, showing salt residue on the sides of the roads as well as a salt-spreading truck. Students were asked to make observations of the photos and to draw inferences from those observations.
- To give meaning to the abstract numbers on the data sheet, Ms. Kane had the students work with digital scales, table salt, and paper cups. The process of creating their own salt water solutions concretized the lesson for the students.
- This story illustrates one of the National Educational Technology Standards (NETS) for Teachers (International Society for Technology in Education, 2008): "Teachers design and develop digital-age learning experiences." In this case, the teacher drew data, photos, and a satellite map from the Web source and at the end of the lesson had students themselves access the source to see the material in its original context.
- Students were surprised that a seemingly harmless action—accelerating the melting of snow and ice by salting the roads—could potentially harm the environment. The concept of unintended consequences of human intervention in the ecosystem is a key teaching idea behind this story.

The Science Ideas behind This Story

- According to the *Science Bulletin* on which this lesson was based, more than four million kilometers of paved roads crisscross the United States, with more built daily. In winter, salt is regularly applied to melt ice on roads in many areas of the Northeast and Midwest. But road salt runoff drains into streams and drinking water.
- Scientists have been testing freshwater in three regions of the Northeast for thirty years. The salt buildup has made some urban, suburban, and rural streams 25 percent as salty as seawater. If excessive salting and road-building continue in the Northeast, by 2100 the area's freshwater may be toxic to wildlife and unfit to drink (Kaushal et al., 2005).
- Salt lowers the freezing and melting point of water. Ice forms when the temperature of water reaches 32 degrees Fahrenheit (0 degrees Celsius). When you add salt that temperature drops; on a roadway, this means that if you sprinkle salt on the ice, you can melt it.
- The salt dissolves into the liquid water in the ice and lowers its freezing point.

Connections to the Next Generation Science Standards

- **NGSS DCIs:**
  - **MS-PS1.A: Structure and Properties of Matter:** Substances are made from different types of atoms, which combine with one another in various ways. . . . In a liquid, the molecules are constantly in contact with others.
  - **MS-LS2.A: Interdependent Relationships in Ecosystems:** Organisms are dependent on their environmental interactions both with other living things and with nonliving factors. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for access to these limited resources, constraining their growth and reproduction.

- **NGSS SEPs:** Students engaged in *analyzing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions,* and *engaging in argument from evidence.*
- **NGSS CCs:** Students examined *patterns* in the urban, suburban, and forested data; they looked at *cause and effect* in their data; and examined condition of *stability and change* in the evolution of these natural systems.

Exploring Further

In order for you to implement this experience in your own classroom, you may want to consider answers to the following:

- In light of the unintended consequence of salting the roads in urban Baltimore County, what suggestions, other than using salt, could be made to local officials?
- The American Museum of Natural History offers many *Science Bulletins* related to contemporary issues in environments around the world. For example, "Urban Heat Island Effect" examines the temperatures in and around Atlanta, Georgia. How much hotter can urban environments get than rural areas? What abiotic factor contributes to this drastic rise in temperature? Do you have any suggestions to reduce the urban heat island effect?

4-6 Field Trips

ecosystem
A natural space in which all the living things (biotic factors) function together with all of the nonliving things (abiotic factors) in a specific environment.

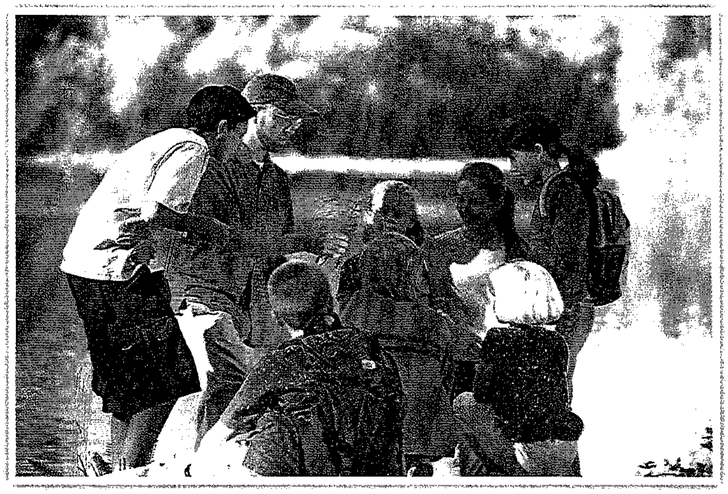
dissolve
When solid particles (such as salt) are broken down into invisible particles when placed in a solvent such as water. The solid particles seem to disappear because they are present in molecular or ionic form.

As we saw from the previous story, science can connect to the world outside the classroom simply by taking the students outside, whether for a short stroll around the school grounds or a more extensive field trip. As Richard Louv remarks, "In the space of a century, the American experience of nature has gone from direct utilitarianism to romantic attachment to electronic detachment" (2008, p. 17).

I was visiting an elementary school in the Northeast one winter morning when a teacher I knew said, "Hi. The class and I are going to visit the Hall of Science today." This is a fine hands-on museum not far from the elementary school. I responded, "Great! How come you are going now?" She said that she had planned the trip weeks ago and thought that, at this time of year, it would be good to get the students out of the classroom.

It struck me that something was lacking in her definition of the trip's purpose. Certainly it is always a treat, if your school has the resources, to take students on class trips, but science field trips can be much more meaningful if they are directly connected to the unit or topic the class is studying. By linking the trips with class study, we reinforce the learning experience—and we demonstrate that science is more than a subject confined to the classroom.

In addition to offering relevant science content, a field trip should provide students with the opportunity to exercise their science process skills. Invite your students to engage in some problem solving outdoors (Photo 4.2). For example, a fourth-grade trip to the seashore might involve taking notes, collecting articles of interest, and perhaps using a ball or two to explore the actions of the ocean waves. The teacher could engage students in recording their observations, drawing what they see, and solving one or more problems that they have previously brainstormed in class. On a similar field trip, an eighth-grade class might collect beach samples in resealable plastic bags to be examined later under a microscope. The students might also collect some ocean water to determine density, turbidity, and salinity. Allowing the ocean water to evaporate is another exciting activity; what remains behind will include the various dissolved and undissolved substances contained in ocean water.



UpperCut Images/Alamy Stock Photo

PHOTO 4.2 These students are not merely collecting plants on a field trip. They are exploring their own questions about the local environment, and in this way the excursion becomes meaningful for them.

Whenever possible, share your rationale for venturing outdoors with the students. Involve them in planning both the excursion itself and the questions it will seek to answer. Ask them, for instance:

- Why do you think we are going there?
- What shall we bring?
- What do you wonder about?

Your students will have good ideas concerning the trip as well as their own stories to tell about related experiences.

4-6a Tips for Outdoor Science Experiences

- Careful planning is essential. For field trips, letters of consent are usually required from parents or guardians, and students should be guided to dress properly for the chosen site.
- Remember to prepare the materials you need to take so students can collect samples and record information. Resealable plastic bags, plastic collecting cups, student science notebooks and pencils, and magnifying lenses always come in handy.
- Students should understand the reason for the outdoor trip and have some ideas about the problem they are exploring.
- The trip should lead to further investigations or research in class, as illustrated by the following science notebook entry by a young student named Ana:

  > *I went on a field trip with my class to the Duck Pond. We were looking for something new we had never seen before. When we came back to the room we all guessed what it was. Based on our past experience we all said it was either a beehive or a wasp's nest. We tried different experiments to find out what it was. After researching it we identified it as a praying mantis home.*

- Adult supervision is required. Depending on the type of excursion and the number of students you are taking, you may need to ask other adults to accompany you. These adults should also participate in the planning for the trip, if possible.

In the following science stories, we will see some examples of science learning experiences both in and outside of the classroom.

SCIENCE STORY

Making Connections, Inside and Outside the Classroom

An Urban Park and the Story in the Rocks

The students in an urban fifth-grade class have been studying rocks and how they form. One city block from the school is a large, beautiful park. Mr. Wallace, the science teacher at this school, takes the fifth-grade classes, one at a time, on a field trip to explore the rock outcroppings in the park. He selects one large outcropping and encourages the students to make detailed observations and drawings.

Before the field trip, Mr. Wallace informs the students that they will need their science notebooks, and he distributes to each student a diagram that looks like a blank circle with grid lines running across and down so that there are sixteen cells within the circle. Mr. Wallace displays two large hula hoops that have been fitted with strings, creating the same sixteen-cell grid. He is also carrying compasses. He explains to the class that their goal for this field trip is to observe the rock outcropping in the way a geologist would. "We are looking for cracks, lines, and scratches and areas where the rocks appear to have been folded over." He wants them to create scale drawings of what they see, using the hula-hoop grids as guides. They will lay a hula hoop over the rock surface and then draw on their own grids what they see in each cell of the hula-hoop grid.

During the short walk to the outcropping, which slopes gently on a hill, Mr. Wallace explains that most of what we learn about the earth's history and structure comes from observations of rocks. "When you are finished making your observations, I will collect your notebooks and see what I can learn from your observations and from what you have drawn."

He asks the students to comment on what they initially notice. The students observe shiny minerals in the rock and conclude that these are mica chips and that this rock is a metamorphic rock. "When we can see micas large enough to reflect light, it is a good bet that the rock is metamorphic," says Mr. Wallace. It is clear that these students have learned the three rock types (igneous, sedimentary, and metamorphic) and their properties. He indicates an area where the rocks appear to have been bent around and curled, and he explains that we can conclude that something must have happened a long time ago to account for this appearance. He places one hoop over a part of the rock's surface and another hoop over another section, a few meters away. The students begin to draw the marks and lines they see on the rock in the corresponding cells on their paper grids. Mr. Wallace says, "Notice the cracks and the grooves. They tell us a story." These are features that interest geologists, he points out. He has centimeter tapes, and the students measure the distances between the grooves. Mr. Wallace explains that these are clues to what lies below. "Clearly the rocks formed and then the cracks. The big question is when did these cracks form relative to when the rocks formed?" The students use a compass to orient their drawings to the cardinal directions (north, east, south, and west) and to show which way the cracks are going.

Mr. Wallace then asks the students how hard they think these rocks are. He reminds them that in geology the term *hardness* refers to what material can scratch the rock; he takes out a penny for the students to use in testing. Can a penny scratch this rock?

The students are busy measuring; drawing, describing, and I get the sense that they will never again see these rocks as just a nondescript grey outcropping. They are now a clue to the history of the region. Mr. Wallace returns to the idea of the order of events. First there were rocks, he suggests, then cracks, then scratches; the cracks go across the folds, so that means the folds came before the cracks.

The students eventually surmise that the cracks line up with regional fault lines. Although this is a tiny piece of the story, the students are getting the idea that geologists make independent observations of all the rock outcroppings in the area, and then their combined data begin to tell the story of the region's history.

The Osage

When a fourth-grade student in southern New York State brings an interesting-looking fruit to class, neither the teacher nor the other students have ever seen anything like it. "This fell from a tree near my house, and I don't know what it is," the student says. "Can we put it in our science center?"

"That's a very good idea," remarks the teacher. "What question can we put on our index card?"

"Let's ask, 'What do you think this is?'" the student replies.

Over the next few days, the class becomes intrigued by the strange-looking fruit. The students write in their science notebooks the qualities they notice about it. It is green, they observe, and has thick, bumpy skin like an orange. It also smells a little like an orange. They wonder why the skin is so thick.

After recording their observations and questions, the students explore the school library and finally ask for assistance. With the librarian's help, they find a picture and description of the fruit in a resource book. It is an osage, they learn. But their curiosity has been piqued, and they don't stop there.

Now they read about where the tree grows, how it got its name, and much more. They learn that an osage is the fruit of the osage orange tree, which belongs to the mulberry family of trees. It was originally found in Texas, Oklahoma, and Arkansas and named after the Osage Indians of that region. It is an inedible fruit, and its tree has a short trunk and crooked branches. It is planted around the United States for hedges and ornamental purposes.

For the rest of the school year, everyone in that fourth-grade class looks for osage orange trees.

Two Seashores

With collection bags in hand, students in a sixth-grade science class on Long Island visit the south shore, the ocean side of the island. The sand forms smooth dunes here, and its fine grains glisten in the autumn sun. The students make drawings of the sparse plant life on the beach, and they study the shells that have washed up. They collect various artifacts to take back to their classroom. Back in the school, using reference books and websites, they identify the marine invertebrates whose shells they have found.

On another trip, they visit the north side of the island, where the bay gently brushes against a craggy shore. They notice how very rocky and pebbly it is. Encouraged by their teacher, the students begin to wonder why this north shore looks so different from the south. They make more drawings and return with sand and rock samples to compare with the samples from the south shore.

In the next weeks, using books, tablets, and the Internet, they learn about the effects of the ocean and inlet bays on landforms. They make inferences, come up with their own ideas, and research areas of personal interest. The students' comparison of the two shores yields some important science concepts.

Investigating a Natural Disaster

A major earthquake strikes California. News of the sudden destruction floods the television and print media nationwide. In Texas the next day, one fifth-grade teacher begins doing "earthquake science," despite the fact that it is not listed in the formal fifth-grade curriculum.

The students clip newspaper stories on the disaster and hang them around the room. Prompted by the teacher, they write down their earthquake questions and research them in library books and on websites. In the science center, some students make clay models of the earth's crust and use plastic knives to cut lines in the clay to represent faults. Others use layer cakes in cake pans that are precut before the cakes are baked. (When you bake a layer cake in a pan that has been cut slightly on the bottom, the layer comes out sporting a large crack, which resembles a fault in the earth's crust.) Using these models, the students learn that an earthquake is a sudden slippage of rock that sends enormous shock waves through the earth.

The students also write stories about the earthquake and take collections for the earthquake victims. Besides increasing their understanding of earthquakes in particular, these explorations help make the students aware of the impact of natural events on human lives.

Coconuts Outside the Door

Outside the door of his apartment complex in south Florida, Mr. Appleton, a seventh-grade teacher at the local middle school, finds a coconut that apparently has fallen from one of many palm trees that line the

Exploring a Coastal Plain

As teachers, we often have fascinating natural phenomena right under our noses, but familiarity tends to breed indifference. The first step in bringing the local environment alive for our students is to pay attention to it ourselves.

In a small coastal fishing community in Maine, ten elementary school teachers accompanied me to a part of their coastline, an inlet where granitic mounds of rock dotted the landscape. This place was just down the road from the elementary school, and the teachers were discussing how to use their local environment as a living laboratory for their students. For me, it was a mysterious and interesting site, but for these local teachers it seemed quite ordinary because they had seen it countless times before. "What do you notice?" I asked them. "Tell me everything, anything." Thus prodded, they began to observe more than they had suspected they would. For example, it was low tide, and my companions pointed out that all the mounds of rock had water marks, which indicated the point to which high tide had risen that day. *Tides*, these teachers knew, are the rise and fall of the oceans caused mainly by the moon's gravitational pull on the earth. The waters on the side of the earth facing the moon bulge out toward the moon's gravitational pull, creating a **high tide**. The other side of the earth, facing away from the moon, has high tide simultaneously because the moon's gravitational pull has pulled on the solid earth as well, leaving the waters bulging on the opposite side of the earth. Meanwhile, as the waters bulge on two sides of the earth, the waters on the other two sides flatten, causing lower levels of water, or **low tides**. Because the earth rotates on its axis once every twenty-four hours, the tide rises for about six hours at a particular point, then falls for about six hours.

The teachers knew all this, but it hadn't occurred to them that they could use the inlet down the road from their school as a place for their students to investigate the concepts of tides, gravitation, and the movements of the earth and moon.

As we stood there, we noticed that some untidy seagulls had left the shells from the mussels they had eaten atop a large rock, which had served as the gulls' dining table. That observation sparked a discussion about food chains.

One teacher picked up a dried scallop shell in which a spider had spun its web. Talking about it, we brought up ideas about animal habitats, ecosystems, and more.

These teachers were so impressed with the natural phenomena under their noses that they took their students to the inlet the next day to collect materials for science center interest.

street opposite the beach. He looks up, and under the spreading arms of the palm tree's large leaf stalks he sees bunches of coconuts, some already brown, that appear ready to detach themselves and fall.

Bringing the coconut into his science class, Mr. Appleton shows it to the students. "Look what I found outside my door," he says. "I was wondering what you think. Is this living or nonliving?" The students are amused; they know they are starting life science in seventh grade, but yesterday they looked at pond water and explored single-celled organisms with their microscopes. "What does this have to do with paramecium?" asks Dean.

"What makes you ask that question?" responds Mr. Appleton.

"Well," Dean says, "I thought we were doing life science now."

"We are," says Mr. Appleton, "so we are wondering: Is this coconut living or nonliving?"

All of the students have seen coconuts before. In their coastal neighborhood in tropical Florida, palm trees are everywhere. The students offer various ideas about the coconut. Most of them are reluctant to say it is not living, but they are unable to say why they think it is alive. The consensus in this class is that the coconut *will become* a living palm tree if planted in the ground, but for now it is "dormant." Mr. Appleton asks what they mean by dormant and invites them to do research on the coconut.

The students then proceed to explore, in research books and on websites, what processes living things perform. As they do so, Mr. Appleton raises more questions about the coconut: "Why do you think it has a hard outer shell?" "What about the texture of the nut inside the shell?" "What purpose does the liquid inside, called the milk, serve?" "Do you think the coconut would sink or float in water?"

In the days that follow, students come to class with additional data about the coconut. They place the coconut in a large basin and watch it float. Although they have seen coconuts every day, they have never before interrogated their own environment in this way, and they are surprised that some of the trees in their daily life have become the science topic for the class.

The Teaching Ideas behind These Stories

- Science comes alive when you think of it as a way to explore nature in your own backyard. In four of these stories, the students' scientific inquiry was connected directly to where they lived. In the earthquake story, the inquiry was linked to news reports the students had just heard and to their own collections to assist the victims.
- We can say that these students followed a "both/and" curriculum (McIntosh, 1983). That is, they pursued both the prescribed, formal curriculum of the school and their own informal, self-constructed, experientially grounded curriculum. In effect, an informal curriculum constructs a new textbook—the textbook of our daily lives. ("Making textbooks of our lives" is a phrase first used by Emily Style, codirector of the National SEED [Seeking Educational Equity and Diversity] Project on inclusive curriculum, based at the Wellesley College Center for Research on Women in Wellesley, Massachusetts.)
- Connecting science to students' own lives—in a way that encourages them to explore their own questions—both engages them in using science process skills and validates their sense of themselves as scientific thinkers. This is particularly important for students who might be discouraged or marginalized by traditional science teaching.
- Since classroom science centers should reflect the lives of the students, it makes sense that they vary with the geographic location of the school and the interests and backgrounds of the students. For instance, classrooms in coastal regions may be rich in seashell collections, and inland regions may have rich rock collections. A school in the Southwest may have a marvelous display of different sands and sedimentary rocks on its science table.
- In the coconut story, notice how Mr. Appleton was respectful of Dean's question about whether they were "doing" this subject now. Students see school science as separate from their world and almost resist broadening their point of view. Undaunted, Mr. Appleton continued with his coconut questions and hooked the students on a product of nature that is part of their everyday lives.
- In the rock field trip story, notice how the teacher referred more than once to the way a geologist would look at the rock. He was making the distinction between casual observation and scientific observation.

The Science Ideas behind These Stories

- There are three rock types: igneous, sedimentary, and metamorphic. **Igneous rocks** are formed above or below the earth's surface when magma (below) or lava (above) cools and hardens. The most common igneous rock is granite. **Sedimentary rocks** are formed when sediments, eroded from rocks on the earth's surface, are deposited by rivers into coastal basins or large lakes. Sand, clay, silt, pebbles, and stones are types of sediments that form sedimentary rocks. Sandstone, shale, limestone, and conglomerate are examples of sedimentary rocks. **Metamorphic rocks** are formed from igneous and sedimentary rocks that are pushed below the surface (by shifts in the earth's crust or by lava flows) and subjected to severe pressure and heat. Metamorphic rocks are the hardest of the three rock types; examples are slate, gneiss, and marble. Slate has been metamorphosed (changed) from shale, gneiss from granite, and marble from limestone.
- Osage trees are distinctive because of the fruit's thick, pebbly skin. Like many other plants that originated in dry climates, the osage fruit has evolved an outer coating that protects it from dehydrating. They are not common in southern New York State, where the fourth grader in our story noticed one.

- Snow forms from water vapor that condenses when the temperature of the air is below freezing. The term *condenses* means that the particles of water vapor come close together, forming droplets of water. When the temperature is below the freezing point, the water vapor condenses into snow crystals rather than into rain. Snow, then, is frozen water vapor. There is a lot of space between snowflakes. The air fills the spaces between the snowflakes, and that is why snow takes up so much more space than the water it turns into when it melts. That is also why the environment seems so quiet after a snowstorm; sounds are absorbed by the air spaces.
- As the students in the Long Island story discovered, seashores have sand particles of different sizes, depending on how the shore was created. On the south shore of Long Island, the constant wave action of the Atlantic Ocean causes rocks to be worn down into tiny sand particles—a process called **weathering**. On the north shore, the water is from a bay, a smaller inland waterway. Here the water action is gentler, the process of weathering is much slower, and hence the rock particles are much larger and coarser than the fine-grained sand on the south shore.
- An **earthquake** is a sudden slippage of rock. Earthquakes occur because the outer layer of the earth (the part we live on), called the *crust*, is made up of huge chunks of rock called *plates*. Rock plates lying next to each other are pressed tightly together. Sometimes the pressure is so great that they need to slip past each other ever so slightly in order to settle in a new position that eases the pressure. This slippage is what we experience as an earthquake. Earthquakes are most common in areas where there are boundaries between the plates or huge cracks in plates. These boundaries and cracks are called **faults**.
- The coconut thrives on sandy shorelines in the tropics. As Mr. Appleton's class discovered, the fruit can float in water, and, in fact, coconuts can travel long distances by floating. When they wash up on a new shore, they can germinate to create new trees. Coconut oil is used in a wide variety of products, including soap, cosmetics, and cooking oils.

Exploring Further

As you consider implementing this type of science experience in your own classroom, consider the answers to the following questions:

- On what kind of landform do you live? For instance, is it a coastal plain, an interior a plain, a plateau, a mountain? How can you investigate what it is called and how the land achieved its current configuration?
- How does nature present itself in your surroundings? Are you near a seashore, a desert, a grassy plain, or a park rich with conifers?
- How many distinct seasons are noticeable in your area?
- In what ways have people changed the natural landscape of your environment?
- What is the local plant and animal life like?
- How can aspects of your local landscape and plant and animal life inform your students' science experiences? How might they be linked to the formal science curriculum?

4-7 Science Centers: Bringing the Outside Inside the Classroom

One way to make science part of the daily life of the classroom is to reserve a table in a center of the room and label it the "science center" or the "science table." In some schools, this area is called the "science center" because it becomes the center of scientific activity in the classroom. Whatever name you choose for it, this area can reflect many possible activities in the life of an elementary school science class.

PHOTO 4.3 Students examine a model of a human skeleton with their teacher.


Purestock/Alamy Stock Photo

high tide
High level of ocean waters, when the waters reach farthest onto land. On the side of the earth facing the moon, high tide occurs because the waters bulge out from the moon's gravitational pull. At the same time, on the opposite side of the earth, there is also a high tide because the moon's gravitational force has pulled the solid earth as well, leaving the waters bulging out on that side.

low tide
Low level of ocean waters that occurs because, as the waters bulge on two sides of the earth, the remaining waters flatten.

igneous rock
Rock formed above or below the earth's surface when magma (below) or lava (above) cools and hardens.

sedimentary rock
Rock formed when sediments, eroded from rocks on the earth's surface, are deposited by rivers into coastal basins or large lakes. These sediments are compacted and become rock through a process called lithification.

metamorphic rock
Rock transformed from igneous and sedimentary rocks that are pushed below the surface (by shifts in the earth's crust or by lava flows) and subjected to severe pressure and heat.

weathering
The wearing away of rocks on the earth by the action of the sun, air, and water.

earthquake
A sudden slippage of rock.

faults
Large cracks or breaks in the earth's crustal plates. Earthquakes are most common in areas where there are major faults.

The materials in your science center need to be clearly displayed in a way that engages the students. Hence signs and materials must be easy to read and in a large font, and directions should be clear and unambiguous. The visual displays should give the students an idea of the topic even if they have limited reading skills. Following the principle of universal design mentioned earlier in this book, make the materials as accessible as possible by all your students. Also be sure to relate each science center topic to overall themes and organizing concepts. Here are a few ideas:

- *Seasonal changes*. The science center can reflect the cycle of ongoing changes in the seasons. For example, an autumn science center might display acorns, pinecones, colorful leaves, chestnuts, and other tree parts that commonly fall to the ground at this time of year in many parts of the country.
- *Materials related to the current science unit*. A science center could reflect the science unit the class is engaged in at the moment (Photo 4.3). For example, a fifth-grade class studying ecosystems might create some small habitats in its science center. A third-grade unit on sound energy might be reflected in the class's science center by student-made instruments.
- *A class nature collection*. A science center can include a potpourri of items from nature that students brought in simply because they found them fascinating. An appropriate title for such a science center might be "The Class Collection from Nature."

4-7a Making the Science Center an Interactive Experience

In many classrooms you can find objects of nature on display in a science center. Unfortunately, if it is just a display area, teachers and students often lose interest in it. These objects merely collect dust and serve no useful purpose.

To connect science with students' lives, the science center needs an invitation for students to explore, a reason for them to visit. For example, the science center can be a place where students are challenged to consider some questions and then generate their own questions. After visiting the classroom science center, students could be encouraged to write in their science notebooks, reflecting on what they did and what questions the experience raised for them. Students should also generate their own ideas for materials that could be added to the science center as well as questions that could be asked about these new objects.

The following sections offer some clues for turning the science center into an interactive experience that engages students in thinking, in exploring, and in developing their science process skills.

Designing the Science Center with Your Students One way to interest students in the science center is to involve them in designing it and supplying its contents. This participation helps ensure that the informal science curriculum reflects their interests.

In setting up a science center with your students, here are some questions you can ask that will engage them in the process:

- What should we put in our science center?
- What can we *do* there?
- What materials will we need when we explore the objects in the center?
- Can we keep a small class pet there?
- What rules do we need about how and when to use the science center?

Guidelines for Creating a Science Center in Your Classroom

- The classroom science center should reflect the students' interests and, wherever possible, be set up by them. Its contents should change regularly to keep stimulating students with new objects and questions they can investigate and ponder.
- All the signs and cards at the science center should be printed in large, bold lettering for students who have visual impairments. Similarly, the signs should not be placed too high or too low; students who have physical disabilities should be able to read them easily.
- No objects that could pose a danger to students should be kept in the science center—for example, no heating devices or objects with sharp edges. See the section on safety tips in "More Resources for Teachers" at the end of this book. Also see the *NSTA Ready-Reference Guide to Safer Science* by Kenneth Roy (2007).
- The center should include tools for measuring different properties of objects, such as a balance scale, uniform masses for weighing, centimeter sticks for measuring distance, and **graduated cylinders** for measuring liquid volume. The center can also include other common science tools, such as magnifying lenses, prisms, magnets, and mirrors. The questions and activities should give students reasons for using these tools.
- If at all possible, place a networked computer in the science center. It should be loaded with some meaningful software programs to engage students in problem solving, and the questions posed in the center should often lead students to use the computer as a tool.
- If the science center reflects the theme of the current science unit, set out materials and experiences that extend the students' thinking. For example, for a unit on electricity, set up the science center so that it invites students to construct different kinds of circuits. The center might feature books about electricity and perhaps have some small electrical appliances (unplugged!) for students to take apart and explore.

graduated cylinder
A device used for measuring liquid volume. In essence, it is a scientific measuring cup—a glass or plastic cylinder calibrated in milliliters.

In the upper elementary school grades, students can largely control the contents and activities of the science center. Science center "crews" can rotate monthly, taking the responsibility for changing some displays and maintaining others, as they see fit. This regular attention helps ensure a regular flow of materials into and out of the center.

For very young students, the teacher can take a more active role in designing the exhibits. Even in these earlier grades, however, you can engage students in designing the science center by offering possibilities and inviting them to share their own special objects from nature.

One first-grade teacher found that her class's science center, which focused on the seashore, was getting *too* exciting, at least in terms of the way students behaved there, so she engaged her students in developing rules for the science center. The teacher felt that any rules she could have imposed on them would have been burdensome rather than effective and helpful, so she let the students consider their own comfort level and come up with reminders that only they could have created. Here are the guidelines the students themselves made up:

1. No traffic jams, please. Three students at a time.
2. Wait your turn and say "please" and "thank you."
3. Share books.
4. Sit the right way.
5. Visit about ten minutes.

With their own rules in place, the students found the science center to be an excellent place to investigate seashore topics independently. Often, during science discussions, these first graders would refer to books they had read in the science center or to questions they had wondered about while exploring the resources there.

Questions and Activities Like the science activity stations described earlier in the book, a classroom science center should have cards (or displayed pieces of paper) that contain questions. For example, if the science center has a collection of acorns, the card could read, "How would you classify these acorns? Why did you classify them this way instead of some other way?" Whenever possible, the teacher should have the students themselves construct the questions when they set up the displays. The students often answer the science center questions in their science notebooks.

4-7b Sample Science Centers from Around the Country

Looking at some science centers that teachers and students have set up in different areas of the country will help you think about ways to connect science concepts with your students' daily lives.

A Third-Grade Science Center in the Northeast This science center contains a collection of seashells in a plastic container as well as the book *Seashells by the Seashore* by Marianne Berkes (2002). An index card on the table next to the shells has the following message neatly printed on it:

> *Can you classify these seashells? In what ways are they the same? In what ways are they different?*

A Second-Grade Science Center in the Northwest One second-grade student has brought a very large pinecone to class. It becomes part of the science center. The teacher asks the students what they want to find out about this pinecone. The children wonder how much it weighs, where it came from, and why it is so big. As the pinecone is placed on the science table, the teacher writes this on the accompanying question card:

> How many red chips weigh the same as the pinecone? How long is the pinecone? Where do you think it came from? Why is it so big?

The children who wander over to the science center are free to explore any or all of the questions.

A First-Grade Science Center in the Midwest A stuffed, furry yellow chick sits on the science table. The index card asks a science question connected to literature:

> In what way is this baby chick like the real chick in the book we read in class? In what way is it different?

The book mentioned here is Ruth Heller's *Chickens Aren't the Only Ones* (1999).

A Third-Grade Science Center in the Autumn A group of leaves sits on the table. They have different shapes, sizes, and colors. An index card reads:

> What types of trees do you think these leaves came from? Are they from very large trees? Deciduous trees? Coniferous trees? Explain your thinking.

A Second-Grade Science Center A small basin of soapy water is surrounded by pipe cleaners shaped to look like bubble wands. Some are triangular, and some are square. The index card reads:

> What shape is a bubble?

In the same science center, next to a prism, an index card reads:

> Hold this up to the light. What colors do you see?

A Third-Grade Science Center A basin of water invites the students to place different objects in the basin to see if they sink or float. The objects on the table are a marble, a paper clip, a wooden block, and a small ball. The children are allowed to try other objects as well (but dunking peanut butter sandwiches from their lunch boxes is discouraged). An index card asks:

> Which objects sink in water? What happens when they sink?

A Sixth-Grade Green Science Center One sixth-grade class was studying the quality of water in the local environment. Using samples of water in small, labeled beakers, students tested tap water from the school water fountains, tap water from home, store-bought bottled water, and rainwater. They had litmus paper and red cabbage juice indicators to determine the pH of the various samples. (The **pH** is a measure of the acidity or alkalinity of a solution. Litmus paper and red cabbage juice both change color in ways that reflect the pH.)

pH
Measure of the acidity or alkalinity of a solution.

As students tested each sample, they recorded the pH of the water on a chart at the science center. Water usually has a pH of 7, which is considered neutral. Water that is too acidic (less than 7) or too alkaline (more than 7) is considered unsafe for drinking. This class learned that about one-sixth of the world's population does not have access to safe drinking water and that these people live predominantly in Africa, Mexico, parts of South and Central America, and parts of Asia (Smolan & Erwitt, 2007).

The science center questions should encourage the students to explore and experiment with the materials at hand. One second-grade science center displayed eyedroppers and a cup of water. Next to them were some pieces of an old newspaper. The card read, "Place a drop of water on the letters in the newsprint. What happens?"

Imagine a science center or science table that changes every few weeks, contains an assortment of objects collected by the students and teacher, and challenges the students to find answers to questions. Since classroom science centers should reflect the lives of the students, it makes sense that they vary with the geographic location of the school and the interests and backgrounds of the students. For instance, classrooms in coastal regions may be rich in seashell collections, and inland regions may have rich rock collections. A school in the Southwest may have a marvelous display of different sands and sedimentary rocks on its science table. This is the sort of informal learning experience in which students can become deeply engaged.

4-8 The Daily Life of the Classroom

When you enter an elementary school classroom, the life of the class is often reflected by the materials that adorn the room. I often look for a science center. When I find it, I spend time exploring the materials on it. Sometimes they tell me only what science unit the students are studying; at other times, though, I learn about the students' own collections and interests. The tacit message I receive from classrooms that have student-generated science centers is, "Science is a regular, meaningful part of the life of this class."

Similarly, in a middle school science classroom, I look for more than the typical scientific equipment and posters. What I want to see is some evidence that the students' own interests and lived experiences have informed their science activities. For instance, the displays may include student research reports that focus on areas of student interest.

The same principles apply to field trips and other outdoor activities. By constructing an informal curriculum out of natural items and events in the students' own world, we make it possible for them to value themselves as scientists and to overcome the traditional factors that alienate many young people from science. We help them understand science content more deeply and more personally as part of a larger picture. Finally, we raise their awareness of their natural environment and the issues it poses for their future life as adults.