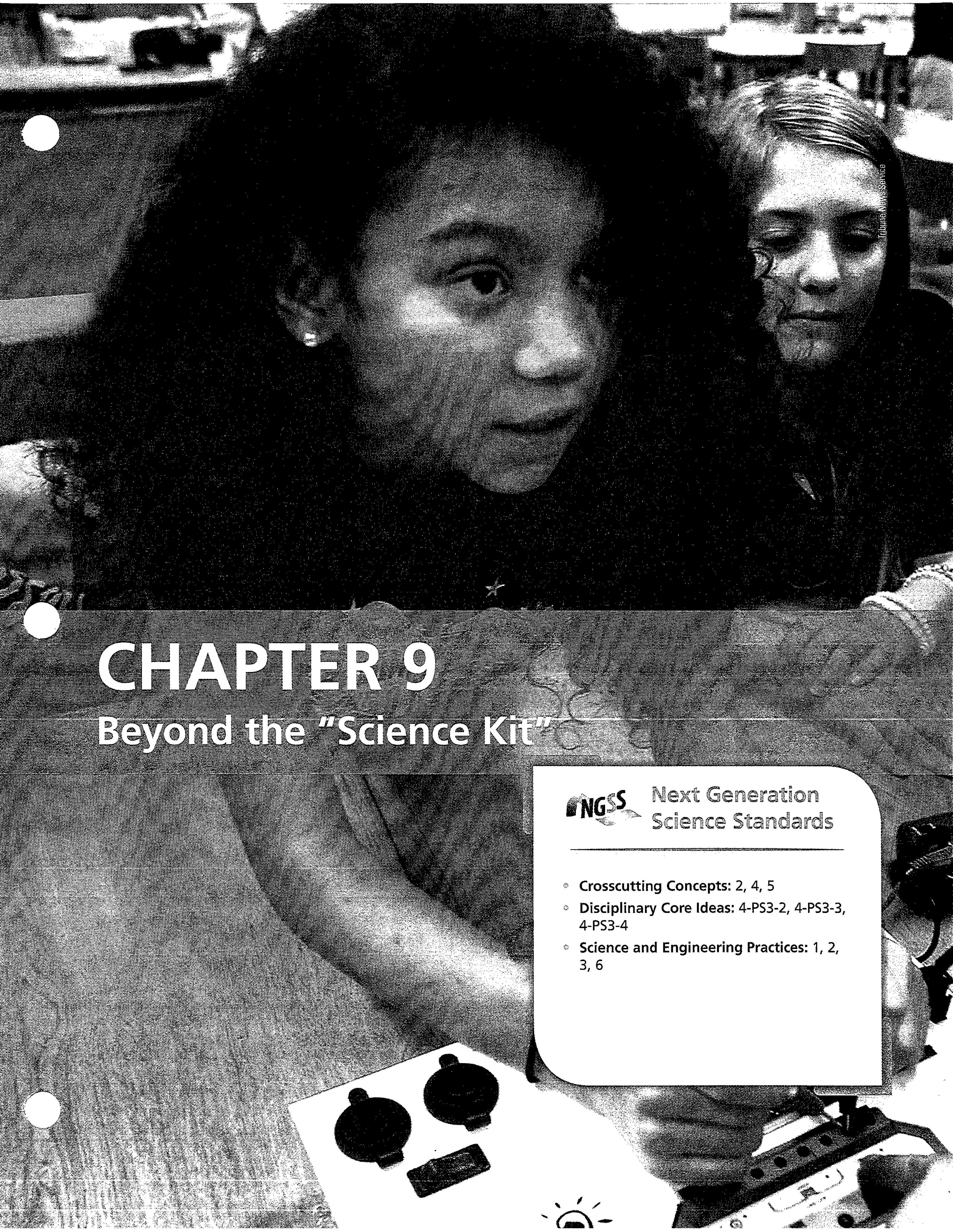


CHAPTER 9
Beyond the "Science Kit"

NGSS Next Generation Science Standards

- **Crosscutting Concepts:** 2, 4, 5
- **Disciplinary Core Ideas:** 4-PS3-2, 4-PS3-3, 4-PS3-4
- **Science and Engineering Practices:** 1, 2, 3, 6

LEARNING OBJECTIVES

After reading this chapter, you should be able to:

- 9-1 Critique the rigid use of the electricity kit materials.
- 9-2 Analyze how the electricity materials can be used to enhance student learning.
- 9-3 Examine how the shoebox house design project employs science and engineering practices.
- 9-4 Understand what is meant by science PCK and its connection to the 5e learning cycle.

Reflection

To Think About:

- Have you ever explored the inside of a flashlight?
- Does your home have fuses or circuit breakers?
- Why does faulty electrical wiring cause fires?
- How many atoms can fit on the period at the end of one of these sentences?

People often use the word *energy* in daily conversation when they refer to not having enough energy or turning off the light to save energy. Yet, in spite of this ready connection to everyday life, energy remains an abstract concept for students because it is not a concrete substance with easily measurable properties in the way that matter is. Yet energy is a fundamental concept in the study of science.

Energy exists in many forms, and comprehending that one form of energy may be transformed into another requires a great depth of understanding. Elementary school students typically explore four forms of energy: sound, light, heat, and electricity. Their understanding deepens gradually as their exposure to these concepts increases, until by middle and secondary school, students can deal with the fairly abstract concepts of energy measurement and transformation. Some of the disciplinary core ideas that are the foundation of the study of sound, light, heat, and electricity include the understanding that the faster an object is moving, the more energy it possesses, and that energy can be moved from place to place by moving objects or through sound, light, and electrical currents.

Since energy is complex science idea, you probably think that many students develop alternative conceptions about it. You're right, as you'll see when you read the stories that follow. But this chapter also focuses on another type of alternative conception or misconception—one that exists in science education itself. It is found among teachers, administrators, creators of curriculum materials, and many others. This misconception relates to the thinking that there is a need for a specific box of materials and step-by-step instructions in order to do science with students. This is plainly not so! To do science with children and young adults, we often need materials, a good plan, an open mind, and a desire to learn what the students are thinking about the investigation at hand.

9-1 The Electricity Kit

In the following two stories, we examine the ways in which two fourth-grade classes explore the beginning of a unit on electricity. Both teachers have been given a typical science "box," that is, a kit of materials to use with their students. The box has arrived complete with specific instructions for the teacher and little booklets for the students. As you read, think about the nature of scientific activity in these two classes. Look for moments when authentic investigations are taking place. Ask yourself: "In which class would you rather be to learn about electricity?"

SCIENCE STORY

Using the Batteries, Bulbs, and Wires Kit

Let's visit Ms. Stone's fourth-grade classroom in a Midwestern suburb. The students are about to begin a unit on electricity, and Ms. Stone is excited. The school district has just received several electricity kits from a commercial manufacturer. Ms. Stone is pleased that she can use these new materials to teach the unit on electricity.

The night before the unit begins, she reads the kit's "Instructions to the Teacher" and prepares her lesson. When she examines the contents of the science kit, she finds packages of D-cell batteries, battery holders, small 1.5-volt bulbs that look like flashlight bulbs, holders for the bulbs, and spools of thin wire labeled "bell wire." The kit also includes several wire strippers and switches. Following the directions in the kit, Ms. Stone cuts 30-centimeter strips of bell wire and uses the wire strippers to remove the plastic insulation from the ends of each strip. With small self-sticking letters, she then labels one end of each wire strip "A" and the opposite end "B."

The next morning she explains to the students that they are going to begin the electricity unit. But first, they need some definitions. She has arrived early to write three definitions on the blackboard, which she now asks the students to copy into their notebooks:

- An *electric circuit* is a continuous pathway for an electric charge or current to follow.
- A *series circuit* is a simple circuit in which the flow of electricity has only one path.
- A *parallel circuit* is a circuit where the flow of electricity has more than one path from the same power source.

Ms. Stone reads the definitions aloud and goes over the words. Quietly the students copy these terms into their notebooks.

Ms. Stone's thinking: *Ms. Stone believes that the students need the vocabulary in order to carry out the investigation meaningfully. She believes in giving the meanings up front, before the students begin the exploration.*

Ms. Stone asks the students to get into their science groups of four. Each group, she explains, will get four bulbs, two batteries, four bulb holders, and two battery holders. Each group will also receive seven stripped wires, each 30 centimeters long, with the ends labeled "A" and "B." One end of each battery holder is labeled "B," and the other end is labeled "A." She explains to the students that they are *not* to touch the materials until she gives them instructions.

When all the materials are distributed, Ms. Stone begins. "Now, will one person in the group take the batteries and place them in the battery holders? Next, another person should gently screw each bulb into the bulb holders."

The students do as they are instructed. Then Ms. Stone continues, "Does everyone see that one end of the battery holder is marked "A" and one end of the wire is marked "A"? Okay, take turns as we follow the next steps. Attach the end of the wire marked "A" to the end of the battery holder marked "A" by putting the wire through the loop and twisting to make good contact. Now repeat what you just did with another wire, only this time take the end marked "B" and loop it through the end of the battery holder marked "B."

"Now you should have one battery that has two wires coming from it, one from each end," says Ms. Stone as she holds up a sample of what she means. The students are fidgety, especially those who are not working directly with the materials at that moment. *Why do you think the students are restless?*

"The next thing we are going to do," Ms. Stone continues, "is to connect the end of the wire that has a "B" on it to one side of one of the bulb holders. . . . Then take another wire and connect the end marked "A" to the other end of that bulb holder. . . . Now take the end of that wire marked "B" and connect it to a second bulb holder. . . . Then take the "A" end of the other wire that is attached to the battery, and connect it to the other side of the second bulb holder."

Ms. Stone talks slowly and waits for the students to complete each step before proceeding with the next step. Finally, the bulbs light!

Ms. Stone's thinking: *Ms. Stone is pleased that the students have followed the directions well. She notices that every group's bulbs worked.*

"Okay," says Ms. Stone. "You have made a simple series circuit. Let's look at the definition on the board." The students listen as Ms. Stone reads the definition again. They are instructed to draw their series circuit and label it in their notebooks.

After Ms. Stone checks their drawings, she continues: "Now we are going to make a parallel circuit. This is a little more difficult, so you have to listen carefully." She proceeds in the same manner with direct, step-by-step instructions, which the students follow until the bulbs light. Once more, all the groups get the same result.

"This is called a parallel circuit," Ms. Stone explains. Together, she and the class read over the definition of a parallel circuit.

"Tomorrow," Ms. Stone tells the students, "we will use our series circuit to test for materials that carry electricity."

9-2 The Electricity Kit—Revisited

SCIENCE STORY

Revisiting the Batteries, Bulbs, and Wires Kit

Ms. Travis is a fourth-grade teacher in another school in the same school district. She is working with the same materials as Ms. Stone—with one difference. She has requested funds from the fourth-grade science budget to purchase twelve flashlights and twenty-four C-cell batteries, two per flashlight. She assembles all of the flashlights with their batteries. When the students enter the room the following morning, she invites them to form science groups of four.

Before starting the activity, however, Ms. Travis asks the students what they would purchase if she asked them to go to the supermarket and pick up a pound of electricity. The students call out different answers. One student says she would buy a pound of light bulbs. Another says he would buy a pound of batteries. Ms. Travis listens and asks them why they made those choices. "Is it the same to say that light bulbs *are* electricity," she wonders aloud, "as it is to say that light bulbs *work on* electricity?"

Ms. Travis's thinking: *Ms. Travis knows that students often think of the materials that produce or carry electricity as being the electricity itself. This alternative conception is common because electricity, a form of energy, does not have mass or volume like matter. Ms. Travis is trying to bring out prior ideas of this sort as the students begin the electricity unit.*

The students listen carefully to Ms. Travis's question. One student remarks that you can't really buy a pound of electricity because it isn't a real thing. Ms. Travis prompts, "Can you say more about that?"

"Well," the student continues, "you can't really hold electricity in your hand, but it can give you a shock." Ms. Travis invites others to think about that.

She then shares the following idea: "We know that anything that has mass and takes up space is matter. So if electricity is not matter, what is it?" This class knows she means "energy" because they have spent weeks studying heat energy. But it is important to Ms. Travis to remind the students again that energy is more difficult to "grasp" than matter because we cannot hold it concretely in our hands.

Now they are ready to begin the activity. She explains that she would like them to explore some flashlights. "Take these flashlights apart; take out the inside parts," she requests as she distributes two flashlights to each group of four students. "It is better to work with one partner for this exploration," she adds. "How many of you have opened and explored flashlights before?" About half the students raise their hands.

"Girls and boys, you will notice that the top unscrews and then several pieces come out, including the bulb. Sometimes those pieces fall out, so be careful not to hold the flashlight too high. As you and your partner examine the insides of the flashlight, draw and label the parts in your science notebook."

The students take apart the flashlights and make rough drawings in their notebooks. Then Ms. Travis distributes strips of bell wire, one to each pair of students. "Let's see if you can use this wire, with one of the batteries and the bulb you have found, to get the bulb to light. Before you begin, let's look at these tools."

She holds up the wire strippers. "Where have you seen these before?" Some students recognize the wire strippers from tool kits they have at home. "Why are they important for our experiment?" Ms. Travis asks. Some students, who have prior knowledge about stripping wire, offer answers. Ms. Travis distributes the wire strippers and suggests that the students use them to bare the ends of their wires.

Ms. Travis's thinking: Ms. Travis wants her students to learn by doing. However, she knows that the battery, bulb, and strip of wire will be cumbersome to manipulate, and she doesn't want the students to get so frustrated by lack of success that they lose interest. Thus she suggests that they strip the ends of their wire, giving them a better opportunity to solve the problem.

The groups of students make several attempts before finding the ways that work. Most groups discover that the bulb will light if one end of the wire is wrapped around the bottom of the bulb and touching one end of the battery, while the other end of the wire is touching the other end of the battery. One group of students succeeds by stripping a portion of the center of the wire, wrapping that portion around the tiny bulb, and then touching either end of the battery with the free ends of the wire.

Students visit each other and try several ways to get the bulb to light. Ms. Travis asks them to draw the ways that work *and* the ways that do not work.

She then proposes that the students use *both* flashlight batteries and the wire to light the bulb. Manipulating the two batteries and one wire is tricky. But when they finally manage to get the bulb to light, they notice it is much brighter than it was with only one battery.

Ms. Travis asks the students to reassemble their flashlights, turn them on, and compare the light from the flashlight with the light that they have just created with the two batteries outside of the flashlight. The students notice that the brightness seems to be identical.

For homework, she asks them to write what they have done this morning in their science notebooks and to list some of the "rules" they have discovered for getting their bulb to light, first with one and then with two batteries.

The next morning, Ms. Travis empties the contents of the science electricity kit on the front table of the classroom. "Let's look at the materials we have to work with here. Can we identify some of them?"

The students recognize the bulbs as looking just like the bulbs in the flashlights. The wire, too, is identical to the wire they used the day before. Although the batteries are somewhat larger, the students have no trouble identifying them as batteries. But this kit also has battery holders and little bulb holders. Some students have seen these before, and others have not.

Ms. Travis says, "Each science group should take two bulbs, two bulb holders, a battery, a battery holder, and 60 centimeters of bell wire to start. You will also need a wire stripper. Our class's problem is this: How can we get both bulbs to light at the same time with as much brightness as possible? Start to explore your materials carefully. Notice how the battery holders and the bulb holders are constructed. Brainstorm with one another about where to attach your wires. Use the rules you developed from last night's homework. Then make a plan with all the members of your group. You will want to try out lots of ideas. Take your time!"

Ms. Travis's thinking: The students are excited about handling the materials, but Ms. Travis knows that connecting the wires to the bulb holders and the battery holders is sometimes tedious. Planning their procedure beforehand may save the students unnecessary labor. Also the discussions among themselves should help them learn.

The students gather their materials and develop their plans. Some have a sense of where to go; some ask Ms. Travis where to begin. She offers responses such as, "You may want to screw the bulbs into the bulb holders."

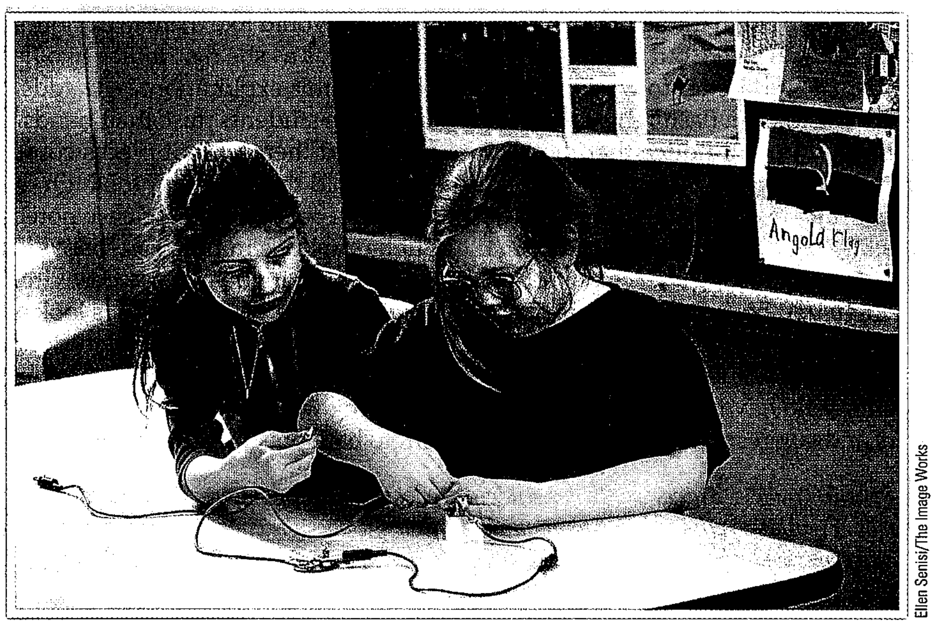


PHOTO 9.1 These students are conducting their own investigation with batteries, bulbs, and wires. They are invested in solving their particular problem.

The students start stripping the ends of the wires. The groups are busy and engaged (Photo 9.1). Walking around the room, Ms. Travis notices varying levels of comfort with the materials. She points things out and makes further suggestions. She reminds one group, "You may have to cut that strip of wire. You may need more than one wire." To the class, she announces that they can have more wire if they need it.

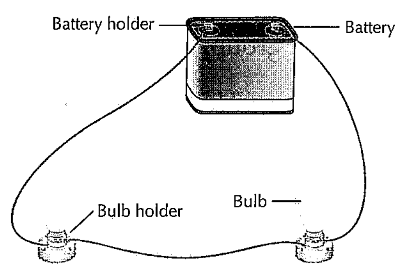
Ms. Travis's thinking: *In walking around the room, Ms. Travis wants to see how the students are thinking. She is hoping that their experience the previous day will help them to construct their own electrical connections using these new materials.*

Most of the groups get the bulbs to light by using three pieces of wire and connecting the first wire from the battery holder to a bulb, the second wire from the first bulb to the second bulb, and the third wire from the second bulb back to the battery. They notice that the lights are very dim—much dimmer than when they used one bulb and one battery the day before.

After applauding their efforts, Ms. Travis begins to provide some labels for what they have created. "Can we label the pathways we have made with these batteries, bulbs, and wires?" she asks. "What do scientists call this type of path?" Some students shout out "circuit," and Ms. Travis writes the word on the chalkboard. Together, she and the students define a circuit as a complete pathway from one end of the battery, through the wire and the bulbs to the other end of the battery, and through the battery again.

This pathway, she tells them, is a continuous route for tiny charged particles called electrons. "These electrons carry the electric charge through the circuit. All these charged particles flowing along the wire is what is meant by an electric current." On the board, she draws a sketch of the circuit that the students have constructed (Figure 9.1).

FIGURE 9.1 A series circuit with a battery in a battery holder, two bulbs in bulb holders, and three wires



At this point she slips in a new question: "I hope this helps to explain why our bell wire is *coated.* Let's think about that as we work."

> ***Ms. Travis's thinking:*** *At this point, Ms. Travis wants the students to associate the correct labels with the pathways they have created. She is not interested in brainstorming about the coating on the bell wire at this time; she just wants to plant the seed of this idea to see if it will germinate as they work with the wire.*

Now Ms. Travis challenges the students to create a circuit that could enable the bulbs to be brighter while both are still lit at the same time. She invites them to take more wire if needed. Once again, she circulates among the groups, directing and coaching, probing the students' thinking, and encouraging them when they get frustrated. "You may want to try one bulb at a time," she says to one struggling group. To another group she remarks, "Draw what you have done here. It really seems to work." With yet another group, she invites them to visit a group in the back of the room that has been more successful. All this time, students are trying to figure out how to light two bulbs at once with a single battery without making the bulbs so dim.

After a while, Ms. Travis asks one member of each group to come to the board and draw the circuits they have constructed. The solutions that work all involve using four wires and connecting each bulb to the battery independently of the other (Figure 9.2). The difference in brightness is very noticeable. The two bulbs connected independently of each other are much brighter than the two bulbs that shared the same circuit.

"It is time to label the two types of circuits you have made," Ms. Travis tells the class. "In this one"—she points to the drawing she made of their first circuit (resembling Figure 9.1)—"the electric charges travel in a single path, through the battery, the wires, and both bulbs. This is called a *series circuit.* In the second type of circuit that you made"—now she points to their own drawings (resembling Figure 9.2)—"each bulb is connected in its own separate pathway. This is called a *parallel circuit.* Now, let's take some more batteries, bulbs, and wires and set up both of these types at the same time."

The students set up a series and a parallel circuit, with one battery and two bulbs in each. Ms. Travis asks them to find different ways of extinguishing one or both of the bulbs. She then asks the students to write about their findings in their notebooks.

After some exploration, the students learn that, in the series circuit, any break in the pathway causes both bulbs to go out. In the parallel circuit, though, each bulb is affected independently, and for both bulbs to go out there must be a break in each of the separate pathways. Further, in the series circuit, the children notice that when they unscrew one bulb, the other one goes out. In the parallel circuit, when they unscrew one bulb, the other bulb stays on.

Before the morning is over, Ms. Travis asks the students in each group to come up with other questions that they want to investigate. "What are you most dying to find out? List the questions that your experiments with batteries, bulbs, and wires can help you figure out. Make sure that you also list the materials you will need."

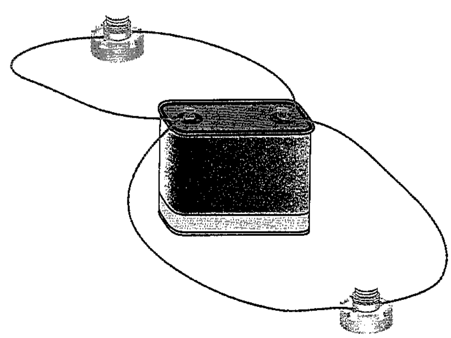


FIGURE 9.2 **A parallel circuit with a battery, two bulbs, and four wires** Because the bulbs are connected to the battery independently of one another, they will shine brighter than the bulbs in Figure 9.1.

Here are some of the students' questions:

- Are the bulbs always brighter in a parallel circuit?
- What happens with two batteries in a series circuit? In a parallel circuit?
- What happens to the brightness in a series circuit that has three bulbs?
- What is a light bulb made of?
- What happens when we combine circuits with other groups?

Ms. Travis writes each question and the name of the child posing it on poster paper in the front of the classroom. The children will be exploring their own questions for many days.

9-3 Applying What They Learned

SCIENCE STORY

The Next Day: Lighting a Shoebox House

The following day, Ms. Travis brings in a large shoebox that is set up like a room in a little dollhouse. It has cardboard chairs and a little sofa. On one inside wall is a picture of a fireplace. Through a hole in the top of the box, a miniature bulb (like the flashlight bulbs the students have been using) hangs as a ceiling light. On the outside of the box, the bulb holder is connected to two long wires attached to a battery. The light works! Unlike a normal household light, however, this light has no switch, and the students are given time to think about what a switch might look like.

The children love the shoebox room. Ms. Travis now brings out several switches for their circuits, and she invites each group to experiment with circuits and switches. (You may remember that switches were included in the kit of materials that all the fourth-grade teachers in this district received.) How, Ms. Travis asks the students, could they make her shoebox room brighter? They all suggest another bulb, but the question of how to connect the other bulb becomes a point of discussion.

Ms. Travis then demonstrates the effects of lighting the room with two bulbs in a parallel circuit versus lighting it with the same bulbs in a series circuit (Figure 9.3). The students immediately notice that the parallel circuit makes the room brighter, just as their two bulbs were brighter in the parallel circuit they made the day before.

Examining Light Bulbs

Ms. Travis now uses the discussion of bulbs as an opportunity to introduce the students to full-size incandescent light bulbs and to compact fluorescent bulbs. They are more familiar with incandescent bulbs; however, Miranda's family has replaced all their incandescent bulbs with the compact fluorescent type. "Why did your family want to do this?" asks Ms. Travis. Miranda replies that the new bulbs use less electricity to make light.

Ms. Travis asks the students to get the networked laptops from the classroom computer cart. Challenging them to explore the Internet to learn how light bulbs work, she divides the class in half. Working in groups, half of the class explores how an incandescent bulb works. The students find a diagram of an incandescent bulb and discover that when electricity passes through the tungsten filament of the bulb, the filament gets very hot and glows, producing the light we see. Ms. Travis suggests that they look closely

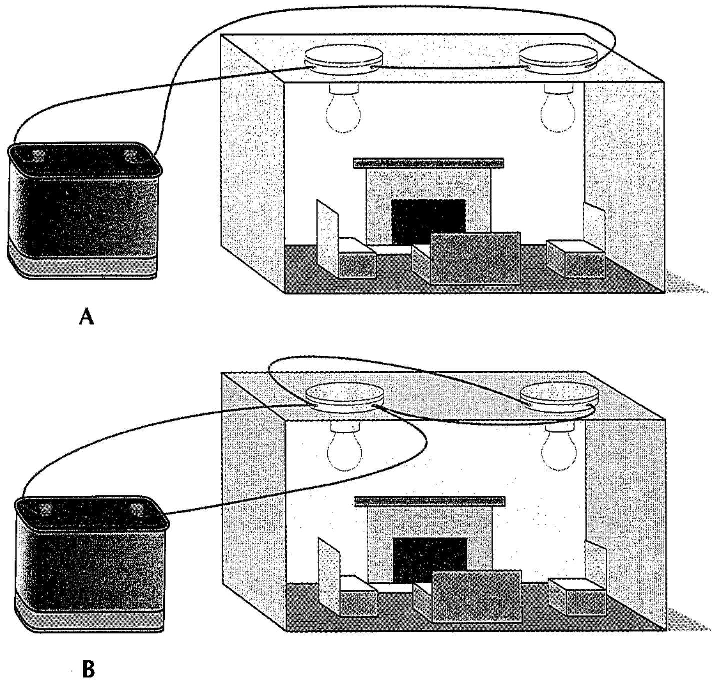


FIGURE 9.3 A shoebox room lighted with two bulbs (A) in series and (B) in parallel. In which setup are the bulbs brighter?

at the little bulbs with which they were working, and the students see that these bulbs have filaments, too. The students realize that these bulbs also work by changing electrical energy to heat energy.

The other half of the class, exploring the structure of the compact fluorescent bulb (CFL), discovers that CFLs work very differently from incandescent bulbs. These bulbs are glass tubes holding a gas made of the elements argon and mercury; the tubes have an interior white coating made of metallic compounds called phosphors. The gas gets excited by electricity and produces ultraviolet (UV) light, which is invisible. When this UV light hits the phosphor coating, it becomes visible light. The CFL has a coiled glass tube and a base that allows it to screw into standard lighting sockets.

Ms. Travis asks the reporters in each group to supply one piece of information they have discovered about each type of bulb. She then asks the class to access information about the CFLs. Ms. Travis poses the question, "Are fluorescent bulbs really more efficient than normal light bulbs?" As a class, the students explore this question together. Because fluorescent bulbs do not use heat energy to make light, the class discovers, these bulbs are more energy efficient than incandescent bulbs. In fact, each compact fluorescent light bulb uses 75 percent less energy and lasts ten times longer than an incandescent bulb! In a standard bulb, a lot of electricity is actually "lost" to heat energy. (You know how hot a standard bulb can feel after it is in use for a while.) The class concludes that we should say "Bye-bye" to regular light bulbs and that stores should sell only compact fluorescent bulbs. In fact, countries around the world are phasing out incandescent light bulbs, and most consumers are now only able to purchase CFLs for their home lighting needs.

Continuing Investigations

As the class's electricity investigations continue, Ms. Travis offers a list of questions for the students to answer at home:

- Is your home wired with fuses or with circuit breakers?
- Can you ask a parent or guardian to show you the fuses or circuit breakers?
- What types of things in your home work on electricity?

- Do you have an idea about which appliances in your house may be connected in a series circuit and which ones in a parallel circuit? How could you find out?
- Do you use compact fluorescent bulbs in your house? Which rooms?
- Why is it important to conserve electricity?
- How is electricity related to greenhouse gases?

In addition to answering these questions at home, the students pursue many interesting activities in the classroom during the following days. Although the groups do not all do the same things at the same times, each group reports its discoveries to the class at large. For example, one group discovers that the more parallel circuits they place on a battery, the faster the battery will burn out. Another group uses a series circuit to make a tester, and they test which materials conduct electricity (Figure 9.4). Two groups create a series circuit around part of the room. It has four batteries and eight bulbs, and the students demonstrate how all eight bulbs go out when a single bulb is unscrewed. Ms. Travis also engages the students in building things with their circuits. Some students make a model flashlight; others build a blinking lighthouse and a quiz board that has secret circuits. Ms. Travis also allows a group of interested students to work on a class statement that provides five good arguments for using compact fluorescent bulbs to light your home or apartment.

The Teaching Ideas behind These Stories

- Notice how Ms. Stone gives vocabulary information at the beginning of the lesson, while Ms. Travis waits until the students have developed some understanding before providing new language. Although Ms. Stone is well meaning and hard working, research in science education reveals that students make better connections to the science vocabulary when it emerges from the context of their activity.
- Ms. Stone engages students in the exploration of electrical circuits on *her* terms. She controls the activities, the time students spend on each step, and the outcomes they should achieve. Ms. Travis controls much of the experimental design and the initial problem posing, but then gives the students control over procedures and findings.
- Ms. Stone is concerned that everyone "get" all the science ideas from her at the same time. Ms. Travis is certain that all the science ideas will emerge from the students, pieces at a time. She relies on the reports from the student groups to address ideas that do not emerge from the initial activities.
- Ms. Stone's procedures are lockstep and rigid. There is no room for students' own ideas about how to explore. Ms. Travis, in contrast, allows a diversity of procedures. Since science is a human activity, differences in specific procedures are common and important for learning.
- Ms. Stone does not provide personal connections or a personal context for the electricity unit. Ms. Travis provides such contexts by engaging the students with flashlights, a mock dollhouse room, light bulbs they have seen at home, and questions about their homes' wiring.

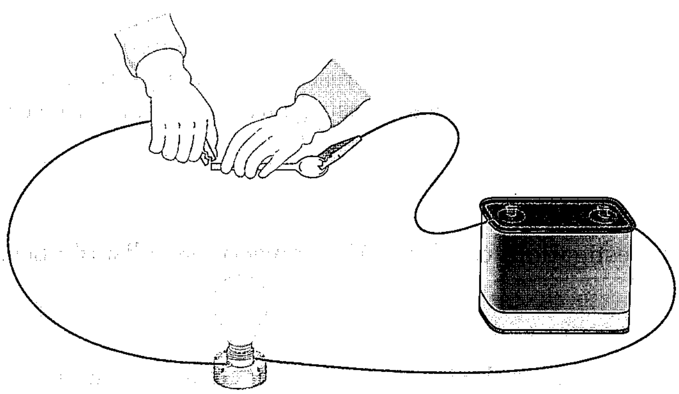


FIGURE 9.4 A simple electrical tester

- Ms. Travis's students are employing several science and engineering practices while exploring the intricacies of electricity.
- Ms. Travis's students are likely to learn better and more deeply because they are conducting their own investigations and becoming invested in answering their own questions. They are doing more than just following directions and repeating the teacher's language.

The Science Ideas behind These Stories

- **Electricity** is a form of energy. In some respects scientists are still unsure of exactly what electricity is, but the word *electricity* is used to describe a flow of electrons. This energy was stored in the batteries the students used.
- **Electrons** are negatively charged particles that are found in the atoms of all elements. Each tiny electron is thought to be a particle of negative electricity.
- An **electric current** is a flow or motion of electrons. Electric currents in wires are caused by electrons moving along the wire.
- An **electric circuit** is a pathway for a current. A circuit requires some source of electrical power, such as a battery or generator; a pathway for the electrons, such as copper wire; and some appliance that uses electricity, like a light bulb or a bell.
- In a simple electric circuit using a light bulb and a battery, the electrons flow from the negative (flat) end of the battery through the wire to the bottom of the bulb (or the side of a bulb holder), through the filament inside the bulb and out the bottom of the bulb (or the other side of the bulb holder), through the other piece of wire to the positive (bumpy) end of the battery. The current then passes through the interior of the battery to complete the circuit. There is a continuous flow of energy through these devices unless some part of the circuit is stopped or broken—for instance, if a bulb burns out, a wire gets loose, or a battery is used up.
- In a **series circuit**—the type of simple circuit just described—the electric current has only a single pathway through the circuit. This means that the current passing through each electrical device is the same. Each time an electrical device, like a bulb, is added to the series circuit, the total amount of electrical force must be shared among a greater number of devices. That is why each bulb becomes dimmer when a new bulb is added.
- In contrast, in a **parallel circuit** each device has a separate pathway—its own separate branch of the circuit. Thus, if one bulb goes out, the other bulbs or devices in a parallel circuit are unaffected.
- Each device in a circuit offers a certain amount of *resistance* to the current. In a series circuit, two bulbs present twice the resistance of one bulb. Since the current equals the force divided by the resistance, each bulb gets only half as much current. In a parallel circuit, on the other hand, there is only one bulb per path; therefore, there is less resistance on each path, the current supplied to each bulb is greater, and the bulbs glow more brightly. This also means that the battery will burn out twice as fast, because it is supplying twice as much current as in the series circuit. See Chapter 10 for more information about electrical energy.

Connections to the Next Generation Science Standards

- NGSS DCIs:
  - **4-PS3-2 and 4-PS3-3: Definitions of Energy:** Energy can be moved from place to place by moving objects or through sound, light, or electric currents.
  - **4-PS3-2 and 4-PS3-4: Conservation of Energy and Energy Transfer:** Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light.

- **NGSS SEPs:** Ms. Travis's students are *asking questions, defining problems, planning and carrying out investigations, constructing explanations and designing solutions*, and *developing and using models*.
- **NGSS CCs:** Students are engaged in the crosscutting concept of *cause and effect* as they test their circuits and *energy and matter*, showing that electrical energy can be transferred in various ways and between objects, in this case, starting with stored energy. They also see how science affects everyday life and that engineers improve existing technologies and develop new ones.

Exploring Further

To implement this activity in your own classroom, you may want to consider the answers to the following questions:

- Explore a small flashlight bulb to see how it lights.
- Why would a house be wired in parallel and not in series circuits?
- In the experiments described in our science stories, why is it important to use bell wire, which is copper wire coated with a plastic sheath?

9-4 Thinking about Teaching and Learning: Science PCK

Let's think further about the two teachers whose classrooms we have visited so far in this chapter. Ms. Travis holds out the expectation that her students are knowers, that they have their own ideas, and that they are capable of constructing and carrying out investigations on their own. This is Ms. Travis's belief system, and it influences her teaching practice. Her teaching is a good example of the principles that this book advocates. These principles can be labeled **science pedagogical content knowledge** or science PCK. This refers to the methods and strategies that specifically help people learn science. The model espoused by Ms. Stone may be thought of as a "transmission" model of science teaching, where Ms. Stone gives the students the content and the procedure for learning about electricity. Ms. Travis's model of science PCK may be thought of as "teacher as mediator." She is a mediator of science content where student predictions, experimentation, and explanation dominate classroom discourse.

She expands the science kit both in a literal sense, by letting her students use more materials and explore a wider range of activities than the school-supplied science box allowed, and in a metaphorical sense, by releasing herself and her students from the intellectual confinement of prepackaged instructions. She also expands the topic by allowing her students to explore ideas that relate to their own interests in electricity and environmental issues.

But what about Ms. Stone? Clearly, Ms. Stone works hard, has respect for her students, and cares deeply about their instruction. She is, however, unwilling to trust that her students can come up on their own with the activities that are neatly laid out, step by step, in the student workbooks in the fourth-grade electricity box. In Ms. Stone's personal model of teaching, she is the authority in the classroom. She believes that this is what the children require. She believes that they look to her for the right answers and that she is not doing her job unless she provides these answers.

This attitude is not uncommon, and it is not at all ill-intentioned. Well-meaning teachers all over the country believe that students learn only if the teacher tells them what and how to learn. You may be wondering, "Well, what

electricity
A form of energy produced by a flow of electrons.

electron
A negatively charged particle found in the atoms of all elements. Electrons revolve around the nucleus of the atom in different orbitals or "shells"; each shell represents a distinct energy level. Each electron is thought to be a particle of negative electricity.

electric current
A flow or motion of electrons. Electric currents in wires are caused by electrons moving along the wire.

electric circuit
A pathway for an electric current. A circuit requires some source of electrical power, such as a battery or generator, and a material through which electrons can travel, such as copper wire. In elementary school science, circuits usually include some simple appliance that uses electricity, like a light bulb or a bell.

series circuit
An electric circuit in which the current has only a single pathway through the entire circuit.

parallel circuit
An electric circuit in which each device has a separate pathway, its own separate branch of the circuit.

science pedagogical content knowledge (PCK)
Refers to science content knowledge that is transformed by the teacher into a format that makes it understandable to students.

is teaching if we don't tell students what and how to learn? What is left for us to do?" Think back to our earlier discussions of the teacher as mediator, and consider whether Ms. Travis is really doing *less* than Ms. Stone. And consider all the other science stories in this book that have shown teachers working very hard with their students. I think you'll find that the teacher who guides and mediates learning is doing lots of planning and active listening in ways that are not required of a teacher who merely "delivers" instruction. Also, even though Ms. Travis does not behave like an absolute science authority in the classroom, she is actually taking on a great deal of authority because she assumes the responsibility of constructing the science experiences with her students. It requires a lot of self-reliance—as well as thoughtful consideration—to take a package or kit of materials, discard the prescribed instructions, and ask yourself, "How can I use the materials in this science box to create a meaningful learning experience for *my* students?"

9-4a The Learning Cycle Revisited

In Chapter 1 we discussed a useful tool for your own science pedagogical content knowledge. This is the learning cycle or the five-phase model of Engage, Explore, Explain, Elaborate, and Evaluate. In each of these phases of the learning cycle, students are active and constructing meaning from experience. Notice how these five phases are implemented by Ms. Travis in her fourth-grade electricity lessons.

She *engages* them by asking them to purchase a pound of electricity. The conversation then yields the difference between matter and energy. The *exploration* phase begins as she distributes materials to the science group and asks them specifically to "explore some flashlights." She suggests that they work in pairs and asks them to draw and label the parts of the flashlight. They continue their explorations with batteries, bulbs, wires, and wire strippers and making a light bulb light.

During the *explanation* phase, she actually provides labels for their electrical pathways and the students are introduced to the terms *circuit*, *series circuit*, *parallel circuit*, and *switch*. They also learn how different light bulbs work and which ones are better for the environment.

The next day, students begin to *elaborate* on their previous explorations by applying what they have learned to making a shoebox room with lights. Their *evaluation* phase is implemented when Ms. Travis requires the students to apply what they know about circuits to the process of design by creating different types of circuits such as a tester for materials that conduct electricity, making a model flashlight, or building a quiz board that has secret circuits.

Teachers need to explore pedagogical knowledge and acquire a depth of understanding of the science content. This is a beginning to developing one's own science PCK. The contrast in this chapter's lessons represents the intersections of knowledge and beliefs as they impact classroom practice and remind us that "we teach who we are." Learning what works best on behalf of your own and your students' science learning is an important step to creating your personally effective model of science teaching.