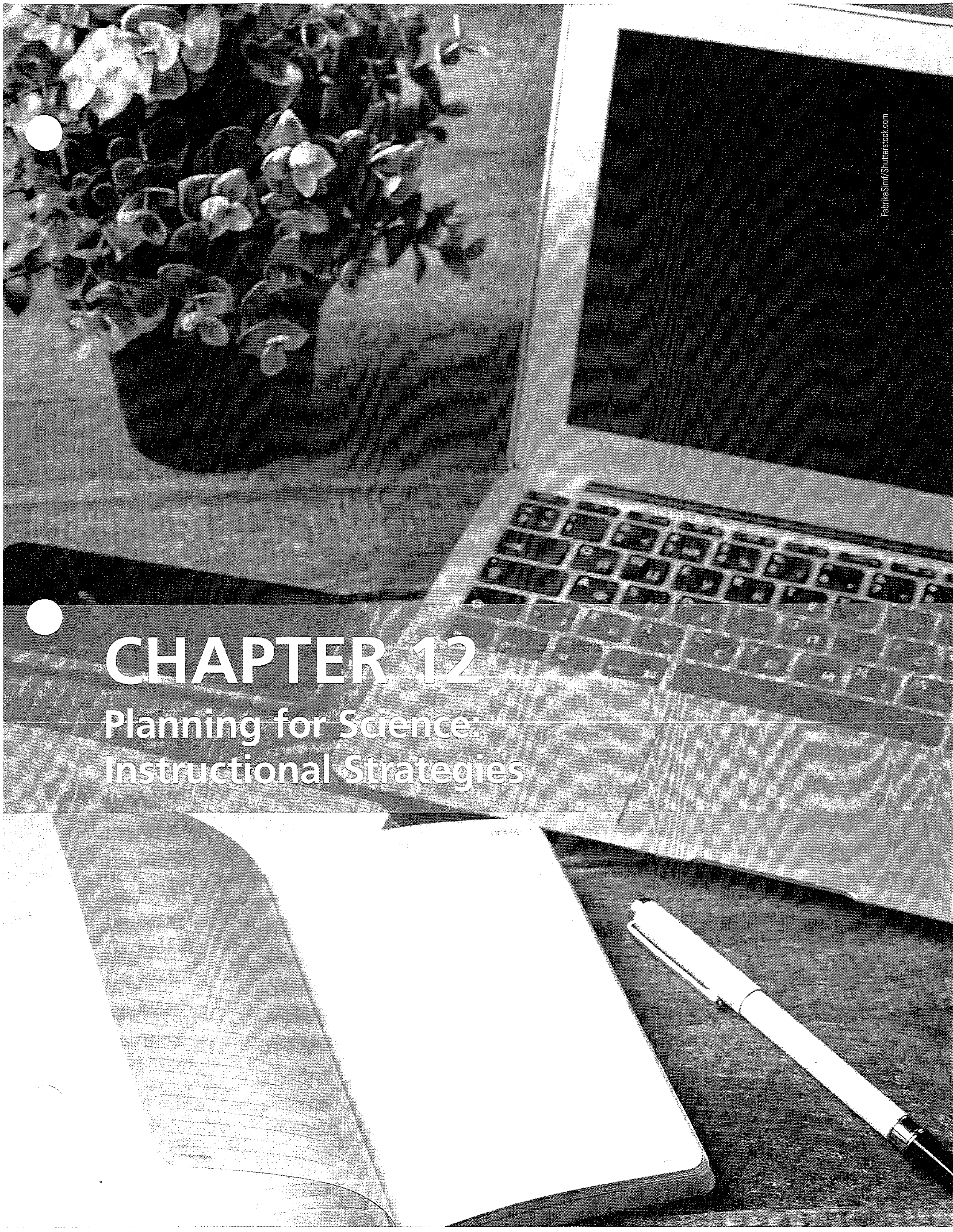

FabrikaSimf/Shutterstock.com

CHAPTER 12

Planning for Science: Instructional Strategies

LEARNING OBJECTIVES

After reading this chapter, you should be able to:

- 12-1 Discuss how to encourage underrepresented groups in science to embrace scientific exploration.
- 12-2 Examine the strategies unique to exploring science with English Language Learners (ELLs).
- 12-3 Analyze how an activity can become a lesson.
- 12-4 Examine and critique a sample science lesson plan.
- 12-5 Explain the role of lesson planning for teaching science.
- 12-6 Provide a rationale for departing from the lesson plan.
- 12-7 Discuss the characteristics of a good question.
- 12-8 Examine why group learning has benefits for individuals.
- 12-9 Examine the best ways to form cooperative learning groups.
- 12-10 Understand what is meant by inclusive science education.
- 12-11 Appreciate how technology can support the success of students with disabilities.
- 12-12 Analyze how to critique your science lesson.

Reflection

To Think About:

- What is the difference between a science activity and a science lesson?
- Do you prefer to learn independently or in small groups?
- How do you plan for the unexpected?
- How can you set up your science lessons if you have only forty minutes in a period?
- What is your own personal style when it comes to planning?

A friend of mine used to say as each school year began, "Remember, Janice, teachers can never be overprepared." As I gained experience in teaching, I discovered what he meant.

Being prepared means, first and foremost, having done your planning. To develop a plan that helps to guide your instructional practice, you need to give serious consideration to the learning experiences you want to provide. Then you need to organize and structure those experiences in ways that make sense to you and to your students. When you come to school prepared, the students recognize it, and they develop an image of you as hardworking and caring. This image helps you create a sense of community in the classroom. It is also a model to your students of what it looks like to work hard and arrive prepared for class.

In an earlier chapter of this book, I mentioned that we teach "who we are." That applies to planning as well as to your performance in class. One size does not fit all. In this chapter you will find suggestions for planning for school science, but I expect that you will adapt these ideas to your own personal style. In Chapter 10 we explored planning for an entire science unit or a curriculum for a grade. In this chapter we examine instructional strategies for the lesson. We begin by visiting the ways in which your students differ from each other. For example, they may all be fifth graders, but their cultures, socioeconomic status, religions, and native languages may be very different.

12-1 Encouraging Underrepresented Students in Science

Various researchers have investigated the reasons why science has often alienated students, especially females and members of minority groups. Studies have found that a major culprit is the absence of personal connections between science and students' everyday lives. For example, minorities and females often have a negative perception of the usefulness of science in "real life," and this attitude contributes to their lack of participation in science activities (Burger et al., 2007; Koch et al., 2014). Conversely, by relating science to our students' daily lives, we can create school science experiences that will invite their participation. We also know that what works for students who feel disenfranchised by science amounts to simply good science teaching. Hence, making connections by showing the ways that science enters our lives as a means of understanding the natural world awakens the interests of *all* students.

Remember that students come to school with a set of biases and beliefs about their world that are constructed from the social, cultural, and gendered contexts in which they live. These beliefs strongly influence students' tacitly held attitudes toward science and scientists. Part of your work as a science educator is to learn about your students' views of science and then use that knowledge to help them modify and enlarge their views.

As we saw in Chapter 1, science is frequently perceived as a domain for white males, from which women and all people of color are excluded. In addition, the mass media often portray science as a relatively impersonal field. For example, many television documentaries show the results of scientific work—the content of science—rather than the process of science or its human side. Science then seems a dry collection of facts and principles. This absence of the human face helps to create in students a deep and abiding lack of interest in scientific study. Hence, it is imperative that teachers use science experiences to make connections with their students' daily, lived experiences.

As we have seen in the stories in this book, there are many ways to integrate scientific study of the natural 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— all students can be put off by a detached, fact-based approach. Hence, a deep understanding of who your students are, what their lives are like, and where and how they live, combined with your own passion for and understanding of the concepts, will help you to plan effectively to engage all students. A first step in planning is (1) understanding the science content and (2) knowing how it fits with the instructional strategies or pedagogy. This refers to the term we introduced earlier, *pedagogical content knowledge*: know the content, know the pedagogy, and combine them! A way to start is to consider some of the following:

1. An activity is important but is not the whole lesson.
2. Students need to ask questions and come up with their own ideas.
3. You need to make your approach visible to the students so they feel a part of the planning.

First, we explore additional planning that is required if we are teaching students with limited English language skills. Students whose native language is not English often struggle with science concepts even though they are very capable. This is because the language of science can often be confusing to students who have not mastered the English language.

12-2 Teaching Science to English Language Learners (ELLs)

As we explore some suggestions for planning the science lesson, keep in mind that, as revealed by the science stories you read, there is a lot going on in a science lesson. For students who are not native English speakers, the instructions and vocabulary may be particularly challenging. The following model of science instruction for ELLs was developed by two professors at Texas Christian University in Fort Worth, Texas (Weinburgh & Silva, 2012). They reasoned that the 5E model of science instruction could be confusing for students whose English language skills were emerging, and they developed a 5R model of instruction to accompany the science lesson and build understanding and new language.

Inquiry-based lessons that model science as practice may appear to an outsider as unstructured and chaotic when, in fact, as the chapter explains, the best inquiry-based lessons are well thought out by the teacher and involve the teacher's orchestration of many interwoven parts. For ELLs, the 5R Instructional Model can be integrated into the planning process as a teacher decides what scientific language is important in developing and expressing a concept and how that language can be introduced and strengthened during a lesson.

The five components of the 5R Instructional Model are *Reveal*, *Replace*, *Repeat*, *Reposition*, and *Reload* (see Table 12.1). Notice how, for ELLs, the teacher needs to introduce the English language terms that the students will encounter as the lesson proceeds. This is not a replacement of the traditional 5E model of planning a science lesson. This is in addition to the model specifically for students who are not native English speakers.

TABLE 12.1 5R instructional model

	Description	Level	Example	Timing
Reveal	The teacher provides or introduces students to the vocabulary (or word labels) for new concepts that are introduced in the lesson. Based on the students' background knowledge, the teacher can anticipate which words will need to be revealed and during the planning phase identifies places in the lesson where the language should be introduced.	Word	Giving the name of parts of an atom (electrons, neutrons, protons) or a new process (distillation)	Anytime in unit
Replace	The teacher uses the language that emerges within student talk from the context of the lesson to substitute informal with more formal words. The students already have an everyday word for the object or concept.	Word	If the students say, "The metal moves the heat," the teacher can suggest they use "conducts" instead. The teacher would say, "In science when we talk about heat, we would say the metal 'conducts' instead of 'moves.'"	Anytime in unit

Repeat	The teacher says the word multiple times and in different forms. This can be different forms of the same word or different sentence structures and different contexts. The teacher also encourages the student to repeat the word.	Word	To stress the word "model," the teacher can say, "I see the model of the earth." "We will use a model for our experiment and I will model how to use your safety goggles." Other examples are the various uses of *erode*—erode, erosive, erosion or divide, division, dividend.	Anytime in unit
Reposition	The teacher, knowing the discourse of science, restructures sentences to have the linguistic features associated with the discipline.	Sentence	If the students say, "It takes up more space," the teacher says back, "The cylinder has more volume."	Anytime in unit
Reload	The teacher uses the strategies of language instruction to visit words a second time.	Word and sentence	The teacher can use Word Walls or other strategies to remind the students of how to pronounce words and how they are used in a sentence.	After introduction

As we examine the components of planning the lesson, think about how the 5R model can be integrated into the science experience.

12-3 An Activity Is Not a Lesson

A major part of planning is setting up the investigation that your students will pursue. As earlier chapters have demonstrated, it is only by providing students with meaningful science experiences—such as experimenting with liquids, exploring atomic structure, or investigating earthworms—that we can lead them toward critical exploration of their world. Planning, therefore, involves acquiring and organizing the appropriate materials and deciding how you will engage the class in the activity. The investigation or activity that you select should be aligned with the NGSS DCIs. Look at the performance expectations for the DCIs as you prepare plan for an activity. For example, for the second grade DCI 2-PS1-1, "Matter can be described and classified by observable properties," the performance expectations state, "Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties" (NGSS Lead States, 2013, p. 16).

Planning for this alignment to the standards and designing an appropriate activity or investigation are just the beginning of the planning process. Although students may have a lot of fun experimenting with the materials you give them, *an activity is not a lesson.* You need to know what science concepts you expect your students to develop. Most important, it is not just the activity but the process of reflection and dialog that can lead to the construction of new ideas. Your responsibility is to facilitate the thought experience as well as the active experience. This involves helping to scaffold the students' ideas. Not every time you do science with your students may include a specific science activity. The students may have completed the investigation in the science time allotted; however, the active reflection part may be relegated to the next day. The science **lesson** includes both the investigation *and* the process of reflection and discussion. In the sections that follow, we will begin with the lesson plan itself and then address the role of questioning, the use of cooperative learning groups, ways to make sure all students are fully included, and some guidelines for reflecting on your teaching experience.

lesson
In science instruction, the process of engaging students in a meaningful science experience and in reflections on the experience.

One more introductory point: Careful planning also includes the plan to drop the plan! This may sound like a contradiction, but when students are engaged in genuine inquiry, one question often leads to another. Your students' spontaneous curiosity will give you excellent opportunities to change your original plan and mediate their experience on *their own terms.* Remember to keep in mind the important science ideas that can emerge from a successful science experience and remember what happened when Ms. Drescher extended the activity and lesson and introduced the construction of liquid science toys in Chapter 7.

12-4 Planning the Lesson

lesson plan
A document describing a teacher's plans for a particular lesson, including the ideas presented in the lesson, the activities that students will engage in, and the ways in which the teacher will help students reflect on their experiences.

Let's imagine that you are planning a new science lesson for your class. What type of **lesson plan**—that is, a document that describes your plans for the lesson—will help you engage your students in a meaningful science activity *and* invite them to think about, reflect on, and construct ideas from this activity?

There are many lesson plan templates or guides to help you get started. They are usually designed to predict the behavior of your students and of you as a teacher. But I have dedicated a great deal of this book to helping you understand that you *cannot* always predict where a meaningful science activity or investigation will lead. In Chapter 2, Mr. Wilson could not have anticipated the ways in which his students chose to weigh the icicles. He understood that there would be many varieties of experimentation when he asked the students to take control of the exploration. The goal, then, is to create a plan that allows for flexible procedures and critical thinking about the lesson. Further, there are many science lessons aligned with the national standards online. Research shows that teachers who modify these online lessons to meet the specific parameters of their class teach lessons that result in greater learning gains for the students (Littenberg-Tobias, Beheshti, & Staudt, 2016).

The guide that follows is one useful model and can get you started in the planning process. Over the years, it has been modified by many teachers as a result of their actual experiences doing science with students. As you begin working with other teachers and see different ways of planning, you too may modify the plan to meet your own personal needs.

12-5 A Planning Guide

The feature "A Guide for Making a Science Lesson Plan" lays practical steps for science lesson planning. Each step is a question that you ask yourself. Notice how the steps correlate with the five phases of the learning cycle that you read about early in this book: engagement, exploration, explanation, elaboration, and evaluation.

To illustrate how to use these steps, let's say that you are writing a lesson plan for an exploration of earthworms like the one described in Chapter 6. The students will be exploring the features of the earthworm with a partner using a magnifying lens and a paper plate. It is useful to start with the Goals and the Disciplinary Core Ideas before you describe your procedures.

12-5a Goals

What am I hoping the students will get out of this science experience? This part of your plan asks you to state the problem or phenomenon the students are exploring and what you are hoping they will learn. In the earthworm lesson, you might say:

I am hoping that the students will notice that:

- *The worms are segmented.*
- *They are soft and secrete a mucus to keep their skin moist.*

A Guide for Making a Science Lesson Plan

Answer fully each of the questions listed below.

Goals	What am I hoping the students will get out of this science experience?
Disciplinary Core Ideas	What are the *science* ideas at the heart of this experience? What concepts am I hoping the students will understand as a result of this lesson?
Procedures	
Engage	How will I attract students' interest in the topic?
Explore	*Science investigation:* What will the students be examining and exploring on behalf of their own learning?
Explain	What kind of meaning will students construct from this experience? How can I help students by scaffolding their ideas? Can they argue from evidence?
Elaborate	How will the activity connect to what we have been doing in class? To the students' lives? How will I help the students organize their thinking and pull this lesson together?
Evaluate	How will I know what the students have learned?

Professional Resource Download

- *They have no internal skeleton.*
- *Invertebrate animals do not have an internal skeleton.*
- *The earthworm's structures are related to its functions.*

12-5b Disciplinary Core Ideas

What are the DCIs at the heart of this experience? What concepts am I hoping the students will understand as a result of this lesson? In this step, you state the science concepts—the underlying ideas about the natural world that you are hoping the students will construct as they engage in and reflect on the activity. For example, in the earthworm lesson, you could write:

- *Earthworms are invertebrate animals with long muscles and circular muscles that help propel them forward.*
- *They have tiny hairs that help them to slow down or stop.*
- *They have a mouth on the first segment of their bodies, and they have a thick part, called the clitellum.*
- *They have rings around their bodies separating their segments.*
- *These are related to DCIs: 4-LS1-1 and 4-LS1-2.*

12-5c Engage

In this phase, often called the *hook,* you ask yourself how you will command students' interest in the topic. Also called "motivation," this part of the plan engages the students in the topic at hand by exposing them to a curious event (remember the balloon that didn't pop?) or just by showing them the materials they will be exploring in a way that arouses their interest. For the earthworms lesson, you might begin with the following question and explanation:

- *Some of you may have had the chance to plant seeds or plants in the soil in an outside garden.*
- *If you dig into the soil, you may find worms that live there.*
- *They are called earthworms, and we have the opportunity to explore earthworms right here in our classroom!*
- *Take out earthworms and place two on a paper plate. Walk around the room and show the worms to the students.*

12-5d Explore

This phase describes the science investigation or activity. What will the students be examining and exploring on behalf of their own learning? For the earthworm lesson, you might write:

- *The students will work in pairs to explore the external features of the earthworm.*
- *Each group will have magnifying lenses and two worms on a paper plate.*
- *Encourage the students to keep their rubber gloves on when handling the earthworm.*
- *Ask them to draw their worms in their science notebooks.*

Often there is a materials list in the Explore section of the plan. For this investigation, materials include:

- Disposable rubber gloves
- Paper plates
- Magnifying lenses
- Earthworms
- Be sure the large jars with soil that will be the earthworm's classroom home are ready, so the students may return the worms after their activity.

It is important, of course, to add quantities to your list so that you have enough materials for all the students to participate. How many paper plates, rubber gloves, earthworms, and magnifying lenses? How many large jars?

12-5e Explain

What kind of meaning do students construct from this experience? How can I help students by scaffolding their ideas? How can I encourage them to argue from evidence (SEP 7)? Any advance thinking you do about your role as a guide and mediator belongs in this section of the lesson plan. You may want to include key questions that you will ask the students during the lesson—for example, questions that will encourage them to use certain SEPs. For the earthworm lesson, these questions could include:

- What do you notice about the earthworms? List your observations; draw your specimen in your notebook.
- How do you think the earthworms move?
- What propels them forward?
- How many parts or segments do they have?

12-5f Elaborate

How will I help the students organize their thinking and pull this lesson together? In this part of the science lesson, you give students the opportunity to formulate and express some of the science concepts they have developed from their experiences. For the earthworm lesson, you might plan the following:

- *Have students talk about their observations of their earthworms and write them on poster paper or record them on the classroom SMART Board.*
- *Gather students' ideas about how the earthworms move and how they eat.*
- *Students can also suggest functions for the thick part of the earthworm.*
- *Introduce the term* invertebrate *to describe the animal's classification. Introduce the term* clitellum *to describe the earthworm's thick part.*
- *Students may want to look up information about the earthworm on their classroom computers.*

12-5g Evaluate

How will I know what the students have learned? Here you are checking for understanding, not mere facts. You can plan an activity, a writing exercise, or a formal assessment. You will want to see how the students' learning fulfills your original goals and any further goals that have evolved along the way. To evaluate the earthworm lesson, for example, you could ask your students to complete a *minute paper.* This is a one-minute exercise in which you distribute index cards or small pieces of paper and ask the students to write two things they have learned about earthworms and two questions they may have. This assessment will help you to plan for future lessons.

12-5h If I Know It, Do I Have to Write It?

In the preceding section, you probably noticed the assumption that you would be *writing* your lesson plan. But you may have been thinking, "Is it really necessary to write the plan? Isn't thinking about it enough? After all, I'm not going to stop in the middle of the lesson and pull out a written plan."

For most teachers, writing your lesson plan down is important, whether or not a written plan is required by your school. It is a way to collect and represent your thoughts, then save and modify them as you go along. Writing the plan down is another step toward becoming a reflective teacher. You should think of the document itself as part of your own teaching journal. It becomes a tool for you to reflect on, use again, and change over time. Many teachers develop their lessons in a word-processing document and save them electronically so they can be modified and refined each time they are used. The more you actively engage in planning, the greater the chances are for student learning.

I still have lesson plans that I hand-wrote during my first year of teaching. The papers, now yellowing, remind me of how my thinking has changed in some ways and remained the same in others. I know that the process of writing these plans helped me and my students, and it continues to do so.

12-5i Time Allotment

Your planning instrument becomes a tool for creating a science lesson in which the students have the opportunity to explore, reflect, and explore again. Sometimes one lesson plan will take you several days or more to implement.

You may wonder how to carry out such a plan in middle school, where you often have only forty minutes per day for the science period. Think back to Chapter 7, where Mr. Hutcheon created a sustained inquiry about floating and sinking by spreading it out over a number of days, sometimes using a single period of science, other times a double period. Sometimes, in middle school, teachers take doable "pieces" of an investigation and perform those in the allotted time, asking students to reflect on the experience for homework. It is important then to keep building on the prior day's activity with your students. Remember also that older students will require less time for distributing and cleaning up materials. In most cases you can plan thirty minutes for the activity itself, leaving only ten minutes for setup and cleanup. In elementary school, where you have more flexibility in your allotment of time, I suggest that you follow two principles:

1. Allow at least one hour of class time for engaging students in any scientific activity, even a fairly simple one.
2. Always build in the flexibility to spend more time on an activity than you originally thought would be required.

12-6 After the Planning, the Letting Go!

Now that you have planned for the science lesson and organized the materials, how prepared are you to abandon your plan and respond to the students' interests, ideas, and questions? Remember the science story about Ms. Drescher's class in Chapter 7, when the students explored liquids? In that case, a fairly simple lesson turned into several days' work on density, a concept that was not in Ms. Drescher's original plan. Remember the milk waste project in Vermont in Chapter 11? The investigation emerged as Ms. Rhodes engaged the students in the topic of conservation. Although she did not plan to measure the milk remaining in the cafeteria containers, her ability to build on the students' interests made the learning experience a success.

Some teachers are so pleased with their lesson plans that the plan becomes an instruction manual for the lesson *rather than a useful guide.* This prevents the teacher from letting go of the plan even when the students' own ideas have taken the lesson to another level of awareness. As you have gathered from the stories in this book, you will often find that your students have questions that emerge from the investigation at hand! You will even have students who ask you directly if they can try a certain experiment that was not in your original plan. More often than not, if appropriate materials are available, it is a good idea to encourage the students to explore these problems of emerging relevance.

But how exactly will you know when to let go of your plan? Be assured that careful planning will give you the confidence to let go. This is because you will be able to evaluate the science concepts connected to each topic and consider the possibilities for students to expand their thinking through new investigations. And the more experience you gain, the more comfortable you will be in thinking on your feet.

Here are some situations in which you can reasonably modify or abandon your original plan:

- The science concept that you were hoping would emerge does not.
- Students reveal alternative conceptions that are resistant to change. (Think about the bottle-and-balloon story in Chapter 2, when the students needed to explore different setups before they would abandon the idea that the air came from outside the bottle.)

A Planning Checklist

Before you complete your lesson plan for the science experience in your classroom, the following checklist can help you decide if you are fully prepared.

- Have I done enough research of my own? Do I understand the science concepts behind this topic?
- Is it aligned with specific DCIs, SEPs, and CCs?
- Do I need special arrangements for live materials?
- Do I need parental or administrative permission for any of the activities?
- Have I decided what types of student groupings I will construct? What will I ask each group to do? How will the groups share information with each other?
- Do I understand how to guide the students to reflect on the activity?
- Have I allowed enough time for the lesson—and extra time in case my estimate is wrong?
- Am I certain enough of the lesson's goals so I can tell when to modify my plan or let the students follow their own ideas?

- The students want to explore a related investigation that you believe is a good idea. (Think about the liquids exploration with Ms. Drescher, when the students developed an interest in density.)
- One or more students need to explore a phenomenon on their own terms. (Remember how Jamie in Chapter 2 had a different question about icicles.)

It is impossible for you to predict where your students will take an investigation that you and they have planned, but it is important that you listen actively to their queries and encourage creative explorations. Active listening requires that you probe your students' thinking as they develop new ideas. During the pulling-it-together time, the students can share the particular meanings that their explorations have had for them. The entire class will be enriched by the detours and alternative paths that your students will take.

12-7 The Role of Questioning

open-ended questions Questions that lead to multiple answers. They are especially important because they help students think critically about their science experiences.

Often you facilitate the science experience through the questions you ask your students. **Open-ended questions**—those that lead to multiple answers—are especially important because they help students think critically about the investigation. Frequently, too, the teacher's questions lead students toward their own new investigations. As you read earlier in this chapter, the nature of the questions you plan to ask can form part of your written lesson plan. Now let's take a closer look at the types of questions and the way they can help you guide students.

12-7a Types of Questions

Your questioning can be categorized in many different ways. We will consider three types of questions: (1) questions that invite students to action—using their senses to make observations, for example; (2) questions that access students' own ideas and prior knowledge; and (3) questions that help you check for understanding.

> "*The central purpose of questioning is to ask or promote the asking of questions that foster deep understanding rather than questions that ask for repetition of memorized information and conclusions.*
> —Jim Minstrell and Emily van Zee (2003)"

12-7b Questions That Invite Students to Action

Often you can use open-ended questions to invite action and encourage students to apply various process skills. Table 12.2 offers samples of questions that promote the use of certain skills. Of course there are many other questions you can use and many useful ways of phrasing each question.

12-7c Questions That Access Students' Own Ideas and Prior Knowledge

Sometimes questioning techniques point students toward certain topics, much like the focusing questions at the beginning of the chapters in this book. Such questions invite students to come up with their own ideas about a specific topic or investigation.

Here are some examples of questions that access students' ideas or prior knowledge related to the earthworm investigation described in the sample lesson plan:

- How would you describe the way the earthworms move?
- How would you test how far your worm moves in twenty seconds?
- How are these earthworms the same as or different from others you have seen?
- How do earthworms take in their food?
- What type of investigation could you design to explore your earthworm's reaction to light?
- What do you think it means for earthworms to regenerate?

TABLE 12.2 Sample Questions and Related Behaviors/SEPs

Question	Student Behaviors and SEPs
What do you notice?	Observation (SEP 8)
Why do you think this is happening?	Inference (SEP 7)
In what ways are these things the same?	Comparing (SEP 8)
In what ways are these things different?	Contrasting (SEP 8)
How would you group these objects?	Classifying (SEP 7)
What do you think will happen?	Predicting (SEP 6)
How would you test this idea?	Planning an investigation (SEP 3)
How would you change this experiment if you repeated it?	Planning an investigation (SEP 3)
On the basis of what you did, what sense do you make of the data you collected?	Interpreting data and drawing conclusions (SEPs 7, 8)
What do you mean when you say that?	Explaining a concept (SEP 6)

12-7d Questions That Check for Understanding

Teachers often get into a pattern of asking questions to elicit single correct answers and then move on to the next question. This often leads students to think that science is about "right answers." Rather, we need questions that inspire students to reveal their thinking so we can use what they understand or what they have missed as a way to move forward with the lesson.

This does not mean that your questions need to be complicated. Often the simplest question can challenge students to think deeply about an experiment or an exploration. My favorite example is, "So, what do you think is going on here?" I use this question to invite students to articulate the meaning they are making of an event.

We also assess student understanding when we ask them to *apply* what they are learning to another context—for instance, when we ask how the phenomenon they are exploring may relate to something they have seen in their daily lives. With the earthworm lesson, you might ask your students, "What other animals have you seen that move like earthworms?"

Another way to evaluate students is to ask them simply, "What did you find out from this investigation? Can you write it in your science notebook?" Or you can ask your students what they liked about an exploration, what they didn't like, and, most important, "How would you change it?" Questions of this type encourage students to think critically. In addition, requiring students to commit their thoughts to writing helps to develop their skills in communicating about science and scientific processes. This process parallels the way scientists function as they carry out their research. They make tentative conclusions, try to connect their ideas to other ideas, and record their findings in their notebooks.

For older students, it is fair to ask them to create their own theories about a phenomenon they have observed. Remember Chapter 8, when Ms. Murray asked her eighth graders to toss a beanbag frog to each other to prompt them to share some of their invented theories about how the particles in an atom's nucleus stay together.

Finally, questions that check student understanding can give you windows into your students' thinking and let you know if they have developed alternative conceptions. Remember that unless you invite students to tell you what they are thinking, a true exchange of ideas cannot take place.

12-7e Don't Rush: A Word about Wait Time

Whether you are asking students questions in their small groups or addressing the entire class, it is very important to allow them ample time to respond. **Wait time** refers to the time that elapses between the moment you ask a question and the moment when you select a student to respond, offer a clue, rephrase the question, or otherwise move ahead.

wait time
The time that elapses between the moment a teacher asks a question and the moment the teacher selects a student to respond, offers a clue, rephrases the question, or otherwise moves ahead with the lesson.

A great deal of research documents the value of providing significant wait time. Studies conducted across grades kindergarten through 12 have compared longer average wait times (generally three to five seconds) with shorter ones (often one second or less). These studies indicate that the longer wait times raise the quality of the student–teacher interactions and the level of the discourse (Chuska, 2003; Rowe, 1974, 1987; Tobin, 1986). Further, research studies indicate that questioning during classroom teaching is unproductive without wait time for students to think before answering (Treagust, 2007).

Wait time provides an opportunity for the students and the teacher to think about the exchange and process their ideas. In whole-class exchanges, researchers believe, longer wait time increases the number of students who participate, so more than just a few students respond. Similarly, in small-group exchanges, longer wait time helps engage all the members of the group.

Four Keys to Good Questioning

1. Ask a question only if you are truly interested in knowing what the *students* are thinking.
2. Design questions to help students construct their own answers.
3. Always employ appropriate wait time to foster participation and higher-level learning (Tobin, Tippins, & Gallard, 1994).
4. *Never* answer your own questions! It is better to leave a question unanswered for a while than to answer it yourself. The questions you ask the students are always more important than the answers you give them.

The literature about wait time has been widely accepted in science education, and yet many teachers continue to rush to call on students. Often this occurs because we are not used to silence in the classroom. Sometimes teachers feel so uncomfortable when students do not respond after five seconds that they answer their own questions!

12-8 Science Learning Groups: Creating an Environment for Team Work

You may have wondered why so many of the science stories in this book feature classrooms in which students are learning in small groups. The teachers in our science stories created environments that nurture collaboration among students. The basic reason is that science and engineering practices including the processes of investigation, reflection, and further investigation, whether undertaken by third graders or by adult scientists, benefit greatly from the collaboration of several people. In addition, research has shown a number of positive results from students' cooperative learning, as we will see in a moment.

In this section, we address several important questions surrounding the small-group model of teacher and student interaction:

1. How do small-group investigations in science relate to what educators call cooperative learning?
2. In what ways is small-group learning consistent with constructivist views of learning?
3. In what ways is small-group learning consistent with the way science and scientists operate?
4. How can I set up small-group learning in my own classroom?
5. How can technology help me engage students in small-group learning?

12-8a Learning Groups

cooperative learning An instructional approach in which students work together in groups to accomplish shared learning goals.

Extensive research has been done on small-group learning, often labeled **cooperative learning,** which can be defined as students working together in groups to accomplish shared learning goals. Studies have shown a variety of both social and educational benefits from cooperative learning. For example, cooperative learning helps students retain more conceptual knowledge. It also fosters a classroom climate in which students interact in ways that promote each other's learning (Johnson & Johnson, 1999; Slavin, 2009).

It is important to recognize, though, that cooperative learning, as the researchers in this field define it, is not just any small-group instruction. It is a particular way of organizing the social interaction among students. If four students sit passively while a teacher talks at them, that may be small-group instruction, but it is not cooperative learning. A **cooperative learning group** is an arrangement in which a group of students, usually of mixed ability, gender, and ethnicity, work toward the common goal of promoting each other's and the group's success. In other words, in a cooperative learning group, each student is responsible for his or her own learning *and* the group's learning.

cooperative learning group An arrangement in which a group of students, usually of mixed ability, gender, and ethnicity, work toward the common goal of promoting each other's and the group's success.

There are many ways to structure such learning groups. One basic distinction is between formal and informal groups. In *formal* cooperative learning groups, the group stays together until the task is done. In *informal* groups, the commitment is for a shorter term, as when each student checks with a neighbor to see if he or she understood (Johnson & Johnson, 1999, p. 15). The science stories in this book have involved formal learning groups, which stayed together until the problem was solved, the model was built, or the task was accomplished.

To be effective, cooperative learning must provide a good deal of structure for the group, and it must be supplemented with direct involvement by the teacher. You saw an example of this in Chapter 9, when Ms. Travis gathered the attention of the whole class to explain the meaning of the term *circuit* to the entire group. Another example is when teachers address the entire class to gather ideas from students before and after a science activity.

12-8b Small-Group Learning Works

Cooperative learning groups, such as the ones you have seen in this book, encourage the very constructivist learning processes that are at the heart of gaining conceptual knowledge in science. In such groups, students have the opportunity to discuss their ideas with others, discover differences between their own explanations and others', and defend their positions or alter their thinking as the group strives for consensus. Why is this interaction so important for learning? There are many reasons, but here we concentrate on three: reflection, the social context of learning, and the implications of cultural diversity and gender.

12-8c Cooperative Learning and Reflection

Throughout this book, as we have explored the ways students best learn science, we have seen that science teaching and science learning rely on the active participation of students. But we have also seen that students must be mentally active as well as physically engaged with activities. In this chapter, by saying that an activity is not a lesson, we have stressed the need for reflective mental processes to accompany the concrete activities.

Small-group, cooperative learning fosters these all-important processes of reflection. When students exchange and clarify ideas with their peers, plan an investigation, or refine their observations and conclusions, their minds are constantly engaged. Each student is prodded to more reflection by the inferences and opinions of others. The collaborative problem solver goes further in constructing new ideas and becomes better prepared for higher levels of thinking. The teacher is also a collaborator, visiting each group and helping it to focus.

12-8d Learning in a Social Context

At the beginning of this book, I noted briefly how our understanding of the world is constructed in a social context. Even if you disagree fervently with your neighbor about, say, the value of exploring Mars, you both are working with many similar concepts, including understandings of what and where Mars is and what kinds of exploration are feasible. You are both also using similar language.

In the same way, students' construction of new science explanations and theories is influenced by the social communication and language norms of our society. Peer communication in a small group helps the group's members find a common language with which to express their meaning, and this process promotes their learning. For example, in a lesson on density, the textbook might say, "Density is the mass divided by the volume." This type of decontextualized language can be baffling to many learners. But in a small-group conversation, the students may talk about how much 100 milliliters of corn syrup weighs and whether they think the corn syrup is denser than the corn oil. One student may then weigh 100 milliliters of corn oil and find out that it weighs less than the corn syrup. As this more contextualized meaning for density emerges from the common social discourse of the small learning group, each student can develop a more personalized, deeper understanding of the science idea. This is especially helpful for English language learners.

12-8e Cultural Diversity and Gender in Cooperative Learning

As we stated earlier, images of scientists have traditionally excluded women and minorities. We know, too, that students who see themselves as marginal in a large group do not readily participate. Thus it is not surprising that girls and students of minority ethnic and cultural groups all too often distance themselves during science lessons, contributing little and learning little.

Cooperative, small-group learning activities can help solve this problem. For girls and culturally diverse science learners, these activities attend to their academic needs far better than do individual learning activities (Barba, 1998; Bruna & Gomez, 2009). Group work and cooperative learning can reduce individual competition and raise the level of cooperation (Diamantes, 2002), and the climate of support encourages the participation of students who are less likely to volunteer and interact in a whole-class situation.

We should not forget, too, that getting culturally diverse students involved benefits everyone else in the group. Remember the story in Chapter 6 of Ms. Byrne's third-grade class, which was investigating fruits and vegetables? The students, who were from several cultures, shared information about foods that were familiar and unfamiliar to them. This type of interaction expands everyone's knowledge and often leads students to develop further questions to investigate.

As we will explore later in this chapter, students with physical or learning disabilities also contribute to the diversity of a cooperative learning group. They bring a way of seeing the world that enhances the science experience for all the group's members.

12-8f Scientific Investigation and Group Learning

In the adult world, scientific investigation is a social process. Scientific researchers collaborate with one another all the time. They work on teams; they share references to important articles; they access others' research through electronic communication and the Internet.

Classroom science learning groups are a real-life model of the collaboration necessary for true scientific inquiry to occur. They help eliminate the false stereotype of the lone scientist in a remote laboratory. They promote the kind of interchange and teamwork that are essential for scientific problem solving. Moreover, by fostering interactions among students who normally would not be relating to one another, they widen the range of students' observations and increase both the breadth and the depth of classroom investigations. The more diverse the perspectives on nature are, the greater is the likelihood of thorough explorations of natural phenomena. In addition, scientists agree that greater diversity in observations and inferences leads to a higher possibility that an accurate idea will emerge in the conversation.

12-9 Structuring Cooperative Learning Groups in Your Classroom

As we noted earlier, cooperative learning groups need structure. For the learning to be successful, the groups and their activities must be carefully selected. There are many different ways of structuring the groups, but some questions will always arise: Which students should be in which groups? What individual roles need to be assigned within a group? And how should I, as a teacher, mediate learning for the various groups in my class?

12-9a Assigning Students to Groups

Most small learning groups are created with two to four students. Sometimes groups of five are effective, but usually the smaller, the better. Keeping the group size small may limit the amount of diversity you can achieve within each group. Nevertheless, try to design the groups with as much heterogeneity as possible. Students of mixed ability, gender, and ethnicity should have the opportunity to work together toward common goals, learning about one another in the process.

As a teacher, you should take the lead in designing the learning groups. When students are allowed to select their own collaborators, the groups are often homogeneous, with males working with males, white students working with other white students, and so on (Johnson & Johnson, 1999, p. 23). As a result, students do not interact with a wide variety of peers—one of the goals of cooperative learning.

You may want to gather information from the students before you design the groups. For example, you can ask each student to write down the names of three people he or she would like to work with. With this information, you can build groups that include at least one person of choice for each member. Groups should work together for as long as it takes for them to be successful, but at some point you will want to reshuffle the groups so that each student has the opportunity to work with as many other students as possible.

12-9b Assigning Group Roles

In formal learning groups, each member is usually assigned a particular job or role. This is important not just to promote group efficiency but to make sure that every student participates fully. When everyone has a specific task that is essential to the problem solving at hand, each student will be a valued member of the group.

You may remember that in some of the science stories in this book the teachers used assigned jobs that included the roles of speaker, director, materials manager, and recorder. Another model for designing cooperative learning groups uses three prominent jobs for each group or team. The director makes sure that the team understands the investigation and completes each task in the directions. The manager collects and returns the materials that the team needs. The speaker asks the teacher and other teams when the team requires help. This model of three roles is popular in some school systems, and some schools even use printed badges that the students wear to designate their roles (Biological Sciences Curriculum Study, 1996). It is not necessary to use any of these particular labels for the group roles; you may design your own labels if you prefer. Whatever you call the roles, group work flows more smoothly when different students have different responsibilities.

In the model of science learning groups that I often use, the teacher designs the groups, but the members of the group then select a leader, who is usually also the spokesperson responsible for reporting results to the entire class. The leader changes from one investigation to another. The teacher also specifies the other roles to be filled, and the group then selects individuals to fill them.

As you can imagine, it is important for students to understand the responsibilities of each role. As a teacher, you will particularly appreciate the ways in which the group member responsible for getting and returning materials reduces the number of students wandering around the room at a given time. The more complex the investigation and the larger the group, the more roles may be involved. Whatever the assigned tasks for one investigation, the roles should change from project to project.

12-9c Facilitating Group Learning

As the teacher, you manage and mediate the students' groups. You give directions for establishing the jobs and assigning the tasks, and then you facilitate the change of jobs when a new investigation begins. You can promote effective group work by monitoring how the group is functioning and making suggestions (Johnson & Johnson, 1999, pp. 42–45). Reminders to individual students like, "Did you check with your group?" or "What does your group think?" can help promote the value of the group.

One method for monitoring the group process involves a cooperative learning structure called "numbered heads together" (Kagan, 1997). The teacher asks the students to number off within groups. In four-person groups, for example, each student would be number 1, 2, 3, or 4. The teacher can then pose a question and ask the groups to "put their heads together" to make sure everyone in the group agrees on the answer. After the group members have consulted among themselves, the teacher calls out a number—3, for instance—and the students whose number is 3 raise their hands to offer their group's answer. Each time a new question arises, the teacher calls out a different number. This technique can be used to check that each student in each cooperative learning group is participating in the group's decision making.

Different groups will make different decisions about how to proceed with scientific investigations, and it is important to honor and value these differences. Sometimes it will even be necessary to allow an individual to go off on an investigation by himself or herself, as Mr. Wilson did with Jamie in Chapter 2. At the same time, however, you need to coach and prompt the groups as they struggle toward problem solving. When appropriate, offer ideas, provide focus, or give specific explanations of the problem at hand.

When the investigation is complete, invite the members of each group to discuss how well they collaborated with each other. Their comments will help you to evaluate the groups' effectiveness and plan for the next group science activity.

As you create this model in your own classroom, you will find that small-group cooperative learning is truly essential to doing science with students. You will see for yourself that the groups encourage the process of problem solving in ways that individual instruction cannot. You will also see the value of diversity in group problem solving.

12-9d Cooperative Groups across the Globe

The National Space and Aeronautics Administration (NASA) offers a program for middle school students, called NASA CONNECT, that engages groups of students in projects that connect science to mathematics and technology. NASA CONNECT lets students become involved in science and engineering activities through school-to-school collaborations and through materials and videos made available at the website. Students from one middle school, for example, can collaborate with students from another middle school to solve a challenge. In one example, the challenge was titled "Better Health from Space to Earth," and students were asked to work in groups to develop daily meal and exercise plans for individuals with special needs.

Another NASA program, NASA Live, offers videoconferences that connect researchers with students throughout North America and beyond. Each videoconference engages the students in an interactive experience, including a variety of multimedia activities. Teachers and students exchange ideas with NASA experts in science and engineering. This type of cooperative group work transcends classroom boundaries and fosters science learning groups across geographic areas.

12-10 Inclusive Science Education

Our goal as science teachers is to offer opportunities for all students to gain sufficient schooling in science in order to become better problem solvers, critical thinkers, and inquiring human beings. In the opening chapter, we discussed *differentiating instruction* so that all students can participate in a science education experience that maximizes the possibilities for their success. We also noted that designing science instruction for all learners involves using multiple approaches with many types of activities and materials and that this type of universal design ensures that all types of learners are engaged in the science experience. We want all students, including women and ethnic minorities, to feel *entitled* to success in science.

Feeling entitled to success in science is often based, as you have seen, on long-held stereotypes that persist in the media and in our minds. Every year in the United States, we celebrate Women's History Month and Black History Month to remind students that those who came before us made significant contributions to our lives today. Among those contributions are advances in science and technology. Each year, therefore, I would ask my sixth graders in middle school to research a woman and/or a person of color who had contributed to advancing knowledge in science and technology. Instead of writing a report, I would ask them to design and construct some artifact that represented their chosen scientist's life or work. Students who researched the life and work of Nobel Prize winner Barbara McClintock, for example, learned that McClintock worked extensively with corn plants in order to discover that genes can move from one place to another on their chromosomes, causing mutations. For their artifact, these students designed and constructed a three-foot model of an ear of corn. Each corn husk in the model had data about Dr. McClintock pasted on the inside of the model leaf. Hence, the artifact represented her work and provided information about her. I strongly urge you to develop similar projects with your students, and not just during special months of the year.

People with disabilities are another group that commonly receives little encouragement in science. Did you know, however, that one of the world's most eminent marine biologists is blind? A professor at the University of California—Davis, this scientist's work is with mollusks, those shelled invertebrates that inhabit marine waters. His extraordinary sense of touch enables him to study these creatures and make observations that elude other scientists. His name is Geerat J. Vermeij, and he has won several honors for his work (see the feature "Geerat Vermeij Speaks about His Work").

Learners may have special needs because of a wide variety of learning disabilities, behavioral problems, or physical or sensory impairments (Hardman, Egan, & Drew, 2017). In the following sections, we will discuss some of the differentiated instruction tasks that work best for students with disabilities. There are many websites available to assist you with instructional strategies. Remember, our goal is to make it possible for *all* students to do science in the classroom.

12-10a Science and the Inclusion Model

The Individuals with Disabilities Education Act (IDEA) and the Americans with Disabilities Act (ADA) extend equal opportunity to those with disabilities so they can experience the same services that have always been accessible to the general population. Under these laws, students with disabilities are not receiving something extra; they are merely gaining access to what the general population has taken for granted (Stefanich, 2007). Similarly, science education reform documents support science education's goal of scientific literacy for all, regardless of any categorization of learners' abilities (McGinnis & Stefanich, 2007).

inclusion model The practice of placing students with disabilities in regular classrooms to the greatest extent possible.

These laws and reform documents lie behind the **inclusion model,** in which students with disabilities are placed in regular classrooms to the greatest extent possible. Findings in educational research support the inclusion model as a more desirable alternative than segregated instruction for students with disabilities. This is true regardless of gender, race, ethnicity, social class, or type of disability.

When "inclusion students," as they are often called, are placed in a regular education classroom, a special educator is usually available to offer support. What has sometimes happened, however, is that the regular classroom teacher has little to do with the development of the student's individualized education plan (IEP). Therefore, the regular teacher ends up presenting the science curriculum content without knowing much about the needs-specific pedagogy. At the same time, the special educator, who knows how to teach students with special needs, does not know enough about the regular content to relate it to the special pedagogy. Hence the student's science education gets lost in the gap between the teachers. To avoid this problem, it is important for the regular educator and the special educator to work as partners from the beginning.

Geerat Vermeij Speaks about His Work

I study the history of life. I want to know when evolution occurred and when it did not. Although my research is concentrated on fossil and living shell-bearing animals like snails and clams, I apply the results to large scientific questions. I am especially interested in looking at the history of life on Earth from an economic point of view. This involves the study of technological innovations, the analysis of how workable ecosystems are constructed and maintained, and an understanding of how shifting availability of resources affects the everyday affairs of organisms in past and present ecosystems. The ultimate aim is to see what the economic history of life can tell us about how to construct human economies that are not dependent for their health on perpetual growth. On the way to these lofty goals, I am having a great time studying the classifications, architecture, and history of snails, whose beauty rivals that of any human artistic creation.

Source: "Geerat Vermeij Interview," Department of Geology, University of California, Davis.

Fortunately, the best science teaching practices—engaging students in using all their senses, in manipulating materials, and in asking questions—represent the type of multimodal approach that is also very successful for students with disabilities. While by no means comprehensive, the following section offers some strategies for helping special education students achieve success in learning science.

Before we begin, however, let's remember what all students need: They need to know that their teacher expects them to succeed and is working hard on their behalf. Holding out the expectation that your inclusion students will be successful in science is an important first step. Remember, you teach who you are.

12-10b Classroom Strategies for Doing Science with Students with Disabilities

Several general strategies are useful for students with any type of disability:

- Allow more time for students with disabilities to complete the task at hand. This is an important step, and it should become routine in your classroom.
- Get feedback from your students with disabilities. Ask, "How am I doing?" "Are you having a particular difficulty with this science experience?" "What are you most pleased about?"
- Explore technologies that can help. Software programs can benefit students with many kinds of disabilities. In addition, there are science tools and materials that help students complete scientific tasks, for example, beakers with special holders, pouring spouts, and larger numbers for calibration.

The following subsections offer a number of suggestions (adapted from Stefanich, 2007) for teaching students who have particular kinds of disabilities. See also the feature "Classroom Survey: How Accessible Is Your Classroom?"

Motor/Orthopedic Disabilities The term *motor/orthopedic disability* encompasses a large number of impairments involving functional or structural aspects of one or more body systems. Examples include cerebral palsy, polio, muscular dystrophy, multiple sclerosis, and spinal cord disorders. Experts find the following instructional approaches useful:

- Review work areas for appropriate height and accessibility of supplies.
- Examine the classroom environment and make sure the student has appropriate access to other students.
- Examine the students' movement patterns and needs. If necessary, rearrange classroom furniture and other objects so the student can move around as needed during a lesson.
- Provide accessible means for reviewing drawings, charts, or graphs.
- Look for adaptive computer software and other special equipment. Contact assistive technology agencies directly, and become familiar with the specialized equipment.

Visual Impairments People with visual impairment are often characterized as having either "low vision" or "blindness." If they have low vision, they may be able to read with the help of large print or magnifiers (Hardman, Egan, &

Classroom Survey: How Accessible Is Your Classroom?

The following survey was developed to help you assess your classroom in terms of its accessibility for students with disabilities. You will notice, though, that many of the items refer to excellent science learning experiences for all students.

What is the average width of the aisles?

____

(Aisles should average 42 to 48 inches minimum. This allows access for students in wheelchairs and those using other assistive devices.)

Describe the work surfaces, lab tables, and so on.

____

____

____

(Spaces under work surfaces should be 29 inches high, 36 inches wide, and at least 20 inches deep. The work surface should be no more than 32 inches off the floor. This allows access for students in wheelchairs and those using other assistive devices.)

Is safety equipment (fire extinguishers, eyewash, fire blanket, first-aid kit, and so on) easily accessible?

____

(This is important for all science classrooms.)

What types of projection devices are used in the class? Overhead projectors? Data projectors used with computers?

____

(Projectors are a useful visual aid for all students.)

What are the light conditions in the room?

____

____

____

(The quality of lighting has implications for all students' learning.)

How are the acoustics in the classroom?

____

____

____

(Again, your answer has implications for all students' learning.)

How are things stored in the room? Consider both the accessibility of desirable materials for doing science and the importance of keeping more dangerous materials, like hot plates and matches, in a locked facility.

____

____

____

Source: Adapted from "Making Science Accessible and Inclusive: Strategies for Teachers in Science Education," a preconference workshop presented by Greg Stefanich, Marcia Fetters, Eric Pyle, Dawn Pickard, and Jim Ellis at the Association for the Education of Teachers of Science International Conference, St. Louis, Missouri, January 2003.

Professional Resource Download

Drew, 2017). People with blindness may be unable to gather any visual information. Here are some ways to differentiate instruction for students with visual impairments:

- Use tactile or auditory signals when appropriate.
- Provide a magnifier if the student wants one.
- Clearly label all items and equipment involved in a lesson.
- Allow for direct manipulation of materials when appropriate.
- Provide enlarged handouts.
- Get thermoform sheets. (Thermoform is a plastic sheet material used for duplicating in Braille.)

- Provide a supportive peer assistant to work with the student.
- Allow the student and his or her peers to continue with science activities outside of the school day or at home.

Hearing Impairments People with hearing impairments can be described by two main categories—those who are hard of hearing and those who are deaf. Individuals who are hard of hearing still have some degree of hearing, which may or may not be enough for them to use auditory information in communication. Deaf persons have no ability to hear.

For your students with hearing impairments, try the following techniques:

- In your classroom seating plan, locate the student where he or she can see your eyes and your lips. Be sure that the background, from the student's point of view, has sufficient contrast.
- Print activity cards in large type so the student can easily read them from a distance.
- Provide a supportive peer assistant to assist during games and construction activities.
- Allow the student and his or her peers to continue with science activities outside of the school day or at home.

Learning Disabilities People who are described as having learning disabilities can suffer from one or more of a number of diverse conditions ranging from dyslexia and attention deficiencies to identifiable brain injuries. The definition of *learning disability* varies between states, and it remains a contentious subject among researchers. Common to most definitions of learning disabilities is the idea of a significantly diminished capability for using and understanding language in spoken and written forms. While students with learning disabilities are of average or above-average intelligence, the disability creates a gap between their inherent ability and their actual performance.

The following suggestions can help you improve your instruction of students who have learning disabilities:

- Eliminate distractions and background noises as much as possible.
- Review directions with students in advance of a lesson or assignment.
- When you interact with a student who has a learning disability, give him or her your undivided attention. Focus on what the student says and listen carefully.
- Be straightforward in your approach. Don't pretend to understand if you do not.
- Allow for noncompetitive participation in classroom activities and games.
- Provide a reader when appropriate.
- Allow for direct manipulation of materials when appropriate.
- Engage students in design and construction activities.
- Maximize the availability of visual materials.

Attention-Deficit/Hyperactivity Disorder (ADHD) Students with ADHD are easily distracted and have trouble concentrating on tasks for any length of time. Some are restless and fidgety, with excessive movements that appear aimless. Some people with ADHD, though—typically females—are quite underactive, and their problem may go unnoticed.

The following techniques are recommended:

- Position the student with ADHD so that you can visually monitor him or her and exercise proximity control when needed.
- Seek out visual media and models to keep the student engaged.
- Slow down the pace of activities, and allow adequate time for student participation.
- Preview an activity sequence in advance and, when appropriate, write a contract with the student specifying what behavior is expected.
- Be straightforward and direct with the student.
- Allow for interaction with materials when appropriate.
- Allow for time-out if a student needs it.

12-11 Technology to Foster the Success of Students with Disabilities

At one university, a National Science Foundation project has increased the success of people with disabilities in STEM fields (science, technology, engineering, and mathematics). Called DO-IT, standing for Disabilities, Opportunities, Internetworking, and Technology, the program uses computers, assistive technology, and network resources to bridge the communication and accessibility gaps for people with disabilities (Burgstahler, 2006). An easily accessible DO-IT website helps educators access resources and techniques for making their classrooms and science activities more accessible (DO-IT, 2016).

In order for students with disabilities to gain success in science, they should begin using computing and networking tools at a young age (see Photo 12.1). These tools help them to gain access to resources, communicate with others,


Ed Kashi/Corbis

PHOTO 12.1 The goal of inclusive science education is for all students to participate in science with success. Often technology provides a useful aid. Here, students with learning disabilities use laptops as part of their science investigation.

assistive technology (AT) Devices or services that promote greater independence for people with disabilities by enabling them to perform tasks that were formerly difficult or impossible.

and perform academic tasks independently (Burgstahler, 2006, p. 16). The term **assistive technology (AT)** refers specifically to devices that promote greater independence for people with disabilities by enabling them to perform tasks that were formerly difficult or impossible. There are many varieties of assistive technology. As you enter your own classroom and become a teacher of science, ask yourself how you may be instrumental in creating positive and accessible learning environments for all students.

12-12 Questions for Your Own Reflection

When the science experience you have planned for your students is over, you may want to document what went on. There is always a lot to write about because you really do not know beforehand where the lesson will go or what the students will say or do. It is the students' thinking that propels you forward. Besides actively listening to the students during the lesson, it is useful to take some time afterward to record their ideas and your own reactions to the way the lesson developed.

Here are some sample questions to ask yourself as you reflect on the lesson and write about it in your science journal:

- What did the students find out in this experience? Were there any surprises?
- How did the students in each group work together? Were there any problems?
- Was the investigation open-ended enough so that students could be involved in the planning? How did the students extend the investigation?
- How did the students connect this experience to their daily lives?
- How did I accommodate students with learning and physical differences?
- Did I use technology effectively?
- Overall, what do I think the students got out of this experience?
- What do I remember most about this science activity?
- Would I do it again? How would I plan differently the next time?

Sometimes it is useful to record comments and reflections directly on the lesson plan itself. Keeping your plans together on a mobile device is a good idea too. Your comments and notes have important implications for how you will address the topic the next time.