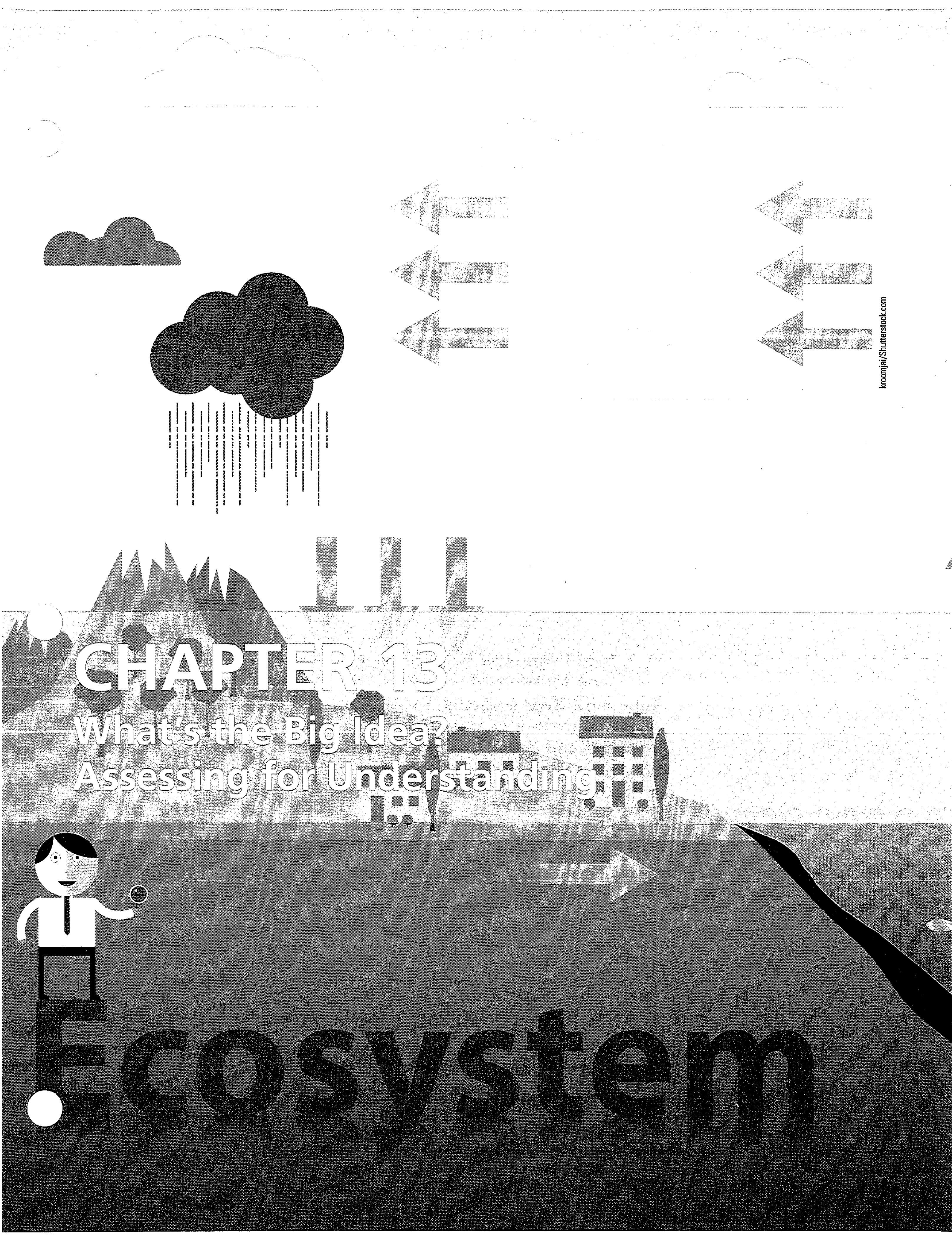

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CHAPTER 13

What's the Big Idea? Assessing for Understanding

LEARNING OBJECTIVES

After reading this chapter, you should be able to:

- 13-1 Explain what is meant by assessment in a meaningful way.
- 13-2 Distinguish among formative, summative, and performance assessments.
- 13-3 Determine how an assessment can be a good instructional task.
- 13-4 Explain how to use science notebooks for assessment.
- 13-5 Analyze how to use writing and drawing exercises for assessment.
- 13-6 Discuss the use of science conversations and interviews for assessment.
- 13-7 Examine how technology can aid assessment.
- 13-8 Explain how using dance and drama can enhance science assessment through performance.
- 13-9 Explain what makes an assessment "authentic."

Reflection

To Think About:

- How do you know if the students understand the concept?
- How can a "performance" be an assessment?
- What is the difference between formative assessment and summative assessment?
- How do teacher-created assessments compare with standardized tests?

When I was in southern Texas working with a group of third- and fourth-grade teachers, they invited me to spend some time with their students. I was interested in learning what the students thought about science—how they would define it, for instance, and how they felt about learning it in school. One day I brought a tape recorder to class and interviewed the students about what they thought science was. This is how it went:

ME: What do you study in science?

THIRD-GRADE BOY: (really thinking) Scienzz, scienzz—what we're learning about scienzz. ... There are stop scienzz, one-way scienzz, and yield scienzz.

My northern accent was clearly unintelligible to this student. He thought I had asked about "signs."

This story reminds me of the many occasions when we are trying to find out what students know but the student misunderstands the very way we ask or write the question. We, as teachers, are seeking one kind of meaning, and our students, with the best intentions, offer another kind. How, then, can we design ways to understand what students really know and are able to do in science? How do we go beyond seeking "right answers" to test questions, for example, to seeking deep understanding of a concept?

This is the central theme of this chapter. Teachers refer to this quest to determine students' understanding with terms like *assessment* and *testing*. Let's explore what these terms mean in theory and in practice.

13-1 Assessment and Testing

Assessment is an activity that teachers and, in fact, everyone else engage in. We constantly find ways to assess ourselves and others. In education, though, this term is used in specific ways.

science assessment
A process of collecting information that is used to determine the quality and character of an individual or group performance in a science learning experience.

Science assessment refers to a process of collecting information that we use to determine an individual or a group's level of understanding of the science concept. As you might imagine, this process of collecting information about what your students know and are able to do includes many different techniques. When we are teaching, we are constantly assessing. When we engage in conversations with the students, we know who has "got" it by the way they ask a question or respond to the dialog. A student can be fully understanding one science concept but then get stuck by the time the next unit is introduced. Assessment is embedded into lessons and is an ongoing experience. In order to collect formal data in the process of assessing, we ask students to perform a variety of tasks and try to understand if they can apply a concept to a new context. The assessment task we use must have instructional value as well. We ask ourselves, "What can my students learn from this assessment device and what can I learn about my students?"

13-2 Formative, Summative, and Performance Assessments

formative assessment
Assessment that gauges students' understanding of a particular topic in a unit in order to judge their progress and adjust the rest of the instruction accordingly.

summative assessment
Assessment at the end of a unit or course, used to document students' achievement or to evaluate the end product of a student's learning activity.

testing
Assessment of students' learning by means of teacher-made tests or state and local tests designed by educational agencies or testing services.

Formative assessment is used to gauge students' understanding of a particular topic in a unit in order to judge their progress and adjust the rest of your instruction accordingly. In contrast, **summative assessment**, which comes at the end of a unit or course, is used to document students' achievement. Final exams are a typical example of summative assessment (Ravitch, 2007).

Testing is a narrower term than assessment. It refers to the use of teacher-made tests as well as standardized tests designed by educational agencies or testing services. Even within these categories, as you are probably aware, tests come in almost infinite varieties. The phrase *paper-and-pencil tests* generally refers to tests made up of short-answer or multiple-choice questions. Essay tests, in contrast, require longer responses involving students' reflective thinking. Although essay tests may be taken with paper and a pencil, the term *paper-and-pencil test* does not usually refer to an essay test.

Short-answer and multiple-choice tests tend to assess small pieces of knowledge, asking students to recall some term or fact related to the unit of study. Typically, these tests assess knowledge in a fragmented way rather than in the context of the students' learning. As we noted earlier in the book, recalling a term or a piece of knowledge is quite different from constructing meaning. It should not surprise you, then, to learn that paper-and-pencil tests are not the best method for assessing the type of deep, contextual scientific learning that is addressed in this book. To assess that deeper level, educators have been turning to performance assessment. This type of testing assesses "active knowledge"—ideas that can be expressed in a variety of ways.

performance assessment
A process of judging how well students execute a task as part of solving a problem in a larger context. Often the execution of the task involves a type of student performance. Also known as *authentic assessment.*

In **performance assessment**, students demonstrate their understanding by solving a problem or performing a task in the real-life context of their classroom or their world. As you have seen throughout this book, the act of doing science always occurs in context. Examples of performance assessments include portfolios, demonstrations, and performing an experiment and drawing conclusions from it (Ravitch, 2007). An essay test can be a performance assessment if it is designed to make students think through a problem or question, as we will discuss later in this chapter when we talk about writing as an assessment tool.

Science is not isolated bits of observing, inferring, comparing, or recording; it is instead a contextual whole in which skills are employed because of a need to know. The skills are not important solely for their own sake. In the same way, a performance assessment sets up a need-to-know scenario that encourages the student to employ the skills that the assessment is intended to measure.

Performance assessments, as this chapter will demonstrate, can take a variety of forms. Whatever form you use, it should be appropriate to the context in which you are teaching. In other words, it has to *match the instruction*. In fact, *a good assessment usually looks like a good instructional task.* For example, as we teach science, we engage students in maintaining science notebooks. These notebooks are also used for assessment.

evaluation
The process of examining all the data gathered from various types of assessments to judge a student's or a group's achievement in a learning area.

Finally, the term **evaluation** refers to the process of examining all the data you have gathered from various types of assessments and making a judgment about how well the students understand a concept and use their science skills. Typically, evaluations relate students' progress to their own prior performance and to that of their peers within the class.

13-3 Assessment and the Instructional Context

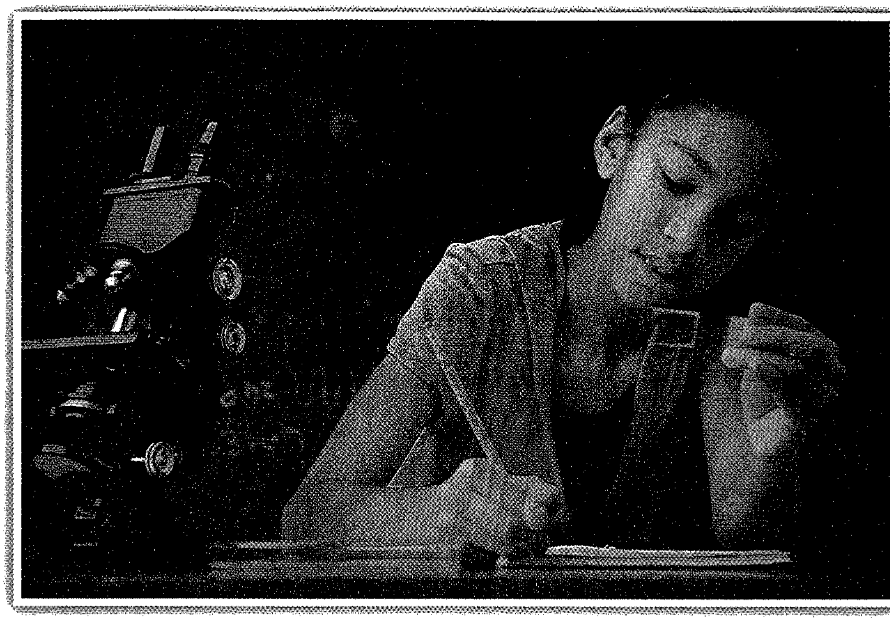
Assessment is not separate from instruction. Rather, the two join naturally together in the instructional context. As indicated earlier, whenever we are doing science with students, we are engaged in assessment. We wonder, "How are they doing? Do they work well together? What science skills are they using? Are they solving a problem? Do they get the science concept? What kind of model are they constructing?" Assessment and instruction may be thought of as siblings. In this sense, assessment is an integral part of instruction.

It is important to explore your students' understanding in terms of their ability to employ knowledge to make sense of a situation or a problem. In other words, you will be looking at their learning in context rather than just their "possession" of a certain item of knowledge. The following sections discuss several useful techniques for assessment of students' science learning. Remember, learning is an active process of constructing meaning. Assessment can also be an active process that encourages students to express what they know and understand.

13-4 Science Notebooks and Assessment

science notebook
A notebook in which students record their observations, reflections, questions, predictions, and conclusions during a science investigation.

There are many ways to invite students to record a description of the concepts and activities with which they are engaged. I encourage the use of **science notebooks** that describe, in specific formats, the students' investigations as well as their thinking about their findings. The structure of science notebooks directs students to the type of information they need to provide. Within this structure, though, the students' personal ideas about their science experiences have plenty of room to emerge. In this way, the notebooks can become a window into students' understanding of a particular science concept (Photo 13.1).



Hill Street Studios/Blend Images/Jupiter Images

PHOTO 13.1 A student records her observations in her science notebook, an important step in drawing conclusions about her investigation.

13-4a A Sample Structure for a Science Notebook

One way to structure a science notebook is to use a list of questions as a guide. Students respond to the questions both by writing and by drawing illustrations. Here is a sample list of questions:

1. What do I know about __________? (Prior knowledge)

For a particular lesson, you would fill in the blank with an appropriate word, such as "earthworms," "electricity," or "seeds."

For example, in the fourth-grade earthworm lesson described in Chapter 6, a student might respond with the following:

Earthworms are slimy and yucky. They live in the dirt.

2. What am I trying to find out? (The problem)

This phase of writing prompts students to define one or more problems relating to the investigation. The students express the main problem they are trying to solve, formulate any other questions they may have, and perhaps think about extensions to the primary activity. By "extensions to the primary activity," I mean ideas that come up as students formulate the question. For example, in this section, a student might write:

How do earthworms move? What do they do when they burrow down into the soil? What happens when you shine a light on them? Why do we have to put black paper around the worm bottle?

3. What materials do I need? (List of materials)

Here the students list their materials. In the earthworm lesson, they would note a flashlight for testing the earthworms' response to light, rubber gloves for handling them gently and safely, paper plates, and a magnifying lens.

4. What did I do? (Procedure)

Once students have answered the first three questions, they proceed with their investigation. Afterward, in question 4, they describe their own activities. In some ways this section is like a log. It provides students with a record of what they did that led to their understandings. It can be written in a series of steps or in a narrative form.

5. What happened? (The results)

   In this phase of notebook writing, the students document their observations. In the higher elementary and middle school grades, this section may be a formal record of findings, and the students may arrange their data in chart form or in graphs. In earlier grades, when the teacher has done a demonstration, this "what happened" section relates to what the class and the teacher have noticed together.

   Even after a demonstration activity, the science notebook should express the *individual* student's experience with the event. Students may draw or write their observations, or both.

6. What did I find out? (Conclusions)

   In this section of the notebook, students express the inferences and understandings they have arrived at as a result of their investigation. For example, in the earthworm investigation, students might write:

   Earthworms have a mouth but no eyes.

   Earthworms like the soil.

   When earthworms move, they wiggle like crazy and bunch up and then they stretch out.

   Earthworms make slimy stuff called mucus that helps them to move.

   Earthworms make holes in the soil so plants can have space for their roots.

7. What do I think about this experiment [or investigation or activity]?

   In this section, students offer their opinions or ideas about the investigation. Sometimes they make connections to the real world—for example,

   I like exploring the earthworms. I used to be afraid of them but I am not anymore.

8. If I did this over again, what would I do differently? (Reflection)

   This section invites students to analyze the investigation and plan modifications. Sometimes, they start the investigation all over again. This analysis and documentation of their thinking often leads them to important findings. After the earthworm lesson, one student wrote:

   Next time, I would put the earthworm at the top of the worm bottle and watch it go down to the sand part.

The science notebook structure guides students' science writing as well as their science thinking. Notebook entries do not always have to take the same form, however. Sometimes you might choose a question that prompts students to apply their knowledge to other situations or problems. For instance, during a unit on electricity, one fourth-grade teacher had students write the following question: "How can we make a metal item into a magnet that picks up 25 washers using just a simple series circuit and no light bulb?" Students were asked to write their ideas, their procedure for testing their ideas, their predictions, and their results. Under the conclusion section of this structure, one student wrote, "My prediction was not right because I said that if we wrap the wire 40 times around [the rivet] it will get 25 washers and it did not because we only picked up four" (adapted from Klentschy, 2008).

Scientists maintain notebooks that become important sources for their research. Architects, artists, inventors, writers, and others keep journals and sketchbooks that record their ideas and observations and inspire further discoveries. In the same way, science notebooks do more than record students' emerging science ideas; they stimulate additional thinking and investigation. When students look back over the science experiences they have described in their notebooks, they feel a sense of pride. As the teacher, you can use the notebooks not only to assess understanding of particular science concepts but also to learn whether your students are becoming independent thinkers.

If science notebooks are written by hand, they should always be kept in a bound notebook, not as separate sheets of paper. Like other creative writing products, science notebooks can be created with a word-processing program and kept on jump drives, iPads, or classroom laptops.

Students who keep their science notebooks electronically can easily add to, update, and correct them. If they have ready access to the Internet, they can insert pictures and other images in their notebooks. Sometimes, when the teacher assesses the students' knowledge and learning, the electronic pages are printed out as hard copy and handed in.

13-4b Pictures and Telling Stories

Students can record their observations in drawings as well as in words. Drawing gives students an opportunity to express themselves in a modality other than the verbal-analytic, and this can be an important consideration for classrooms of increasingly diverse learners.

This form of assessment is not limited to the early grades. In fact, older students are often pleased and challenged when they are invited to draw what they have observed and experienced. Older students usually place captions on their drawings as a way to explain the image.

Remember that we are not telling the students *what* to draw. Rather, we are creating an opportunity for them to express their own ideas through the drawing. Nevertheless, the students have to know why we are asking them to draw and what we expect their drawings to contain in order to demonstrate their understanding. In other words, we need to establish criteria for judging the students' drawings, just as we would with any other assessment technique.

In this context, I'm reminded of a third-grade teacher who took her students on a "tree walk" and then asked them to draw a tree and label its "most important" parts. Her minimum expectation was that the students would properly identify trunk, leaves, bark, and roots. Many of her students, however, did not draw the roots because they were underground. Instead, they drew the trees as they had seen them on the tree walk. This clash of expectations can be avoided when the teacher establishes assessment checklists that match the context of the students' experiences.

With young children, it is useful to have them tell a story about their drawings. As they elaborate on what they drew on their paper, the teacher gets an idea of what they know about the topic. This combination of drawing pictures and telling stories is a wonderful assessment tool for early childhood science education.

13-4c Assessing Student Notebooks

rubric A set of criteria used to determine the scoring value of an assessment task.

For some purposes, you may want to use a specific scoring **rubric** or set of criteria to evaluate your students' understanding on the basis of the writing and illustrations in their science notebooks. The checklist in the feature "Checklist for Assessing Science Notebooks" can guide you.

For purposes of grading, teachers often use qualitative terms for science notebooks—for instance, "unacceptable," "acceptable," "very good," or "excellent." In younger grades, labels like "budding scientist," "scientist," and "super scientist" can be useful.

Whatever system you use to assess science notebooks, you'll find that they give you many insights into the ways in which your students construct meaning. You'll see what the students understand and how they have come to understand it. You'll also discover what, if any, alternative conceptions need to be addressed in subsequent activities.

Checklist for Assessing Science Notebooks

Assessing for Conceptual Understanding

1. What evidence is there that the student can correctly explain the science concept?
2. Does the student use the vocabulary of the scientific concept accurately?
3. Is there any evidence of student meta-cognition? Are they reflecting on their thinking about the scientific concept?
4. Do the drawings accurately represent their activity?

Assessing for Science as Practice

1. Is the problem or question stated clearly?
2. Can the student list the steps of the investigation?
3. Are observations recorded clearly?
4. Have they stated what was kept the same and what was changed (where appropriate)—constant and variables?
5. Does the student draw conclusions from evidence?

Source: Modified from Shepardson and Britsch (1997).

Professional Resource Download

13-5 Other Types of Writing Assignments

Science notebooks are not the only format for science writing. Many other kinds of writing assignments can serve as both instructional activities and assessments. As an example, one middle school earth science teacher asked her students to write about plate tectonics as though they were explaining it in a textbook. The assignment read this way:

> *You are now experts on the theory of plate tectonics. Pretend you are an important geologist contributing to an earth science textbook. How will you explain this theory in your new book?*

In order to grade this writing assignment, the teacher developed a scoring rubric and shared it with the students. The rubric served as a tool for students to self-monitor; it became their own personal checklist of sorts.

You may be wondering how long this type of assessment takes. You would be correct to assume it takes much longer than a short-answer test and is therefore difficult to include for every unit. It may also require you to make adaptations for English language learners and other students who have a difficult time expressing themselves extensively in written English. Remember the 5R model from Chapter 12. Nevertheless, compared to a short-answer test, this kind of assessment offers a more in-depth perspective on students' understanding of science concepts.

blog
An online journal (short for "weblog"); in education, blogs are personal journals in which students and teachers post their thoughts and observations and others can respond.

Still another kind of science writing assignment involves the use of blogs. **Blogs** are online journals using software that makes it easy for the user to create frequent entries and for visitors to add their own comments and responses. Many of you may be regular contributors to blogs of all sorts. Blogs have become increasingly popular with science teachers because they offer a forum for communication between the teacher and each student and among the students themselves (Photo 13.2). Blogging can be very open-ended and creative, even when students respond to a structured assignment such as the following.

PHOTO 13.2 These middle schoolers are writing new entries for their science blogs. Later they will comment on each other's posts, engaging in an open-ended discussion of their scientific observations and ideas.

13-5a Middle Schoolers Blog about Organelles

Mr. Fletcher, a middle school science teacher in the province of New Brunswick, Canada, frequently uses blogs to assess students' understanding. One day during a cell structure unit, when students had been exploring the parts of the cell called organelles, he asked them to respond in their blogs to the following assignment:

> *YOU ARE FIRED!!! You are an organelle of your choice and you are about to be fired. You must defend yourself and explain why it would be a huge mistake to fire you.* (Fletcher, 2008)

The students were allowed to use external links on their blogs as they made their case for the chosen organelle, and they could download pictures to place in their stories. Mr. Fletcher also offered students instructions for posting comments to their classmates' blogs:

> *Choose a blog entry of a fellow classmate. Answer the question they asked in the last assignment. Your response should be thoughtful and based on information you were given or read about in the links.* (Fletcher, 2008)

Each student wrote a blog entry about a particular organelle and then visited classmates' blogs to respond to questions or comments. The students learned from the comments made on their work and from their own reflection on those comments.

Grading rubrics for blogs typically include guidelines for written expression. Students understand that their blogs are for public consumption and may be read not only by classmates but also by others outside of their class (like me!). Blog assignments like this one serve as a useful formative assessment and help students learn with and from their classmates.

authentic assessment A process of judging how well students execute a task as part of solving a problem in a larger context. Often the execution of the task involves a type of student performance.

Other writing prompts engage students in expressing their understanding in authentic ways. Written essays and the like are considered **authentic assessments** because they contain a variety of documentation representing student understanding in context. As an example of assessment activities that are based on writing, think back to the electricity lessons in Chapter 9. Ms. Travis might offer her students the following prompts:

- Write a letter to a relative explaining how a simple circuit works.

- Build a five-question game card using hidden electrical circuits. (The game card would be made with materials like aluminum foil, a manila folder, and a circuit tester consisting of a battery, three wires, a bulb, and a bulb holder. Only the card would go into the student's portfolio.)
- Describe the reason that houses should be wired with parallel circuits.
- Explain why circuit breakers are important.
- Using the letters in the word *electric*, write one statement about electricity beginning with each letter.
- Describe an activity that you have done with static electricity. What did you find out?

With an assessment technique like this, students become actively engaged in representing their understanding to the teacher.

13-6 Using Science Conversations for Assessment

science conversation (or science interview) A direct discussion between a teacher and an individual student about a science learning experience. This activity allows teachers to ask students to elaborate on their ideas—a good way to determine the depth of a student's understanding. Through such conversations, teachers gain important clues about how students construct personal meaning, and these clues then influence future instruction.

Not all students can demonstrate what they know in writing as well as they can in "telling." An oral **science conversation**, sometimes called a **science interview**—that is, a direct communication between an individual student and the teacher—can overcome the problems that are created when we assess students solely on what they can explain in writing.

Chapter 12 stressed the importance of how teachers question their students. But the usual questioning process, even something as simple as, "What do you think about this?" or "Why do you think this happened?" may leave out some members of the class. In personalized communication, you can engage a particular student one on one, find out what he or she is thinking, and negotiate the meanings of any terms that are problematic.

Consider the story at the beginning of this chapter about my visit to southern Texas. After the student and I straightened out the pronunciation difficulty and we both understood that we were talking about science rather than street signs, we had the following conversation:

ME: What do you do when you do science?
STUDENT: We do experiments.
ME: What is an experiment like?
STUDENT: Well, one time we measured how much popcorn we had in a cup. Then we popped the popcorn and measured it again.
ME: How did you measure it?
STUDENT: We filled up other plastic cups with the popcorn and counted how many cups we had.
ME: What did you find out?
STUDENT: We got over twenty cups of popcorn from one cup!
ME: Wow, that's a lot of popcorn.
STUDENT: Yeah, the whole class ate it.
ME: Why do you think there was so much popcorn after you popped it?
STUDENT: Not sure. . . . I think it was something about how big each kernel got when it popped.

You can see that in a science conversation teachers can ask students to elaborate on statements, and in this way they can determine the depth of a student's understanding. Oral interviews such as these have proved to be an effective way for both teachers and students to communicate what is known (Gallas, 1995, 2003). Teachers gain important clues about how students construct personal meaning, and these clues then influence their future instruction.

13-7 Using Technology to Assess Understanding

Technology-rich environments provide students with many additional ways to express their understanding to others. For example, as mentioned earlier, science notebooks kept on a computer can incorporate images as well as words. Students easily access websites to "cut and paste" pictures or other graphic materials that enhance their scientific explanations in their notebooks. They may take photos with their phones for inclusion in electronic science notebooks.

Even more dramatically, technology offers students the opportunity to design products that demonstrate what they know about a given topic. Almost daily, it seems, new software products are emerging that are designed to reveal students' understanding of a topic. Many students, particularly those who may have difficulty expressing themselves in typical oral or written forms or in traditional test formats, embrace technology-based assessments as a way to express themselves creatively. These activities are also a good way to challenge gifted and creative students to expand their horizons.

The possibilities for technology-supported assessment are endless, but in this section we will look at two specific tools: concept maps and electronic presentations.

13-7a Concept Maps

You may recall that in Chapter 2 Ms. Parker used a concept map to help develop and scaffold the complex understanding of the surface tension of water. This type of concept map, with arrows and circles, may be created by students as a form of assessment.

Think about how you might use concept maps for the sixth-grade unit on the moon described in Chapter 8. You might give students this assignment: "Placing the term *Moon* in the center of a concept map, demonstrate your understanding of how the moon shines and how it moves. The terms you may use include, but are not limited to, *Rotation*, *Revolution*, and *Reflection*."

Now, combine this with Web-based or application software that helps create the symbols in concept maps, and the students can easily be creative in expressing their understanding of certain features of the moon. Students can readily create the sort of concept map shown in Figure 13.1. Notice how the ovals relate to two different kinds of concepts about the moon and how the arrows demonstrate their linkage. This structural representation of

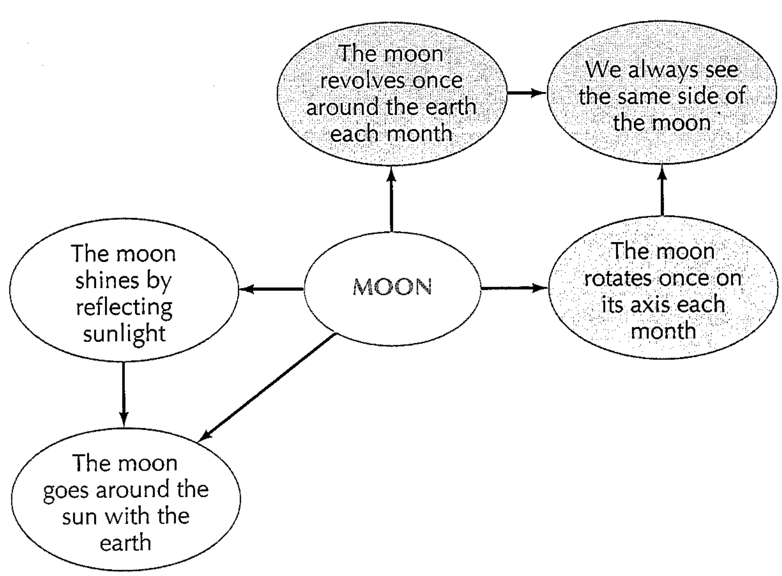


FIGURE 13.1 Sample concept map for a sixth-grade unit on the moon

understanding gives students another way of expressing meaning. The more ways in which we ask students to demonstrate what they know, the more possibility there is for students to actively engage in thinking deeply about a concept.

Concept maps may be saved and developed further as students continue to build their knowledge. You can make a concept map assignment open-ended by asking students, for instance, to link "everything you have learned about the moon to the center circle." With current software, they can easily create links and arrows and build confidence in organizing information, understanding concepts, and expressing their thoughts. Remember, though, that just as a concept map shows what students know, misdirected links or wrong connections reveal what they don't understand. When using students' concept maps for assessment, you need a scoring rubric that details the accuracy of the links, the level of explanation, and the complexity of the concept (Stoddart et al., 2000).

13-7b Electronic Presentations

Another kind of software that allows students to express their understanding is *presentation software*. This general category includes various programs that combine text, graphics, video, and sound in a single presentation. Microsoft's PowerPoint, widely used in business, is the most common example.

PowerPoint presentations consist of a series of "slides" that appear on the computer screen and can be projected onto a larger screen. You have seen this used often by teachers and may have had to create your own as an assessment tool. Teachers can provide rubrics to explain their expectations and then ask students to create their own presentations. For a PowerPoint presentation on earthworms, the class might be asked to design four slides that explain how earthworms move, what they eat, what their habitat is like, and how they respond to stimuli. One slide might display a drawing of an earthworm along with a short, descriptive passage of text. Students might design this slide so that, with the click of a mouse, the earthworm would appear to move slowly across the screen, accompanied by a recording of a student's voice offering observations about the movement. Creating such a personal design package and presenting it to the class is an excellent way for students to use computer technology for assessment.

As with all other types of nontraditional performance-based tasks, technology design efforts must be evaluated according to an assessment checklist and rubric. If the students in Ms. Travis's fourth-grade class were asked to work in groups to design a PowerPoint presentation to compare series and parallel circuits, the following assessment checklist might guide them:

- Does your presentation state the goal of the program?
- Does your presentation include the materials that make up electric circuits?
- Does your presentation show drawings of the two types of circuits?
- Does your presentation offer real-life examples in which both types of circuits are used?
- Does your presentation analyze the strengths of both types of circuits?

Regardless of the form your students' presentations take, the students themselves must be aware of the criteria for success if you are using their performances to measure the level of their understanding. Remember, the more varied the types of assessment you use, the more authentic information you will gain about students' understandings.

13-8 Multiple Types of Performances

The options described so far in this chapter, including science writing assignments, notebooks, portfolios, and presentations, are all useful methods for performance assessment. That is, they all can engage students in carrying out an assessment task that is relevant to the instructional context. These methods are far from the only possibilities, however. The following stories describe different ways in which students exhibit their understanding through performance.

13-8a Third Graders Enact the Water Cycle

In Ms. Nelson's third-grade classroom, the students have been exploring the water cycle and weather. On several days they have gone outside to observe the sky and make drawings of different clouds. They have been heating water and watching what happens. One day, Ms. Nelson places a pan of ice cubes over a pot with steam rising from it, and the students observe water droplets forming on the bottom of the pan. As these water droplets grow in size, they become so heavy that they fall back into the pot.

Many science ideas have emerged during the students' investigations of what happens to water when it is heated, what happens to steam when it is cooled, and the connections between their classroom models and the weather outside:

- When water is heated, it changes into steam.
- Steam rising from the pot looks like smoke.
- When steam is cooled, it turns back to water.
- The water falls back to the pot, filling it up again.
- The water becomes steam again when it is heated.
- When I see my breath in the winter, it is like a cloud.
- Steam is really a gas called water vapor.

Toward the end of a week of exploration, Ms. Nelson introduces three terms: *evaporation*, *condensation*, and *precipitation*. She asks the students to think about how these terms describe some of the big ideas they have gathered.

The students have heard the term *evaporation* often. They know that the word applies to what happened when they washed the blackboard and the water seemed to disappear. Also, they have heard the term *precipitation* in weather reports, so they can connect it with their water droplets falling back into the pot. But they are not sure about the term *condensation*.

At this point, Ms. Nelson draws a chart with arrows depicting water evaporating, becoming part of the clouds, and then precipitating back down to the earth. The students reason that condensation must be the process of the gas's turning back into the water droplets. Ms. Nelson is impressed with their reasoning.

After some time, Ms. Nelson asks, "How shall we express what we know about the water cycle and weather?" The students come up with a variety of ideas:

Write a poem	Write a song
Do a dance	Write a story

Ms. Nelson asks, "What should all of our water cycle and weather projects have in common?" The students decide that their projects have to explain their understanding of *all* the big ideas about the water cycle they have listed that week.

Now Ms. Nelson guides the students to form groups that reflect their various talents and interests. Class time is set aside for group meetings, and resources are made available. The dance group, for example, needs a tape recorder; the art group needs brown butcher paper, pencils, and colored markers.

Eventually, all of the groups present their projects to the class. The song group sings a song they have composed about the water cycle, with instrumental accompaniment provided by one of the members who has brought in his guitar. The members of the dance group, except for the student playing the role of the sun, mime raindrops in the water cycle. They start out crouched on the floor like water particles, reach up to the sky like gas particles, shiver and huddle together to form a cloud, and gracefully fall down to the ground as rain—all to the background music of "Raindrops Keep Falling on My Head." Some students have opted to write personal water cycle stories, which they read to the class. One student has imagined that she is a drop in the water cycle, and she describes her journey through evaporation, condensation, and precipitation.

In Ms. Nelson's class, all of the students have become engaged in the experience, thought deeply about it, made personal choices, and reflected a high level of understanding about the water cycle. The multiple assessment modes have allowed them to use various talents and means of presentation to express what they know. This is one way to implement what Brooks and Brooks (2001) refer to as "assessment in service to the learner."

You may remember that we explored stations in a "science circus" in Chapter 3 and then again in Chapter 11 when students participated in a "magnet circus." These activities also lend themselves to performance assessment as students respond to tasks at each station to measure their understanding of a concept. In the next story, second graders respond to questions about states of matter on a station-to-station assessment task.

13-8b Second Graders Do a Station Assessment for a Unit on Matter

station assessment
An assessment activity in which workstations are set up around the room to create a genuine context for the students to perform tasks. The students typically use an answer sheet to respond to the questions at each station. Each workstation assesses a different aspect of the science unit.

Setting up workstations around the classroom is an assessment format often called a **station assessment**. The students use an answer sheet to respond to the questions at each assessment station. You must be sure that these workstations create a genuine context for the students to perform a task. Each station must challenge them to create meaning based on their prior knowledge and on the experiences in which they were engaged during their science study.

Consider this station assessment developed by second-grade teachers for a science unit on matter. Their school is in the Northeast, and it has been a snowy winter. The children will visit three stations.

At Station 1 they find a plastic bag of air, a plastic bag of water, and a plastic bag of ice. The children are encouraged to examine these bags but not to open them. The card on the table reads: *Look at the plastic bag of ice cubes, air, and water. In what ways are they the same? In what ways are they different?*

At Station 2 are two identical glasses of water. One is covered, the other uncovered. The card reads: *What do you think will happen to the water in the glass with no cover if we leave it out on a sunny day?*

At Station 3, the students discover sheets of paper for them to take. Each sheet has three boxed pictures on it. The pictures represent different stages of a snowman melting. The card reads: *Take one sheet and cut out the pictures. Paste the pictures in order. What is happening in each picture?*

When the second-grade teachers designed these stations, they knew they also needed an assessment checklist and rubric, so they developed the one shown in Figure 13.2. After using the assessment in their classes, all of the teachers felt it had worked well. For the students, it was an important experience. For the teachers, the tallies of the class's performance led to a useful evaluation of the science lessons. The results of this assessment helped the teachers modify the curriculum and instruction to meet the students' needs.

The following hands-on assessment of the second-grade unit on matter will provide us with a better understanding of what students know and are able to do as a result of their experiences with the matter unit.

1. Stations 1 and 2 invite observation, comparing, classifying, and describing.
2. Station 2 asks students to predict an outcome that they cannot observe at the moment.
3. Station 3 asks students to place events in their proper time sequence and describe the event in each picture.

Scoring Rubric—Matter Assessment

	YES	NO
1. Uses scientific terms such as: *solid, liquid, gas, evaporation*		
2. Accurately describes the water.		
3. Accurately describes the ice.		
4. Accurately describes the air.		
5. Makes reasonable predictions about the glass of water that is uncovered: Water will get warm. Water will disappear.		
6. Correctly sequence events.		
7. Describes pictures accurately.		

The following categories reflect the number of "yes" checks:

Budding scientist	Scientist	Super scientist
2–3	4–6	all 7

FIGURE 13.2 Sample checklist and scoring rubric for a station assessment

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To develop station assessments, you need to do the following:

1. State the goal of the assessment.
2. Describe the format of the assessment tasks, making sure that they match the instructional activities.
3. Develop a scoring rubric for measuring student competence.
4. Evaluate the students' responses to the experience.

13-9 Assessing, Teaching, and Learning

If we engage students in meaningful science experiences that relate to real-world contexts, then we need to assess them with meaningful experiences that relate to real-world contexts. To put it another way, when we allow students to be active participants in their own learning, we should assess their understanding with tasks that actively demonstrate what they know and are able to do—tasks that match the instruction.

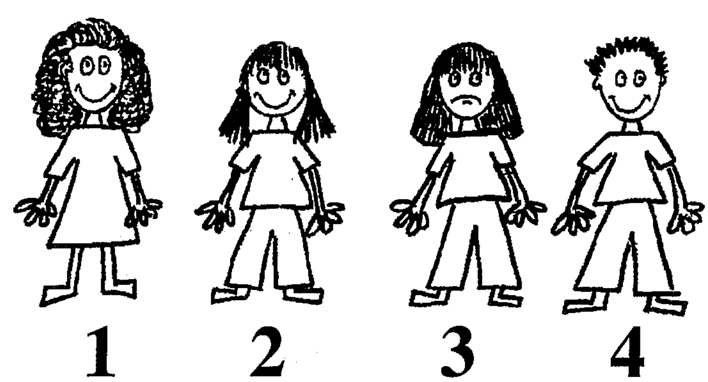
Assessment tasks are authentic when they ask students to apply their science knowledge and reasoning to situations and contexts that are found in the real world. This enhances the real-world context of science instruction. This chapter has advocated extensive and multiple means of performance assessment, including problem solving, creative writing, drawing, drama, technology applications, and other original forms of presentation.

After contemplating all these performance-based assessment measures, you may wonder whether there aren't any traditional paper-and-pencil tests that would be useful. You can indeed use paper-and-pencil tests, with multiple-choice or fill-in questions, to assess your students' familiarity with terminology and their recall of particular bits of science knowledge. Also, paper-and-pencil assessments have been constructed to measure students' science process skills (Smith & Welliver, 1990). In the example shown in Figure 13.3, developed for fourth graders, the test questions were matched to specific science process skills. Looking at the figure, you should be able to identify questions that relate to the skills of observation, inference, comparing, contrasting, and so on. But notice that although each question engages the student in using a process skill, there is no apparent reason to do so. There is no real-world context. Hence, tests of this type may have limited usefulness for teachers who want an active demonstration of their students' understanding.

Since educational data profoundly influence the lives of students, the design of assessments requires careful consideration. The drive to support authentic instruction with authentic assessment is a reaction to the many paper-and-pencil standardized tests that, because they are administered on a very large scale, lack much of the authenticity of performance-based assessments. Often, teachers use these tests as guides for teaching their unit. This "teaching to the test" has been prompted by the high stakes connected to student performance. This does science teaching and the students a disservice. If we authentically teach and authentically assess, then the depth of understanding that develops will be more than sufficient for adequate performance on the standardized tests.

FIGURE 13.3 A paper-and-pencil test that invites students to use process skills

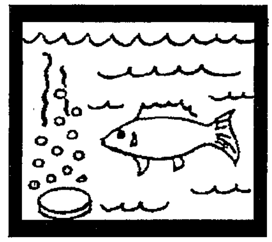
Look carefully at these students.



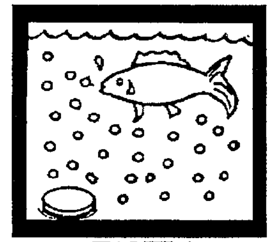
4. Which of the following statements about these students is correct?
   A. Students 1, 2 and 3 all have long hair
   B. Students 2, 3 and 4 all have long pants
   C. Students 1, 2 and 4 are all smiling
   * D. All of the answers A, B and C are correct

5. A. One student has short hair
   B. One student is wearing a dress
   C. One student is not smiling
   * D. All of the answers, A, B and C are correct

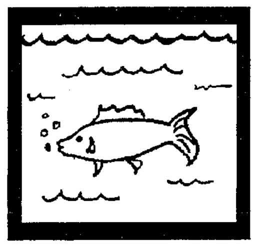
FIGURE 13.3 *(continued)*



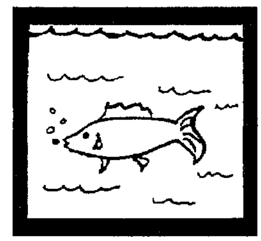
TANK 1
Guppy swimming -- Student drops an alka-seltzer tablet in the tank. The bubbles are carbon dioxide.



TANK 1
After one minute, guppy stopped swimming and had trouble breathing.



TANK 2
Guppy swimming -- Plain water.



TANK 2
Guppy swimming -- Plain water <u>after</u> one minute.

8. Which sentence would best describe what effect alka-seltzer has on a guppy?
   * A. Guppies may not be able to survive long when carbon dioxide is in the water.
   B. Guppies become active when carbon dioxide is in the water.
   C. Guppies show <u>no</u> change in behavior when carbon dioxide is in the water.
   D. All of the answers A, B and C are correct.

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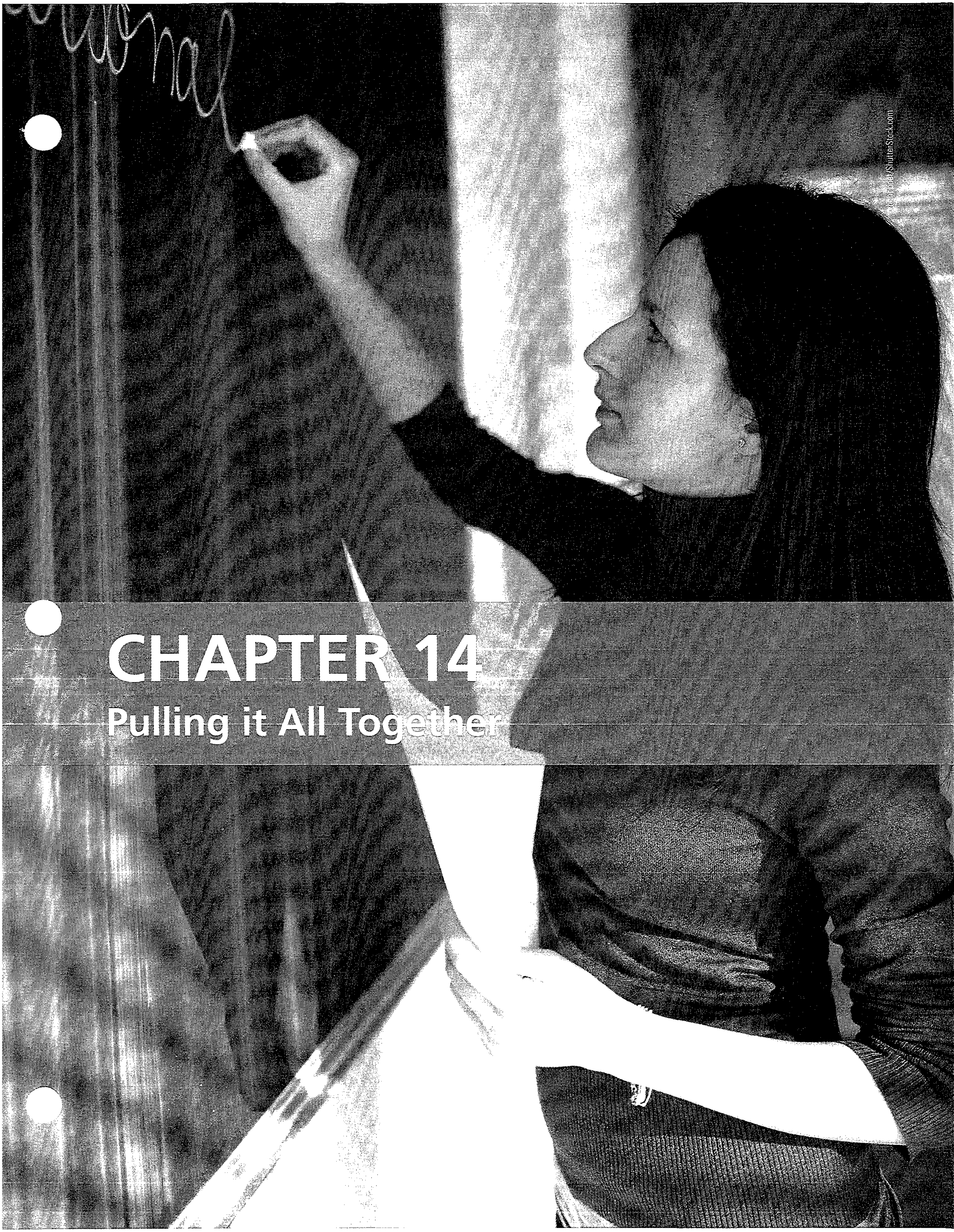
As you have seen throughout this chapter, a good assessment task fits into the science experience and is a good instructional task as well. The students do not feel judged or threatened, and the teacher discovers what they know and understand about a science concept. Understanding what your students know about a topic will then influence your science instruction. Hence, assessment and instruction are interactive.

Remember that your class will probably include diverse groups of students with different learning styles and multiple ways of communicating their ideas. If you vary the types of assessments you employ, you create a more equitable learning environment. The chances are that by using multiple modes of assessment, you will find a match for the mode of expression that each student feels most comfortable with. When you use a single assessment approach, you place students who are not comfortable with that selected way of expressing themselves—or students who have disabilities in a specific mode of communication—at an unfair disadvantage.

Remember that assessment is ongoing. It is embedded in all the work you do with your students. Keep asking yourself questions like these:

- Who are my students?
- How can I learn about what they understand?
- In what ways do they express themselves?

Assessing your students' learning can also lead you toward an assessment of your efforts as a science teacher. The next chapter will discuss how you can reflect on your own teaching as you engage students in science.



CHAPTER 14
Pulling it All Together

LEARNING OBJECTIVES

After reading this chapter, you should be able to:

- 14-1 Assess your own scientific self.
- 14-2 Develop a personal science teaching philosophy.
- 14-3 Examine professional development options.
- 14-4 Engage in self-evaluation.
- 14-5 Continue your science autobiography.

Reflection

To Think About:

- Have you begun to make observations of the natural world in ways that are new to you?
- Have you been exploring scientific websites?
- Have you examined one or more science lessons?
- Have you discovered your scientific self?

We close *Science Stories* where we began—with our own scientific selves. You may wonder why I return so regularly to our scientific selves. It is because we do our best science teaching when we are a *model* to our students of curiosity and excitement about how the natural world works.

14-1 Your Scientific Self

You would like, I'm sure, to show your students what it looks like to wonder, to get messy, to explore nature, to yearn to find out about the natural world, and to be thrilled at the prospect of experimenting. In order to convey these feelings to your students, you need to feel them authentically inside yourself.

My own feelings about science are not static. My descriptions of science and scientific study change as I grow and develop, and I am always adding to my list. I invite you to develop your own descriptions of science as you have opportunities to do science with students. The following list contains statements that are true for me at different times. They change as I change, as I interact with nature and with students.

- Science is a way of exploring nature.
- Science is both a method and a set of ideas.
- Science is a subject in which you expect the unexpected.
- Science is an area of study that can be frustrating.
- Teaching science can help reveal your students' thinking.
- Science is a dynamic area of study, ever changing, always revealing new evidence, and its practitioners are always revising their ideas based on new evidence.
- Science is a joyous activity when shared with students.
- Science is not about knowing but about trying to find out.

Which of these statements do you agree with now? Have your ideas about science changed as you read this book? What descriptions can you add?

A large part of your journey toward becoming a successful science teacher involves locating your scientific self and becoming comfortable with it. Find ways to explore nature and write about it in a science journal; think about the characteristics of exploration; and come up with *your own* ideas and test them. Remember that we use scientific skills in our daily life, so look for experimentation in everyday places. Watch for opportunities to observe, infer, predict, classify, and investigate. Do research and gather evidence, for example, for global climate change. Engage in arguing from evidence. Some adults experiment in the kitchen or the garage or the garden. Ever curious about your environment, take these multiple opportunities to ask yourself:

- Where is "nature"?
- What do I notice?
- What do I wonder about?

Write down your thoughts, and then share them with your students.

When you find your scientific self, you can no longer view science as just a subject taught in school. As you open your eyes to nature, you feel a sense of confidence about exploring the scientific reasons for natural events. Look in your newspaper for items of interest that relate to scientific discovery; share these with your students and encourage them to do the same. Ask yourself: What contemporary scientific issues especially engage me? Are they environmental issues? Or do they relate to health and nutrition? At this writing, I am struck by the shrinking ice sheet on Antarctica. My good friend does research there every year and sends me photographs of the shrinking habitat for the Adélie Penguins that she studies. On my Twitter account, I wrote briefly about how unpredictable the ocean currents and prevailing winds have become since the rise of ocean temperatures across the world. We are, indeed, surrounded by science stories.

Similarly, take time to visit local community resources. Look around for zoos, museums, botanical gardens, science and technology centers, bird sanctuaries, and other informal science learning sites. Watch for dandelions in the cracks in the sidewalk. Being alert to all these opportunities to explore the natural world will help you become a successful science teacher as well as a lifelong science learner.

14-2 Developing a Personal Philosophy

Locating your scientific self takes time, and it often requires that you reflect on nature and the way nature presents itself in your world (Photo 14.1). This reflection is an *active process* involving deliberative thinking, not passive musing. Further, it often leads to additional action to consolidate your understanding. When you reflect on an aspect of nature, you may be impelled to ask questions about it, to learn more about it, and to make sense of it. The bird story early in this book—the entries from my science journal about the birds in the tree behind my house—is an example of how reflection stimulates further learning.

Being an effective teacher similarly requires frequent reflections on your students' thinking and on your own teaching practices. These reflections, too, lead to further action. Reflecting on how your students are responding to a lesson may require you to alter your lesson plan and change the course of subsequent lessons. On a larger scale, being reflective about your teaching practice will prompt you to seek out additional means for professional development, such as workshops and contacts with other teachers.

As you begin your teaching career and engage students in scientific experiences, you will develop your own personal philosophy of teaching. By thinking about what you firmly believe and what you remain unsure about, you can promote your development as a teacher.

iStockphoto.com/ vandervelden

PHOTO 14.1 The teacher explores a natural environment with her students.

One useful technique is to develop a personal philosophy statement. It should contain your thoughts and feelings and indicate their connection to your actions as a teacher. As one such exercise, try completing the following statements (adapted from Kochendorfer, 1994):

- I am the kind of science teacher who thinks that . . .
- When I do science with students, I feel . . .
- The science experiences that I believe are most worthwhile include . . .

If you can complete those sentences, you already have a rough draft of your philosophy statement. But it undoubtedly will change over time. Consider engaging in this sort of reflection during every school year, and keep track of your philosophy statements. You may be amazed at your own growth as a scientist and as a teacher.

14-3 Professional Development

professional development The process by which teachers strive to improve their work as teachers in order to grow in their profession. It is generally based on inquiry into their own teaching practices, active engagement in their own research, and teacher workshops and courses.

Professional development is the process by which teachers strive to improve their work and to grow in their profession. It is education intended to refine your skills, keep you updated on new developments, or engage you in specific projects related to curriculum and its implementation. Your personal professional development is based, most of all, on inquiry into your own teaching—inquiry that leads to research and action. Reflection is part of that inquiry process, but there are numerous additional activities and resources to which you can turn. Many of them involve interactions with your professional colleagues, either within your school or in more extended networks.

14-3a Networking in the Profession

As you teach science, you will have many opportunities to interact with colleagues and join networks of teachers whose personal philosophy about teaching and learning is similar to your own. Local teacher centers and science organizations offer workshops and courses that create such networking opportunities for you.

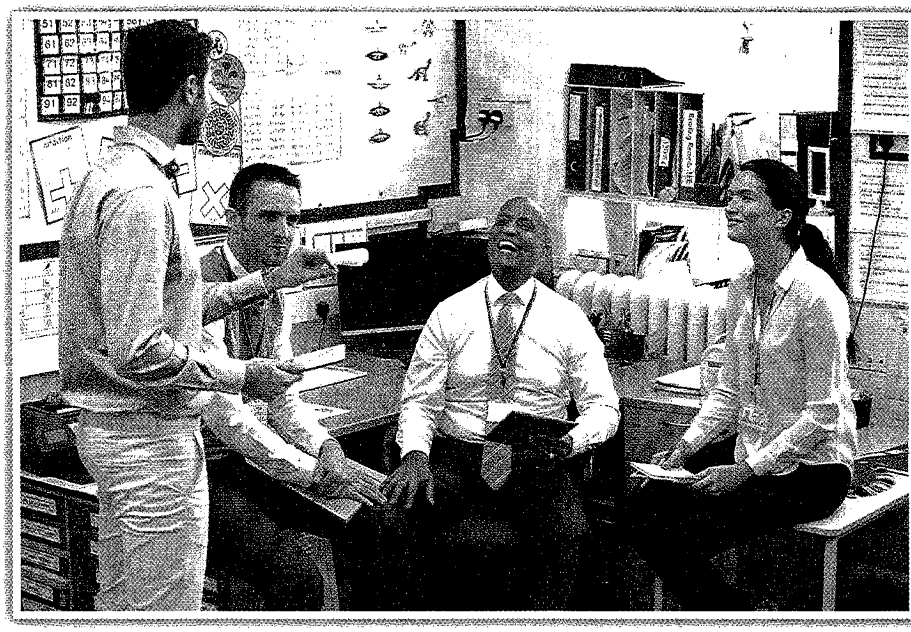


PHOTO 14.2 Meetings and discussions with colleagues play a major role in a teacher's professional development.

Why should you spend time on professional networking? Research tells us that teachers who engage in professional communication with colleagues refine their practice throughout their careers (Darling-Hammond, 1998). (See Photo 14.2.) Networking activities can include experiential learning—for example, working with colleagues on concrete tasks, such as developing a science station assessment. They can also include working with a mentor teacher in your own school, observing an exemplary teacher, and attending teacher discussion groups centered on teaching practice.

Look for such opportunities in your own school and district. Be alert for opportunities to attend science teaching workshops. Inquire whether your school or district will offer funding for you to attend national or regional conferences. Research online courses or workshops that refine your own science teaching and content understanding.

As a first step, you can join your state science teachers' association and the National Science Teachers Association (NSTA). Membership in the NSTA includes a subscription to *Science and Children* or *Science Scope,* which are journals devoted to science teaching.

14-3b Promotion and Certification Requirements

Increasingly, teachers are being required to show evidence of their professional development in order to earn promotions or even to have their teaching certificates renewed. Since requirements vary from state to state, you should explore the criteria in your own locale.

On the national level, certification is being offered by the National Board for Professional Teaching Standards (NBPTS). Established in 1987, the NBPTS is a nonprofit organization governed by a board of directors that includes classroom teachers as well as school board leaders, former governors, and business and community leaders. The mission of the NBPTS is to establish high and rigorous standards for what accomplished teachers should know and be able to do and to operate a national, voluntary system for assessing and certifying teachers who meet these standards. By 2015, there were more than 112,000 National Board–certified teachers (NBPTS, 2015). For elementary and middle school teachers, there are generalist certification standards for teaching students in early childhood (ages 3–8) and middle childhood (ages 7–12). For science teaching in particular, there are certificates for teaching students in early adolescence (ages 11–15) and adolescence through young adulthood (ages 14–18+). Some elementary school teachers become so interested in engaging students in science that they return to school part-time and take more science courses for higher-level certifications.

The five core propositions around which the National Board has organized its standards are the following:

1. Teachers are committed to students and their learning.
2. Teachers know the subjects they teach and how to teach those subjects to students.
3. Teachers are responsible for managing and monitoring student learning.
4. Teachers think systemically about their practice and learn from experience.
5. Teachers are members of learning communities.

Advocates of the National Board believe that offering professional credentials brings prestige to the teaching profession, and they hope that schools and school districts will see NBPTS certification as a valuable teaching qualification. You may want to visit the NBPTS website and explore the requirements for certification. You must have been teaching for a minimum of three years, have had a valid teaching license for all three years, and have completed your baccalaureate degree to be eligible to take the series of assessments that lead to an NBPTS certificate.

14-3c Further Means of Professional Development

Besides networking with colleagues and fulfilling state and local requirements for advancement in the field, there are many other ways that you can promote your own professional development as an elementary or middle school science teacher. Here are some ideas:

- Do research on science topics. If there is a topic that you wish you knew more about, turn to good search engines to research it. Be sure to gain confidence in the science content areas that you will be exploring with your students.
- For exemplary science instructional materials, refer to the curriculum guides listed on the MindTap for this book in addition to other resources mentioned throughout this book. Great Explorations in Math and Science® (GEMS) is a wonderful source of pre-K–8 curriculum materials.
- Trust your own judgment. If you come across a scientific investigation that does not appeal to you, most likely it won't appeal to your students either.
- Keep a science journal for both in-class and outside-of-class science activities.
- Do your own research on what is happening in your classroom. **Action research**, also known as **classroom research** or **teacher research**, involves research projects in which classroom teachers explore some area of their teaching or some aspect of the students' learning. For example, they may study how their students are experiencing a science unit, lesson, or activity. The goal of action research is to improve your own or a colleague's teaching. Sometimes an action research project is a questionnaire you distribute to students to learn what they thought about an investigation or a

action research (also called classroom research or teacher research)
Refers to research projects in which classroom teachers explore some area of their teaching or some aspect of the students' learning with the goal of improving their own or a colleague's teaching.

1. How am I providing opportunities for students to explore nature?
2. Am I allowing ample time for students to complete their investigations?
3. Do the students express their own ideas? Why not?
4. Do I encourage the students to ask questions? How?
5. How am I a coach or facilitator for the science experience?
6. What happens when the students ask questions that we do not have time to explore?
7. How do I use technology for science teaching and learning?
8. How good am I at letting go of my plan if necessary?
9. What assessment techniques am I using?
10. Am I having a good time doing science with my students? What is the best part?

FIGURE 14.1 A checklist for self-evaluation

Professional Resource Download

unit. Sometimes the research design is more extended, depending on what you want to find out. Doing research in your own classroom is not complicated and can reap many rewards.

- Join a science teacher chat room or add regular comments to a blog. Reading other teachers' stories and commenting on them can bring you new ideas as well as a sense of community. The NSTA website can network you to discussion groups.

14-4 How Am I Doing? A Guide to Self-Evaluation

Science teaching, like all other teaching, is a commitment to becoming a lifelong learner. As you reflect on what you have learned and how you teach, the checklist in Figure 14.1 may help you evaluate your professional growth. Revisit the table's questions from time to time.

If you are unsure of your progress in any of the areas listed in Figure 14.1, ask a colleague to make a video as you teach. Videos are often useful as personal guides for developing professionally. Use the checklist to review the video and assess your own progress.

But don't let the checklist—or any other teaching guidelines—intimidate you. Go easy on yourself at first. Be prepared to fumble now and again. You are traveling in what may often be uncharted territory. Do not be discouraged—science takes time.

14-5 Looking Back to Look Ahead: A New Chapter in Your Science Autobiography

Science Stories has been an attempt to have a conversation with you about science teaching and learning—about yourself as a science learner and a science teacher. As one of the goals for the book, I hoped to engage you in the stories of real students and real teachers who were learning science together and separately. To encourage your professional growth, I've also tried to connect you with some of the research that has influenced this way of doing science with students. In Chapter 11, I examined connections to other disciplines and encourage you to seek those connections.

Science teaching needs to encourage, invite, engage, excite, interrogate, and challenge. I also like to say that it should shine like a beacon, signaling that science is truly for everyone. Science teaching can make connections to students' lived experiences and help them to frame their own questions about natural phenomena as a way of making meaning of their world. I always hope that students will take ownership of their own knowledge and gain autonomy as they seek their own answers. But everything I hope for the students I also hope for you, their science teacher.

When you have your own classroom, take a moment after the first hectic months and draw a picture of yourself as you are teaching a "typical" science lesson. Drawing skill is not important—just try to portray what is going on. Place a caption under your drawing and have a look at it. You can interrogate your drawing by asking: What am I doing? What are the students doing? What is my position in the room? How confident do I feel in my science teaching? This exercise will help you continue to develop as a science teacher.

Right now, as a result of your own journey toward science teaching, you may be ready to begin the next chapter of your science autobiography. You may even want to start writing your own science stories. One teacher summarized her feelings about doing science with students in a poem; the first letters of the lines spell out the word *inquiry:*

Investigate and you will find,
New information of some kind,
Question all your observations,
Understand through your explanations,
Integrate what you have discovered,
Reflect and share what you have uncovered.
You are doing science! (Carol Federico, 2002)