1

Constructing an Understanding of Science Inquiry

Through discussion and reflection, students can come to realize that scientific inquiry embodies a set of values. These values include respect for the importance of logical thinking, precision, open-mindedness, objectivity, skepticism, and a requirement for transparent research procedures and honest reporting of findings.

—*A Framework for K–12 Science Education,*
National Research Council, 2012, p. 248

Ask a roomful of science teachers to explain the meaning of inquiry and you will probably get a roomful of different answers. We should not be surprised, because each teacher would answer the question according to his prior knowledge and experience with inquiry-based instruction. The purpose of Chapter 1 is to guide you in assessing your present understanding of inquiry and comparing and contrasting your understanding with the understanding of others in your course or study group or the understanding of your colleagues. You will also compare your awareness of educational standards to statements from various national organizations. This chapter is quite different from others you may have read about inquiry. In an attempt to model constructivist principles, I will not tell you what you should think inquiry is. Rather, you must construct your own meaning by stating your values, beliefs, and attitudes about inquiry and, later, making changes and accommodations on the basis of the readings. To begin constructing a definition of inquiry, you must start with your present understanding.

As an initial exercise, write down your present understanding or definition of inquiry. You may choose to write several statements on 3 × 5 cards (one statement per card), make a bulleted list, or make a concept map or graphic organizer to structure your thoughts. Concept maps are schematic diagrams illustrating the relationships and interconnections of concepts surrounding a particular topic. They are, in a way, cognitive maps that guide our thinking. Research suggests that when teachers and students frequently use concept maps, they learn how to negotiate meaning and organize ideas, see patterns and relationships, and transition from novice to expert learners.

When constructing a concept map, it is important to

1. place the main idea at the center or top of the map,
2. organize the words or concepts from most general to most specific,
3. use a *linking word* (verb, preposition, or short phrase) to connect and illustrate the relationships and linkages from one idea to another,
4. use *crossing links* to make connections between words in different areas of the map, and
5. add to the map as new knowledge is constructed (see Figure 1.1).

Some readers may ask, "Why should I use a concept map?" According to the National Research Council (NRC), experts differ from novices in that experts notice features and patterns of information . . . [and] have acquired a great deal of content knowledge that is organized in ways that reflect deep understanding . . . and their knowledge cannot be reduced to a set of isolated facts or propositions but, instead, reflects contexts of applicability (Bransford, Brown, & Cocking, 2000, p. 31) and "most important, they have efficiently coded and organized this information into well-connected schemas . . . [which] help experts interpret new information and notice features and meaningful patterns of information that might be overlooked by less competent learners" (Pellegrino, Chudowsky, & Glaser, 2001, p. 73). As we gain mastery in using concept maps, we develop an understanding of relationships among elements of a concept, ultimately making incremental gains in moving from novice to expert learners. Furthermore, by constructing concept maps, we enhance a metacognitive approach to learning by negotiating our ideas, taking control of our own learning, and monitoring our progress (Llewellyn, 2007b). As we physically draw the connection between two subtopics, we reinforce that same connection mentally, thus using the map to monitor our progress of understanding through pre-assessments and post-assessments.

Whether you use 3 × 5 cards, bulleted lists, or a concept map, it is important at this time to reflect on your presently held conceptions and cite your understanding in writing that is as explicit as possible. By committing your thoughts to paper, you solidify your ideas and make them available for deliberation at a later time. When your initial thought process is completed, take a few moments and reflect on your statements and definition of inquiry. You may want to add statements or modify them. Save the statements and return to them several times throughout the course of this book. You may even save them to read in a year, or three years from now. Later in this chapter, you will use other statements from the Exploratorium, the NRC, and the National Science Teachers Association (NSTA) to tweak and refine your definition. As you continue through this book, you will use a constructivist approach to assimilate new information about inquiry and make accommodations to your own mental model while constructing a personal meaning for inquiry. Throughout this book, you will be asked to meditate on your statements and definitions for the purpose of assessing your "pre" and "post" understanding and determining how, if any, they are evolving.

If you need a suggested starting point, this simple graphic organizer may help you categorize your thoughts (see Figure 1.2).

Figure 1.1 Concept Map

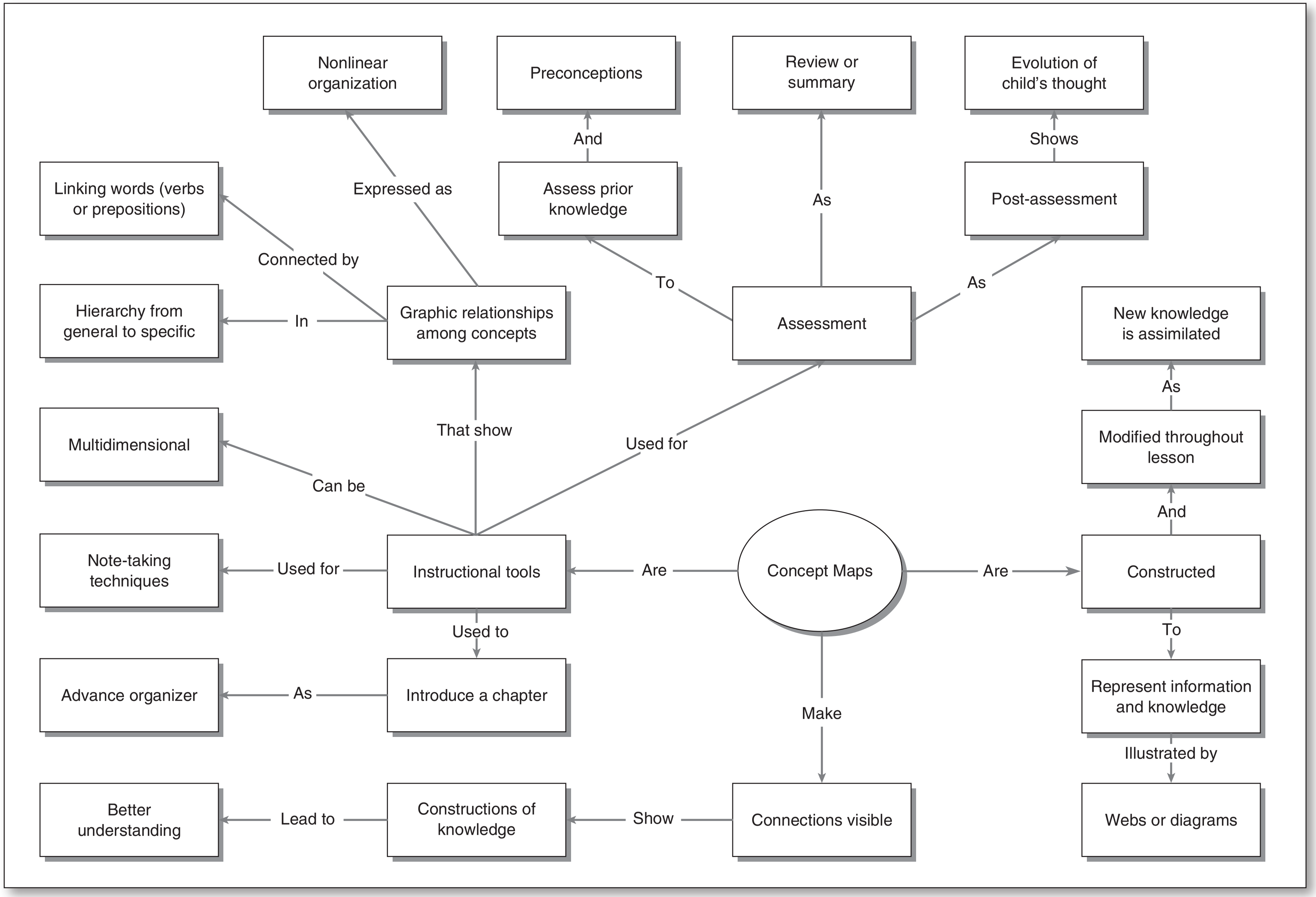
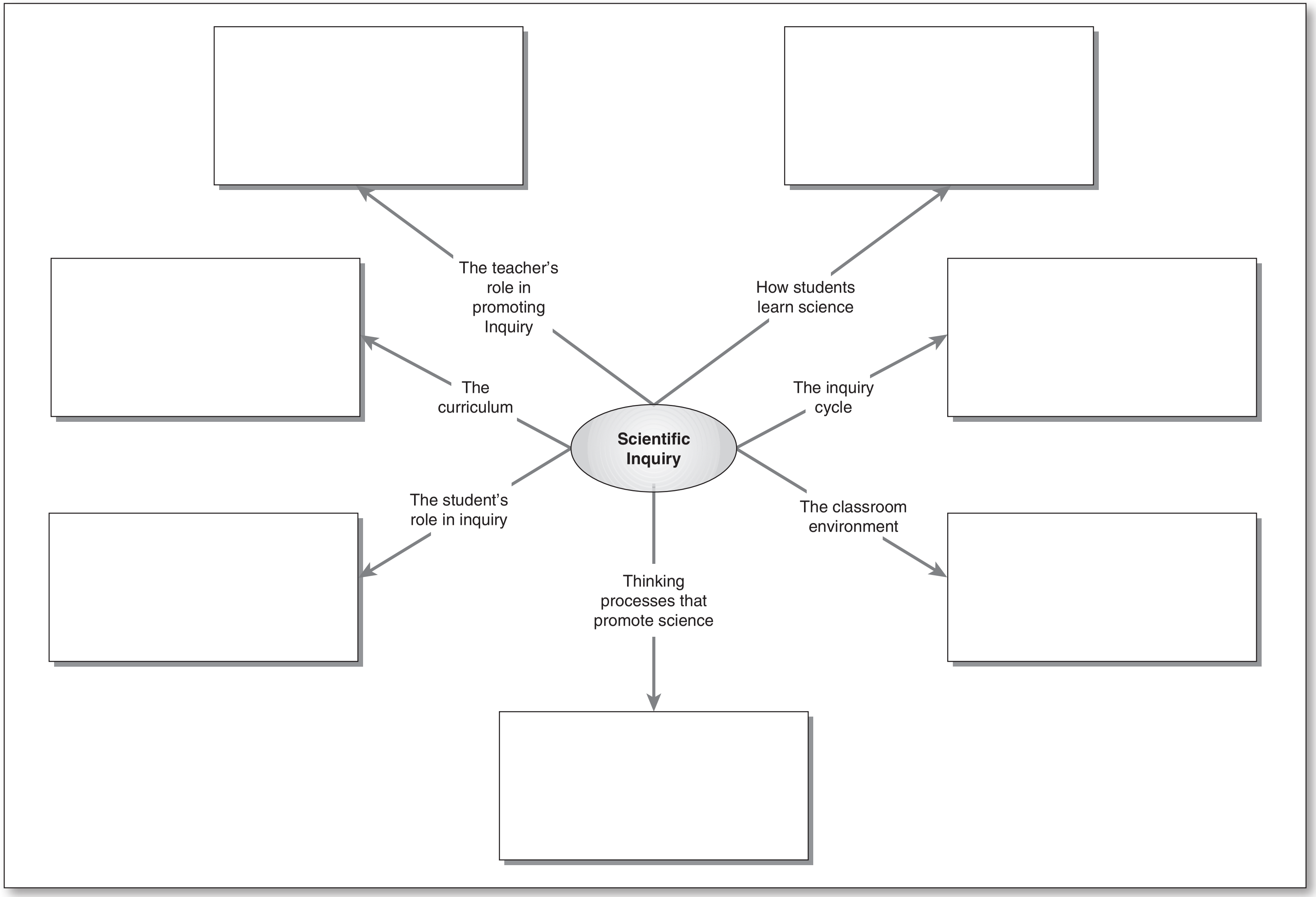


Figure 1.2 Scientific Inquiry



What the Exploratorium Means by Inquiry

The Exploratorium, located in San Francisco, CA, is a premier museum for science and discovery. Through its Institute for Inquiry, the Exploratorium (n.d.) provides several statements regarding the definition of *inquiry*. As you read these statements below, use them to reflect on your own thoughts about inquiry and to enhance your understanding. According to the Exploratorium,[1]

> Inquiry is an approach to learning that involves a process of exploring the natural or material world, and that leads to asking questions, making discoveries, and testing those discoveries in the search for new understanding. Inquiry, as it relates to science education, should mirror as closely as possible the enterprise of doing real science.
>
> The inquiry process is driven by one's own curiosity, wonder, interest, or passion to understand an observation or to solve a problem.
>
> The process begins when the learner notices something that intrigues, surprises, or stimulates a question—something that is new, or something that may not make sense in relationship to the learner's previous experience or current understanding.
>
> The next step is to take action—through continued observing, raising questions, making predictions, testing hypotheses, and creating conceptual models.
>
> The learner must find her or his own pathway through this process. It is rarely a linear progression, but rather more of a back-and-forth, or cyclical, series of events.
>
> As the process unfolds, more observations and questions emerge, providing for deeper interaction with the phenomena—and greater potential for further development of understanding.
>
> Along the way, the inquirer collects and records data, makes representations of results and explanations, and draws upon other resources such as books, videos, and the expertise or insights of others.
>
> Making meaning from the experience requires reflection, conversation, comparison of findings with others, interpretation of data and observations, and the application of new conceptions to other contexts. All of these serve to help the learner construct an improved mental framework of the world.
>
> Effective teachers rely on many different ways of teaching science. At the Institute for Inquiry, the focus is on inquiry learning, a powerful tool in learning science and in keeping wonder and curiosity alive in the classroom.

As you reflect on the Exploratorium's definition of inquiry-based learning, compare it with the statements you wrote earlier. How does the Exploratorium's definition of inquiry compare to your definition? How is it similar to or different from the statements you wrote? For additional information on the Exploratorium and its Institute for Inquiry, visit www.exploratorium.edu/ifi/about/index.html.

What the *National Science Education Standards* Say About Inquiry

In 1996, the NRC released the *National Science Education Standards* (*NSES*), although the *NSES* have been superseded by *A Framework for K–12 Science Education* (NRC, 2012) and the *Next Generation Science Standards* (NRC, 2013). In regard to the inquiry standards, the NRC states,

> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

The NRC (1996) standards highlight the ability to conduct inquiry and develop an understanding about scientific inquiry:

> Students in all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about the relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. (p. 105)

The inquiry standards set forth by the NRC (1996) are divided into three separate grade levels or junctures: K–4, 5–8, and 9–12. Each juncture identifies content standards specific to those grade levels. The standards help science educators identify what students should know and be able to do at particular junctures. You may also be interested in reading the NRC's accompanying text, *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (2000) listed in Resource A and at www.nap.edu/bookstore.

In the content standards for K–4 and 5–8, inquiry is presented as the ability *to do* scientific inquiry as well as the *understanding about* scientific inquiry. According to the standards,

> scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (NRC, 1996, p. 23)

Thus, for practicing scientists and classroom students, the ability *to do* and *understand about* scientific inquiry includes

- asking questions;
- planning and carrying out investigations;
- using equipment and tools to collect, analyze, and interpret data;
- using data and evidence to develop claims, explanations, and models; and
- communicating the procedures of an investigation as well as the findings and their explanation.

What the National Science Teachers Association Says About Inquiry

In 2000, NSTA adopted a position statement on Scientific Inquiry. That statement can be found at www.nsta.org/about/positions/inquiry.aspx. Read over the position statement and return once again to your definition of inquiry. Compare it with the statements from the NRC's 1996 *NSES* and the NSTA. How is your definition of inquiry similar to and different from those of the *NSES* and the position statement? This time, make your additions or changes to your concept map by using different colors. With successive additions and corrections, continue to use a different color. This will allow you to capture, visually and over time, how your understanding about inquiry is evolving.

What *A Framework for K–12 Science Education* and the *Next Generation Science Standards* Say About Inquiry

In 2012, the NRC published *A Framework for K–12 Science Education*. According to the NRC (2012), the *Framework*, whose foundation is based on the previous *NSES*, identifies a general description of the science content and skill development that all U.S. students should be familiar with by the end of Grade 12. The *Framework* also lays the groundwork for the development and publication of the *Next Generation Science Standards* (*NGSS*), released in 2013.

Like the *NSES*, the *Framework* and the *NGSS* identify and articulate the core science ideas around which standards should be developed in life sciences, physical sciences, earth and space sciences, and engineering design. In addition to the core ideas, crosscutting concepts and science practices are identified and sequenced across the K–12 level. Each of these three dimensions of the *Framework/NGSS* introduces the vision of the scope and nature of science education as a crucial aspect in fostering scientifically literate citizens for the 21st century. And as with the *NSES*, inquiry, once again, plays a significant role in the advancement of scientific literacy.

Inquiry and Scientific Practices

In the *Framework* and the *NGSS*, the term *practices* is used to represent the term *inquiry*. However, the practices identified in the *Framework/NGSS* still strongly reflect certain common qualities to problem-solving and inquiry approaches. According to the NRC (2012), the practices in the *Framework* document reflect the performances that scientists and engineers actually engage in as part of their work. The eight essential practices of science include

1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics, information and computer technology, and computational thinking
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information (p. 42)

Each of the eight essential practices is elaborated on in greater depth in the *NGSS*. The *Framework*, however, makes a stronger commitment to the importance of developing claims and supporting evidence as a result of an inquiry investigation. In the *Framework*, scientific argumentation and reasoning play a central role in learning science. These two topics will be addressed in greater detail in Chapter 2, "Integrating Language Arts and Argumentation Into Science." Readers are strongly encouraged to become familiar with the *Framework* and the *NGSS* and their implications for inquiry-based teaching and learning. The *Framework* can be viewed or downloaded free at www.nap.edu/catalog.php?record_id=13165. Additional information about the *Next Generation Science Standards* can be seen at www.nextgenscience.org.

In the years ahead, scientific practices and argumentation will play an ever-increasing role in the United States' goal of achieving scientific literacy. The *NGSS* are poised to advance the next wave of guidelines to focus students in acquiring 21st-century learning skills.

Twelve Beliefs (and Rebuttals) About Inquiry-Based Teaching and Learning

So far, we have been reading what scientific inquiry is. Now, we will address what inquiry is not by exploring several commonly held myths and misconceptions. To introduce the argument process, each misconception is stated as a belief followed by a rebuttal. If your statements or concept map reveal any of the myths and misconceptions described, you can alter them accordingly.

Belief 1: Doing hands-on science is the same as doing scientific inquiry.

Rebuttal: Providing students with an opportunity to do hands-on science does not necessarily mean they are doing inquiry. Many science activities are very structured. They tell the students what question to answer, what materials to use, and how to go about solving the question or problem. In most cases, they even provide charts or tables to record the observations, measurements, or data. This type of "cookbook activity" provides step-by-step procedures and follows a linear path to a solution. Although most inquiry activities are hands-on, not all hands-on activities are inquiry oriented. Others may even suggest that some student inquiries, such as those involving Internet researching, can be minds-on and not hands-on.

Belief 2: Doing scientific inquiry results in students knowing about scientific inquiry.

Rebuttal: An implicit assumption teachers may hold is that if they provide their students with opportunities to do inquiry, students will come to know about inquiry. This idea likely parallels the Nike saying, "Just do it!" Lederman (2006) suggests, however, that "such an expectation is equivalent to assuming that individuals will come to understand . . . photosynthesis by watching a plant grow" (p. 315). Students come to know about scientific inquiry by modeling the process; reflecting on the scientific endeavor itself; and engaging in constructive skepticism, arguments, and negotiation regarding the evidence and explanations provided and the role the findings play within the community of science.

Belief 3: Inquiry is using the scientific method.

Rebuttal: Doing inquiry does not necessarily imply following the steps of the scientific method. Many contemporary science educators will argue that there is no *one* scientific method; in fact, there are many methods to doing science. While Schwartz and Crawford (2006) suggest a multiplicity of scientific methods, others (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) go so far as to say that the scientific method is actually a myth, despite what many science textbooks propose. Inquiry uses a logical approach to solving scientific questions but does not necessarily use the delineated, specific steps of a scientific method. Understanding the overall intention of a scientific method has a role in planning investigations; however, there is more to inquiry than a sequential set of procedures. With the new vision for science reform, as presented by the *Framework* and the *NGSS*, inquiry and scientific practices are a step beyond science process skills such as observing, inferring, predicting, and experimentation. The new vision requires that students combine scientific practices and knowledge as they use scientific argumentation and reasoning to develop their understanding and appreciation of science. Chapter 6 of this book will explain further how teachers use scientific practices and argumentation to plan inquiry- and argument-based investigations.

Belief 4: Inquiry is unstructured and chaotic.

Rebuttal: In some schools, the sign of a good teacher is a classroom that is quiet and under control. Classroom management skills are essential for inquiry learning, but an active, child-centered classroom should not be equated with chaos or unstructured instruction. When students do hands-on and manipulation-based science, we can expect the noise level to rise somewhat. On the surface, inquiry may appear to be open-ended and unstructured; however, as student involvement increases, so does the need for the teacher to manage classroom movement and communication. When teachers use inquiry-based strategies, they may find that teaching requires more preparation and anticipation of possible student questions than do traditional teaching approaches. Some studies suggest that teachers new to inquiry often feel less in control when students move about the room. Although most teachers actually maintain control, they may perceive otherwise. To establish inquiry-centered environments, teachers must accept changes in their role and changes in the culture of the classroom.

Belief 5: Inquiry is asking students a lot of questions.

Rebuttal: A common misconception held by science teachers is that inquiry requires asking a battery of questions. You may have sat in many science classrooms where the teacher fired off question after question. Asking a lot of questions does not necessarily make an inquiry lesson. Chapter 10 presents several examples of effective questioning strategies, such as probing, prompting, and re-directioning, which support inquiry settings. In inquiry-centered classrooms, teachers provide open-ended experiences that lead students to raise their own questions and design investigations to answer them.

Belief 6: If I provide opportunities for my students to do inquiry, they will be learning about inquiry.

Rebuttal: This is a typical belief of many elementary and middle school teachers. Contrary to this popular, yet naïve, conception, no substantial research indicates that when students are actively engaged in scientific inquiry, they are implicitly learning about scientific inquiry and the nature of science. To promote a deep understanding of scientific inquiry and the nature of science, teachers must follow an investigation with explicit "coaching" explanations and scaffolding discussions about the selection of the questions and the procedures used and evaluating and debating the evidence and claims generated from the investigation. Furthermore, teachers need to vary the inquiry landscape by providing natural opportunities for both low-level and high-level interventions. In the vignettes throughout the book, look for instances in which the teacher concludes an exploration or investigation with explicit science language and instruction to enhance students' abilities regarding scientific inquiry. Balancing the "implicit-explicit continuum" (Holliday, 2006) within science inquiry teaching should be a goal of all effective inquiry-based teachers.

Belief 7: Inquiry is fine for elementary school students, but middle school science teachers don't have extra time in their courses.

Rebuttal: For many secondary school science teachers, lecture and discussion methods are the primary means of delivering content instruction to students. These teachers perceive lecturing as the most effective and efficient way to transmit large amounts of science information to their students in a relatively short period of time. Lecturing is the method by which many teachers learned science when they were in high school and college. With this as their prior experience, why should we be surprised that so many science classes are lecture based?

Secondary school science teachers often talk about time constraints. With more and more concepts being added to the curriculum, many middle school science teachers say they are hard-pressed to cover a great number of concepts within the school year. It is true that inquiry-based learning takes more time; however, developing higher-level thinking skills and having students pose questions, plan solutions, and collect and organize data are skills that must be practiced and nurtured over time. There are no shortcuts to developing critical-thinking skills. To create inquiry-based curricula or classrooms, teachers need to use their instructional time effectively while presenting topics and concepts at the core of the curriculum.

Belief 8: You can't assess inquiry-based learning.

Rebuttal: Inquiry-based learning can be assessed like any other concept or topic in science. To assess student progress in inquiry-based learning, teachers need to use alternative methods of evaluation. For inquiry-based learning, popular objective-type multiple-choice questions alone do not provide adequate assessments of student progress. Inquiry-based teachers often rely on student portfolios, student journal entries, student self-assessments, and rubrics in conjunction with objective-type questions to assess students' academic progress. Examples of each of these alternative assessment measures are presented in Chapter 8.

Belief 9: Inquiry is the latest fad for science education.

Rebuttal: Those who have studied the history of science education know that questioning, discovery learning, and inquiry date back to the Greek scholar Socrates. Progressive education reformer John Dewey is credited with being one of the first American educators to stress the importance of discovery learning and inquiry (Dewey, 1900, 1902, 1916). In his early work, Dewey proposed that learning does not start and intelligence is not engaged until the learner is confronted with a problematic situation. Inquiry was also the basis for several elementary school science programs funded by the National Science Foundation in the mid-1960s, based in part on the work of Joseph Schwab (1962). During this "golden age" of science education, programs such as Science—A Process Approach (SAPA), Elementary Science Study (ESS), and Science Curriculum Improvement Study (SCIS) were all based on the philosophy of integrating inquiry teaching and learning with science process skills. At the secondary school level, premier science programs such as the Biological Sciences Curriculum Study (BSCS) are deeply rooted in instructional methods of learning that stress the importance of inquiry-based instruction. Today, nearly every elementary and middle school science textbook or hands-on science program proclaims inquiry as an aspect of the program.

Belief 10: Inquiry is "soft science" and not content related.

Rebuttal: We sometimes hear critics of inquiry-based instruction call inquiry "science lite." Inquiry, according to the NRC, is one of the areas identified as an aspect of science content. That elevates inquiry to the same level as knowing the concepts, principles, and theories of life, earth, or the physical sciences. The *Framework,* as well as the *NGSS,* views the teaching of science as helping students acquire scientific knowledge and core ideas of the natural world, in addition to performing the practices of real scientists and engineers, and understanding the crosscutting themes and concepts that bridge multiple areas of science together. Only through the weaving of these aspects can students develop the scientific habits of mind for becoming scientifically literate citizens and meeting the global competitiveness of the 21st century.

If students are to gain an appreciation for science and compete in a scientific and technical society in this new millennium, they will require a program that promotes active learning, raising questions, and opportunities to solve their questions as well as discourse and reflection. Within the last several years, much has been written about inquiry-based science as an effective means to enhance scientific literacy. Additional research has led to the conclusion that inquiry promotes critical-thinking skills and positive attitudes toward science. Although inquiry is no panacea, it is one more strategy teachers can use, at the appropriate time, to engage students in investigations and satisfy their curiosity for learning.

Belief 11: Inquiry is for high-achieving students and not for students with special needs or learning disabilities.

Rebuttal: The recommendations set forth by the NRC apply to all students regardless of age, cultural or ethnic heritage, gender, physical or academic ability, interest, or aspirations. The *Framework* stresses that the recommendations apply in particular to those who historically have been underrepresented in the fields of science—mainly students of color, female students, limited English proficiency students, and persons with disabilities. According to the *NSES,* "Given this diversity of student needs, experiences and backgrounds, and the goal that all students will achieve a common set of standards, schools must support high-quality, diverse, and varied opportunities to learn science" (NRC, 1996, p. 221). The ability to think creatively and critically is not solely for the high-achieving student. Inquiry-based instruction can and should be taught equitably at all levels.

Belief 12: Doing school-based science inquiry is the same as authentic scientific inquiry as practiced by career scientists.

Rebuttal: Although teachers often tell students during their science investigations they are "acting and thinking like scientists," in reality, given the obvious limitations in time, materials, and the curriculum, classroom or school-based inquiries are quite different from authentic inquiries practiced in the scientific community. On the one hand, the apparent differences include the level of knowledge, sophistication, and complexity of scientific reasoning one brings to the activity. Although we encourage students to think like a scientist, use the scientific practices scientists use, and foster critical thinking skills, we need to understand classroom constraints. For that reason, all the scientific investigations in this book fall under the category of school-based science inquiry. On the other hand, through the practice of argumentation, students can model the way real scientists practice real science. Painting a realistic picture of formulating a question, designing and carrying out investigations, analyzing data, making and defending claims based on supporting evidence, and communicating the findings and explanations of the investigation truly model the work of real scientists. And for many teachers, that's the authentic goal of teaching science.

Inquiry as a Thinking Skill

Learning through inquiry empowers students with the skills and knowledge to become independent, lifelong learners. Finding solutions to their own questions also allows students to gain an appreciation for scientific knowledge and the discovery process. Through inquiry, students are easily able to assimilate and anchor their prior experiences and knowledge with newly formed experiences and knowledge.

In the next section, you will read how fifth-grade students use their thinking skills to make and negotiate meaning through the process of inquiry, demonstrating that constructive inquiry starts with the formulation of a self-directed question. This is a major departure from traditional and teacher-led lessons, where students expect the teacher to provide the question and the procedure for the investigation. With inquiry, students are given the opportunity to meet problems head-on and generate questions and solutions on their own. If we want our students to become critical thinkers, we must provide opportunities for them to think on their own.

"Inquiring With Fruit"

Now that we have expanded our understanding of inquiry, let's consider a group of fifth-grade students exploring the properties of fruit, raising questions, testing their ideas, and discovering new concepts in density. The objective of this lesson is to allow students to explore the properties of fruit and raise questions to investigate. In this session, students are given the task of predicting whether a particular group of fruits will float or sink when placed in a two-gallon tub of water. (The names of the teacher and students are fictitious.)

"Inquiring With Fruit" aligns with the *NGSS* (NRC, 2013) for Grade 5:

Practices

- Asking questions
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Constructing explanations
- Obtaining, evaluating, and communicating information

Crosscutting Concepts

- Scale, proportion, and quantity

Core Ideas

- 5-PS1-1 Make observations and measurements to identify materials based on their properties.

As the lesson begins, Mr. Roberts assesses the students' prior knowledge and preconceptions about fruits that float and sink. He poses the question, "What would happen if I placed this apple in the tub of water?" The unanimous response is that the apple will float. As Mr. Roberts lowers the apple into the tub, the students' prediction proves correct. "Now," he says, "what would happen if I cut the apple in half and placed it back into the tub?" He goes on to say, "Take time to predict whether you think the apple will float, sink, or maintain a position halfway down the tub." Mr. Roberts encourages them to record a prediction and to provide the reasoning for the prediction. He then takes time for students to share their predictions in small groups and discuss the reasoning for their answers. Mr. Roberts circulates from one group to another listening to their conversations and noting any misconceptions that arise. After a while, Mr. Roberts says, "Let's test our half apple." He lowers the apple into the tub and the students observe that the half apple still floats.

After the demonstration, Mr. Roberts says, "It's time to move on to less familiar fruits." Each student has an opportunity to observe (using all five senses) a lemon, a kiwi, a grape, a banana, an orange, and a mango and make predictions about whether each one will float or sink when placed in a tub of water. After the students assign each fruit with either an "F" (for *float*) or an "S" (for *sink*) marked on their worksheets, they *pair and share*, exchanging their fruit predictions. During this part of the activity, Mr. Roberts encourages students to provide explanations of their thinking to support their individual predictions. Students then rearrange their desks in groups to discuss their different predictions. After 10 minutes, the groups are told to produce a group consensus for each fruit. Each group is then asked to record its predictions, test each fruit, and record the results.

As the students test each prediction, they record their data by constructing a table with two columns, *floaters* and *sinkers* (see Figure 1.3).

At this point, Mr. Roberts encourages the students to go beyond the initial exploration and raise their own "What if" and "I wonder" questions. In one group, Kayla asks, "Does the outer peel of a fruit affect whether it will float or sink?" She leads her group through a brainstorming session to determine ways to test whether a peeled banana versus an

Figure 1.3 Floaters and Sinkers

Inquiring With Fruit Results

Floaters	Sinkers

unpeeled banana will float or sink. They decide to place one peeled and one unpeeled banana in the tub and compare the results. They soon observe that both bananas float and conclude that the peel makes no difference.

As Kayla observes the floating banana with the ends pointed downward in the water, she calls Mr. Roberts over to her table and asks, "Why is the banana floating upside down?" (see Figure 1.4).

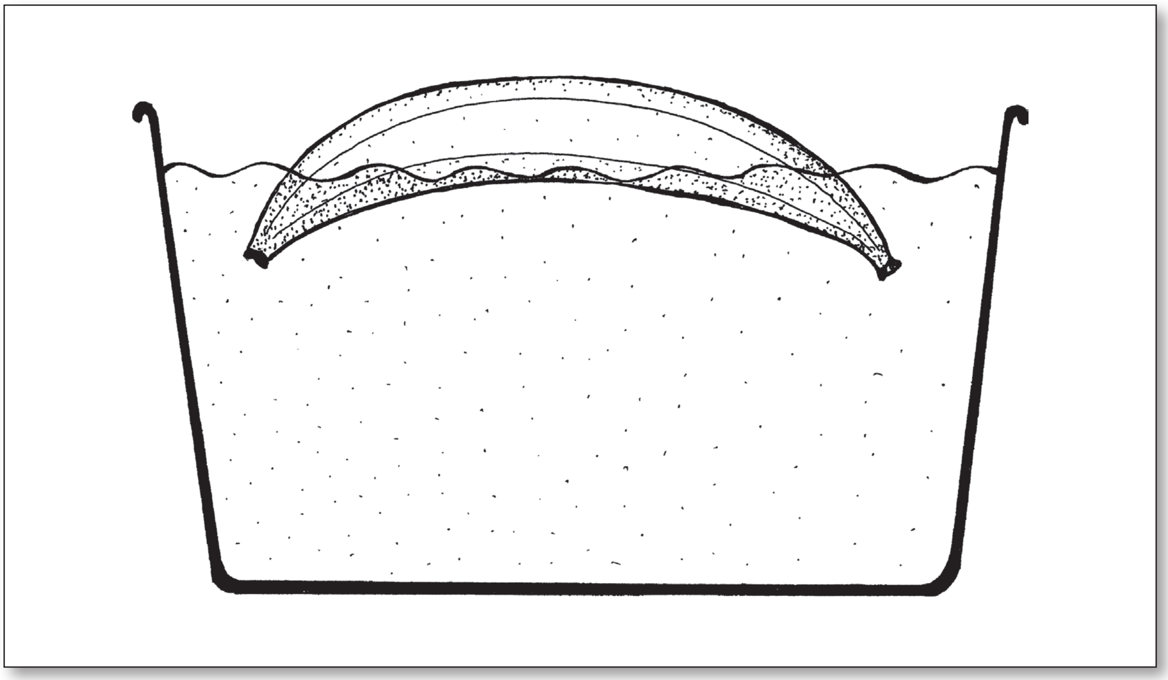
Mr. Roberts probes her thinking to determine the root of the question. Kayla admits that she thought the banana would float with the ends upright, like a "banana boat" (see Figure 1.5). Mr. Roberts quickly realizes that she was using her prior understanding about bananas and boats to predict that the ends of the banana would float upright, like a boat!

Kayla's group proceeds to discuss floating and sinking in relation to the term *density.* They all know that objects less dense than water float and objects denser than water sink. Mr. Roberts suggests that they apply the principle to the floating banana. There is still confusion, however, about why the banana doesn't float like a boat. Frank, another member of the group, poses the question to the teacher, "What would happen if we cut the banana in half?" Rather than answering the question, Mr. Roberts assumes that the group can answer the question without his help, so he responds, "How could you find out?" Frank shares his thoughts about the floating banana and suggests a procedure to test his question.

As the group decides on a plan of action, Frank pulls the banana from the tub and cuts it in half. Just before Frank is about to place the two halves back in the water, Mr. Roberts says, "Wait! What do you think will happen to each half of the banana?" Debbie predicts that each half will float with the pointed end downward. Then Rob asks her to support her prediction. Debbie responds by saying that the ends probably will act the same as they did when the banana was whole. Figure 1.6 shows how the two halves look after they're placed in the water.

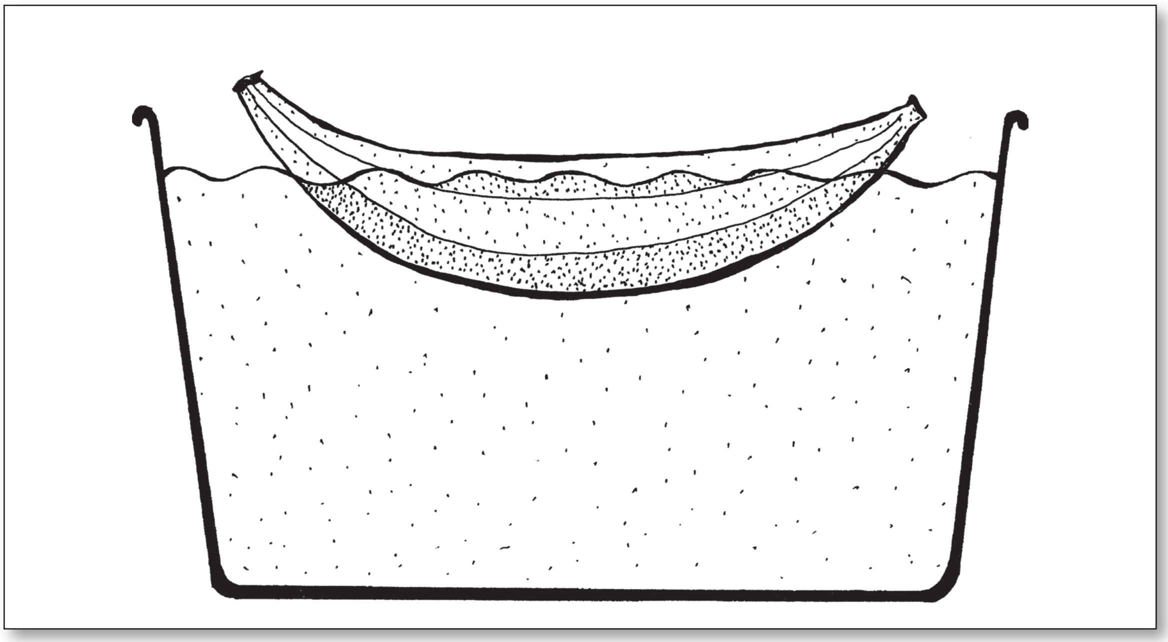
The observation spurs "Wows" and more "What if" questions. Sara asks, "What if we cut each of the halves in half again?" Frank then cuts each banana in half again and, just before lowering the banana quarters into the water, he jokingly asks the other group

Figure 1.4 Banana Floating With Pointed Ends Down



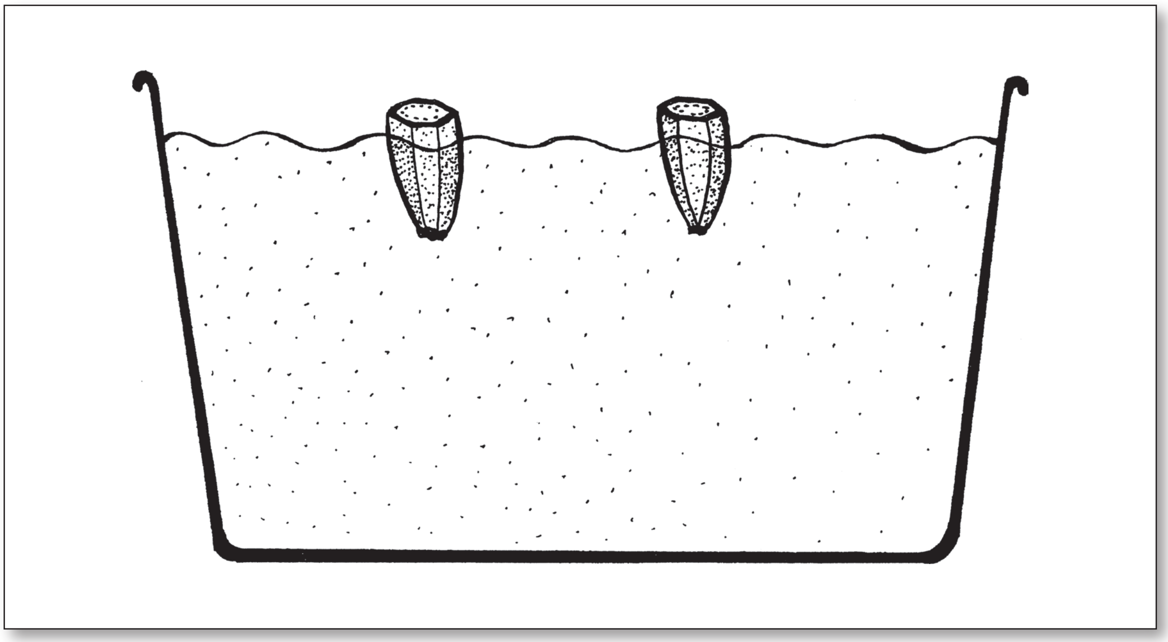
Source: Created by Alan Lacey.

Figure 1.5 Banana Floating With Pointed Ends Up



Source: Created by Alan Lacey.

Figure 1.6 Two Halves of a Banana Floating



Source: Created by Alan Lacey.

members, “What is going to happen when I drop these pieces into the water?” Their inquiry leads to more observations (see Figure 1.7).

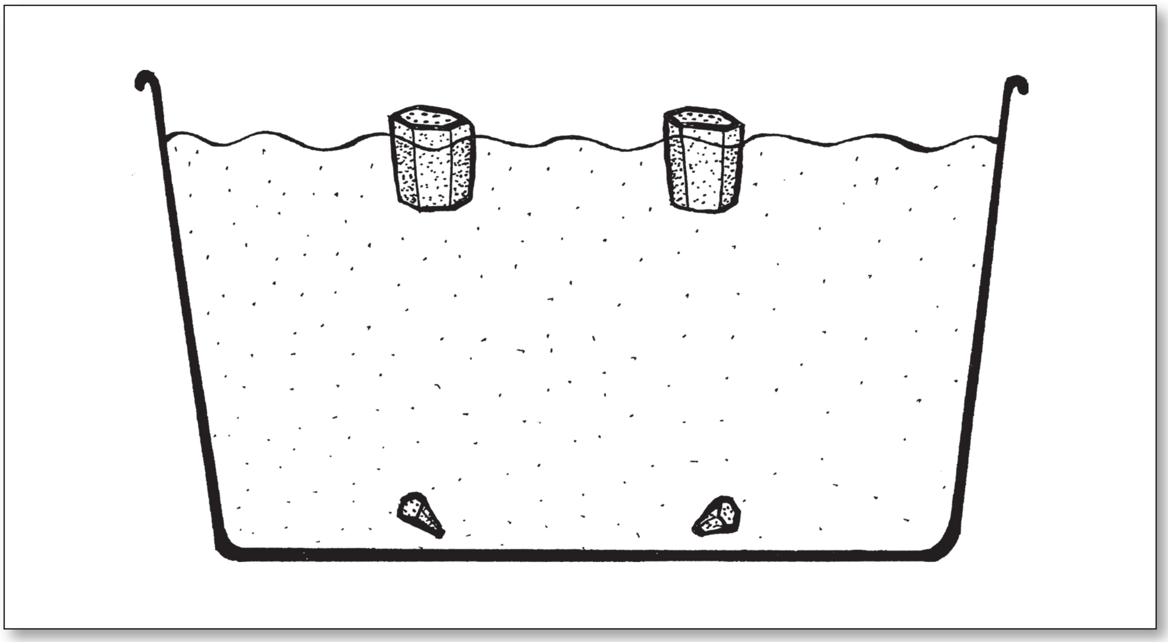
Seeing the ends of the banana at the bottom of the tub and the two middle quarters floating on top leads Sara to conclude that the evidence leads to the claim that the banana must be denser at the ends and less dense in the middle. She then draws an illustration to support her claim (see Figure 1.8).

Having their evidence fit their newly developed model, the group members are confident that they understand why the banana floated “upside down.” Mr. Roberts suggests that they add to their explanation by looking up the formula for density and actually measuring the mass and volume of the banana pieces to confirm their model mathematically. Excited with their new findings, Kayla, Frank, Debbie, Rob, and Sara search their textbooks for a way to calculate density.

The following day, Mr. Roberts reviews the investigation skills the group used as part of their inquiries. He also spends time clarifying their understanding about scientific inquiry and the newly acquired content regarding density. Mr. Roberts knows he needs to provide closure to this investigation by explicitly discussing and reflecting with his students on the procedures they developed. He suggests they consider alternative claims and explanations based on the evidence collected and how different groups in the class might have made different conclusions from the same investigations.

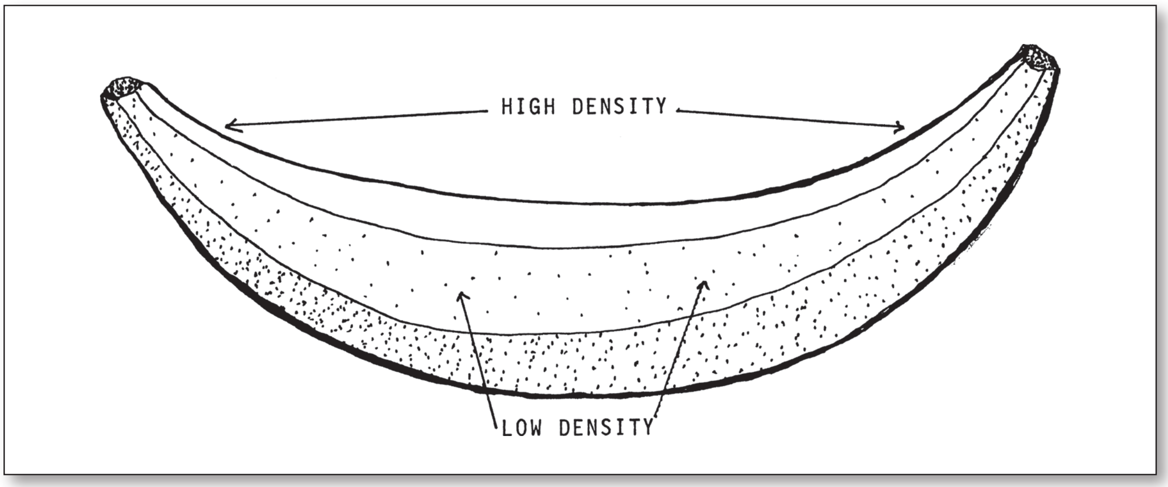
Not surprisingly, his students have more inquiries to explore. Kayla wants to know if fresh bananas float differently than overripe ones. Frank suggests they test larger bananas versus smaller ones. Debbie and Sara want to test bananas versus plantains, and Rob intends to find out how a banana would float if he placed it in saltwater as compared with fresh water. Although their questions will keep them busy for several days, it’s time for Mr. Roberts to provide a discussion on density.

Figure 1.7 Banana Pieces Floating and Sinking



Source: Created by Alan Lacey.

Figure 1.8 Model of Banana Density



Source: Created by Alan Lacey.

Although, according to the *NGSS*, density is not within the assessment boundary, Mr. Roberts offers an enrichment activity during which students are provided with the mass and volume of several fruits and use the data to calculate the density of each fruit and sequence the fruits from the least to the most dense. The second part of the activity involves a critical thinking question as students are given the following problem: "Suppose you have a bar of candy. If you cut the bar of candy in half, what will happen to the candy's density? Will it increase, decrease, or remain the same? Provide a justification for your answer."

The Inquiry Cycle

"Inquiring With Fruit" is just one example of an exploration that encourages students to raise questions and think critically. Although different kinds of questions require different kinds of investigations, in analyzing the group's work, the *inquiry cycle* shown in Figure 1.9 represents aspects of many scientific investigations:

1. *Inquisition*—stating a "What if" or "I wonder" question to be investigated
2. *Acquisition*—brainstorming possible procedures
3. *Supposition*—identifying an "I think" statement to test
4. *Implementation*—designing and carrying out a plan
5. *Summation*—collecting evidence and formulating claims and explanations
6. *Argumentation*—communicating claims, evidence, and explanations to others

During the inquisition phase, students usually initiate their inquiry by posing a question. It is often stated as a "What if" question and can originate from observing an open-ended exploration, a discrepant event, a demonstration, or a teacher-directed activity. Teachers often plan explorations that end with an observation that is counterintuitive to students' normal experience. The event seeds disequilibrium in the students' minds and causes them to ask "Why?" Educators often call this a *teachable moment*, when a student raises a question and opens his mind to imagination. In the "Inquiring With Fruit" investigation, the inquisition phase is initiated by the predicting activity.

During the acquisition phase, students rely on their prior experience to brainstorm possible solutions to the inquiry. Here, students ask, "What do I already know about this situation that could help answer the question?" In the acquisition phase of the fruit activity, Kayla's prior conceptions about bananas and floating affect how she perceives the outcome of the group's question.

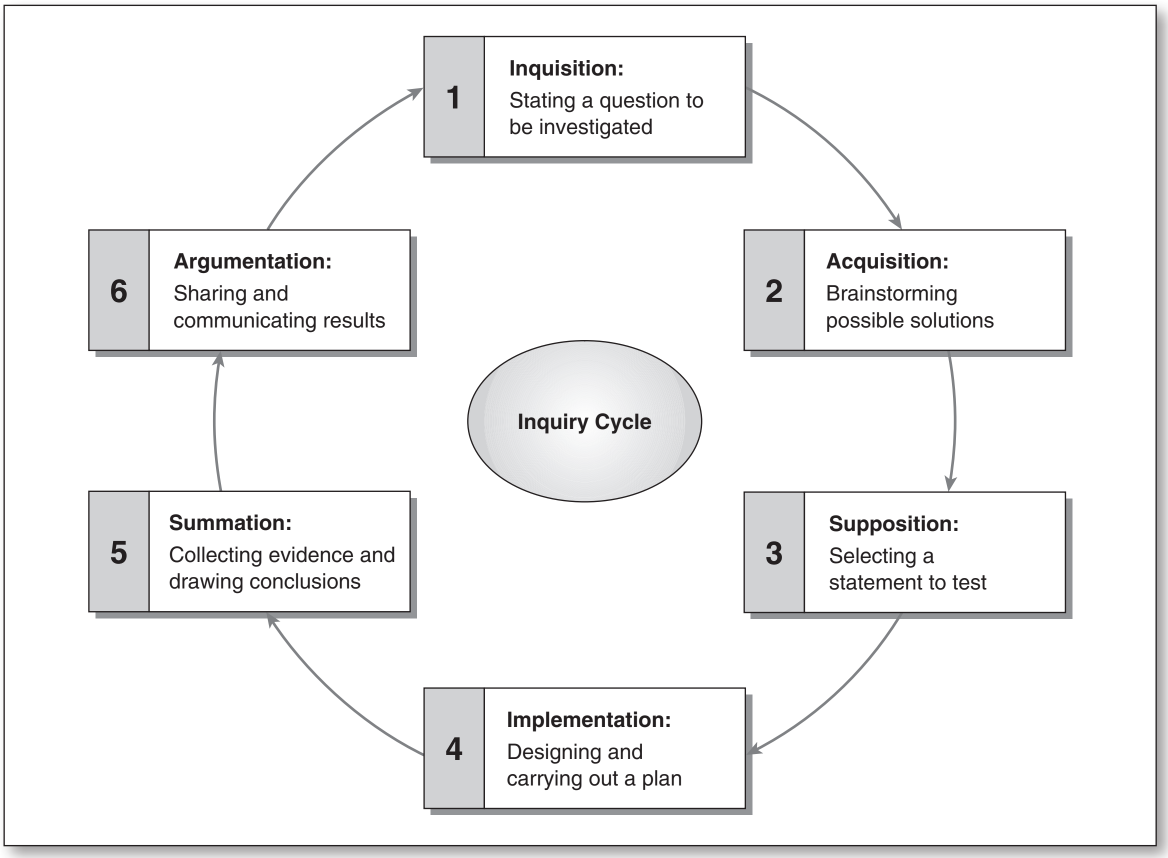
During the supposition phase, students consolidate the information under study to propose an "I think" statement. This phase generally includes a design of the plan to answer the question under investigation. During the fruit activity, Frank provides leadership to the group in identifying possible statements to test.

During the implementation phase, students design a plan to investigate the phenomenon in question and carry out the plan.

During the summation phase, students record and analyze their observations to use them to address the original "What if" question. Mr. Roberts also encourages further investigations by suggesting that the group confirm its results by calculating the density of each banana piece. During the summation phase, students are often led to other discrepancies and "What if" questions, returning the group to the inquisition phase.

During the argumentation phase, students communicate their evidence and claims in the form of an oral or PowerPoint presentation, a poster or trifold display, or a written report. In the fruit activity lesson, the group is eager to share their findings and conclusions about density.

Figure 1.9 The Inquiry Cycle



The inquiry cycle can serve as a general format for teachers planning inquiry-based investigations for their students. The model serves as an approach to raising and answering questions. Following the inquiry cycle, students often enter and reenter the phases at different aspects of their inquiry process. Thus the cycle serves as a model to guide students through their investigations rather than a linear, sequential, step-by-step procedure.

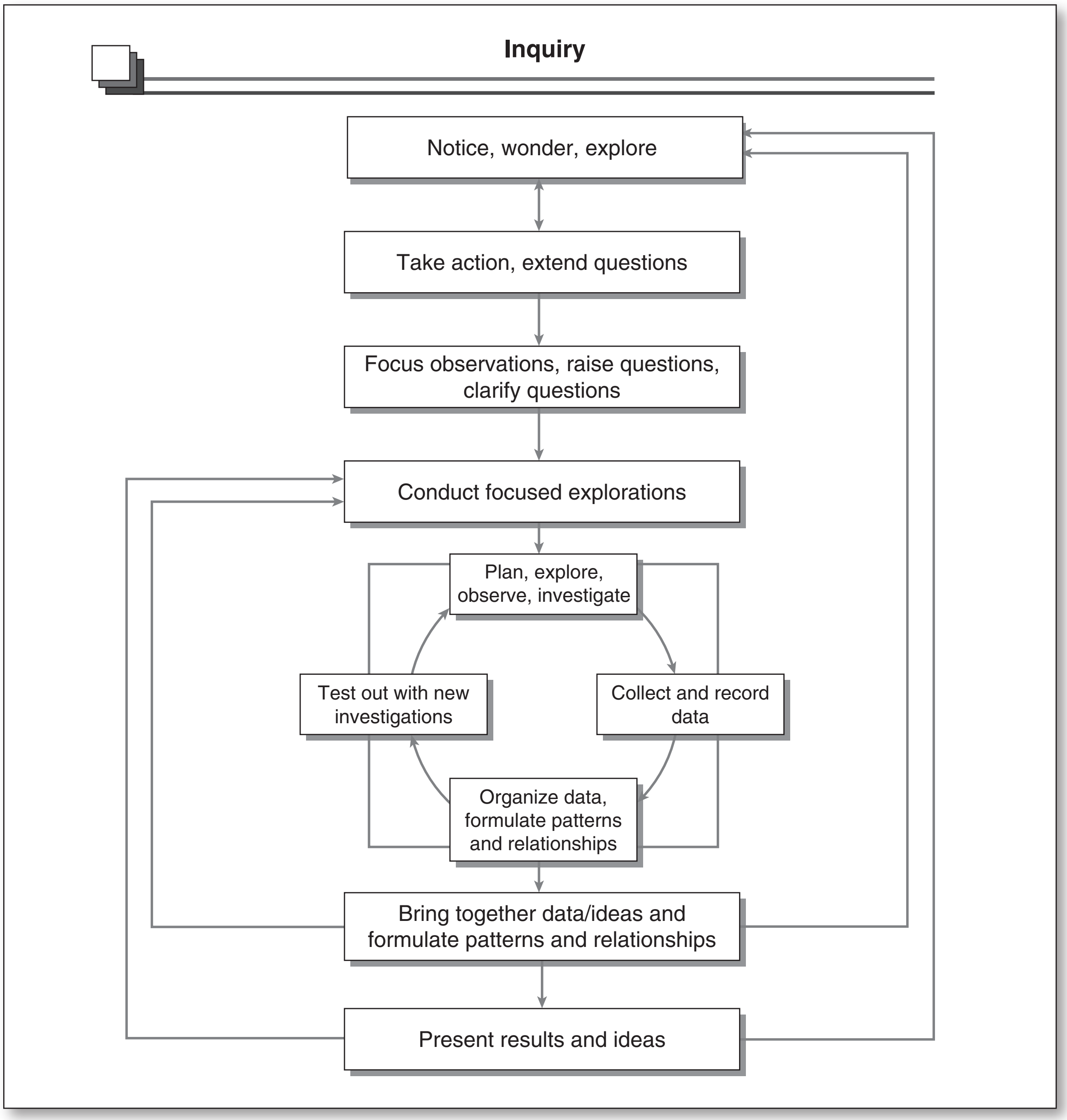
Similarly, Hubert Dyasi and Karen Worth (n.d.) describe the process through which knowledge about the natural world is developed. Figure 1.10 shows the dynamic and cyclical nature of scientific inquiry.

A Definition of Inquiry

From the previous readings, we see that inquiry has a three-prong meaning. According to Flick and Lederman (2006),

> inquiry stands for a fundamental principle of how modern science is conducted. Inquiry refers to a variety of processes and ways of thinking that support the development of new knowledge in science. In addition to the *doing* of science, inquiry also refers to knowledge *about* the processes scientists use to develop knowledge that is the *nature of science itself*. Thus, inquiry is viewed as two different student outcomes, the ability to *do* scientific processes and the knowledge *about* the processes. (p. ix, emphasis in original)

Figure 1.10 The Scientific Inquiry Cycle



Source: Dyasi and Worth (n.d.), www.exploratorium.edu/ifi/resources/worth.html

The third prong of its meaning has to do with teachers using an inquiry approach as a means of teaching students science content and the methods and processes scientists use. Flick and Lederman (2006) go on to say that "the logic here is that students will best learn science if they learn using a reasonable facsimile of the processes scientists follow" (p. x). Thus, for effective inquiry instruction, science teachers need to balance both the understanding *about* scientific inquiry and the abilities in *doing* scientific inquiry.

Inquiry involves the science, art, and spirit of curiosity. It can be further explained as the scientific process of active exploration by which we use critical, logical, and creative thinking skills to raise and engage in questions of personal interest. Driven by our curiosity and wonder about observed phenomena, doing inquiry investigations usually involves eight essential aspects:

1. Generating a science-related question or problem to be solved, one that physically, mentally, and personally engages the student
2. Brainstorming possible solutions
3. Formulating a statement to investigate
4. Designing an action plan and carrying out the procedures of the investigation
5. Gathering and recording evidence and data through observation and instrumentation
6. Drawing appropriate claims and explanations from the evidence collected
7. Connecting the explanation to previously held knowledge
8. Communicating the conclusions, claims, and explanations through argumentation

As we communicate and share our explanations, inquiry assists in (a) connecting our prior understanding to new experiences, (b) modifying and accommodating our previously held beliefs and conceptual models, (c) providing opportunities for an argument-based discourse, and (d) constructing new knowledge. In constructing newly formed knowledge, students generally are cycled back into the processes and pathways of inquiry with new questions and discrepancies to investigate.

Finally, learning through inquiry empowers students with the knowledge, skills, and attitudes to become independent thinkers. In many ways, it is a preparation for lifelong learning, fostering curiosity and creativity. Teachers can encourage students to use communication, manipulation, and problem-solving skills to increase their awareness and interest in science, setting them on the path to becoming scientifically literate citizens. For science teachers, the inquiry approach requires a different mind-set and expectations. At first, inquiry can be both seductive and intimidating to the novice teacher. As teachers come to understand the role they play in facilitating an inquiry-based classroom, the transition from a teacher-centered to a learner-centered classroom becomes promising. For this reason, rather than just providing a compendium of inquiry activities, this book principally emphasizes understanding the philosophical ideology and role-changing process considered necessary for inquiry instruction.

Inquiry and Scientific Literacy

Having defined inquiry, we now are ready to move on to scientific literacy and the nature of science. A scientifically literate individual, Flick and Lederman (2006) suggest, embraces the foundations of scientific inquiry and the nature of science. When we think of a literate person, we picture one educated with specific knowledge and skills and having certain dispositions in a particular subject matter. It is the intention, therefore, to provide some discussion regarding the relationship among these ideas.

Most of us would agree that a scientifically literate person possesses several qualities: (1) the understanding of practices, crosscutting concepts and themes, and the core ideas that govern science; (2) the application of these understandings for sound decision making and addressing personal and global challenges; (3) the capacity to think logically and methodically; (4) the skill to ask questions and find answers to questions derived from interest in everyday experiences; and (5) the ability to explain natural phenomena in a clear and concise manner. In addition, most of us would agree that achieving science literacy means achieving for *all* students, not different standards or different instructional programs for particular groups of students. In a democratic society, we should seek attainment for all equally and without exception. Given this goal, the challenges facing teachers today put a tremendous burden on them, especially when considering the amount of subject content being pushed into the schools' curricula and loaded into high-stakes standardized testing throughout America's schools. Just looking at the number of pages in a typical middle school science textbook today causes us to think about how much content is demanded of today's students. It is not unusual to find a middle school science textbook with 400 to 500 pages.

Despite these demands, science educators need to look no further than the morning newspaper to read about the new technological advances and potential hazards we encounter each day: acid rain, global warming, environmental pollution, cloning, new semiconductors, new viruses, new galaxies, new fuels, and new practically everything else. The rational decision-making process about these growing issues and technologies will necessitate a scientifically literate population.

James Trefil provides us with a broadened scope of the issue. According to Trefil (2003),

> a person is scientifically literate if he or she can deal with scientific matters that come across the horizon of public life with the same ease as an educated person would exhibit in dealing with matters political, legal, or economic. In a society that is becoming increasingly driven by science and technology, a society in which the citizenry is increasingly called upon to deal with issues that contain a large scientific or technical component, this kind of literacy isn't a luxury—it's a necessity. (p. 151)

Several proponents of science literacy (DeBoer, 2000; Shamos, 1995; Sutman, 2001) suggest that achieving a citizenry that is scientifically literate will be difficult, if not impossible, unless educators at the elementary and secondary school levels become clear themselves about the meaning of literacy for their particular field and practice the reform efforts proclaimed by the *Framework* and the *NGSS*. So what needs to happen in our schools? At the K–12 level, teachers need to hone their understanding of what it means to be scientifically literate, read books and articles on the subject, and have in-depth discussions about its impact in today's classrooms. Curriculum coordinators need to emphasize an inquiry-based approach for all students throughout all levels of a district's learning outcomes. Science supervisors need to provide teachers with effective and ongoing professional development that advances the *Framework*, science literacy, and inquiry-based learning. School administrators need to hire teachers familiar with the *NGSS*, with the competencies to teach through inquiry-based and problem-solving modes, and with the ability to create learner-centered classrooms. It is only through a multifaceted approach that school districts will achieve literacy in science for their students.

Inquiry and the Nature of Science

Understanding how science works is vital to understanding how scientific inquiry works. The nature of science, according to McComas (2004), "is the sum total of the 'rules of the game' leading to knowledge production and the evaluation of truth claims in the natural sciences" (p. 25). McClough and Olsen (2004) add, "Understanding how science works is crucial to scientific literacy because bound up in the content and public decisions involving science are issues regarding what science is, how knowledge comes to be accepted, and what science can and cannot do" (p. 28). Similarly, Lederman (2006) says, "The phrase 'nature of science' typically refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge" (p. 303). He adds that several aspects of nature of science are viewed as important to include in science curriculum and instruction:

- Science knowledge is tentative and subject to change,
- Science knowledge is empirically based and in part derived from observations of the natural world,
- Science knowledge is human enterprise, subjective, and based on individual or group interpretations, and
- Science knowledge may be interpreted through several possible explanations for a particular phenomenon.

Scientific inquiry is often confused with the nature of science (Lederman & Lederman, 2004), although the concepts overlap and share many similar principles. Both rely on empirical evidence to formulate and justify conclusions. Like inquiry, the nature of science involves interpreting data and evidence; however, two researchers (or students) can derive conflicting results from the same set of data. For a further explanation, read the NSTA's position statement on the *Nature of Science* at www.nsta.org/about/positions/natureofscience.aspx.

It is important that teachers encourage habits of mind that complement scientific inquiry and the nature of science. These habits include attitudes and behaviors in a creative and humanistic endeavor: commitment, curiosity, diligence, fairness, imagination, innovation, integrity, persistence, and patience, as well as skepticism—all attributes we want children to demonstrate as they investigate their natural world.

As previously mentioned, inquiry and the nature of science have a subjective element (McComas, 2004). As with the construction of knowledge, science itself is tentative at best. Ideas and theories are constantly evolving based on newly discovered evidence. Every day, new species of organisms are being found in remote corners of the world, new remedies and drugs are being formulated to control diseases once thought to be uncontrollable, and new discoveries in space test our understanding of the cosmos. From an understanding of science as a human activity, scientific inquiry and the nature of science both provide avenues to bringing historical relevance to our lessons. Through discussions of the biographies of scientists in class, history tells the story of discoveries and dispels the stereotypic notion of what a scientist looks like or that scientists work alone in isolated laboratories. Adding the human aspect to our lessons also provides opportunities to explain the contributions made by people representing historically underrepresented groups in science: women, African Americans, Hispanics, and physically disabled scientists—perhaps inspiring a new and diverse generation of scientists.

Inquiry and Naturalistic Intelligence

Theories on learning and human intelligence have been around throughout the twentieth century and continue to develop. With recent research on brain functioning and cognitive development, new theories on intelligence have emerged. This section of the chapter will focus on Howard Gardner and his work with Project Zero at Harvard University and explain how inquiry is associated with naturalistic intelligence.

In 1983, Gardner published his landmark book, *Frames of Mind*, and proposed that human intellect was far more involved than what can be measured by a single test determining intelligence. Utilizing research from cognitive development, psychology, and sociology, Gardner proposed that questions from an IQ (intelligence quotient) test too narrowly define intelligence. According to Gardner, IQ is reliable in predicting mental reasoning but does not take into account other abilities and talents that individuals possess. In *Frames of Mind*, Gardner proposes that humans can demonstrate multiple intelligences (MI), other than linguistic forms, and he suggested that human intellect is not fixed throughout one's lifetime. He put forward seven types of intelligence, each with its own distinctiveness. Gardner's theory of multiple intelligences discusses various types of intelligence:

Verbal/linguistic

Logical/mathematical

Visual/spatial

Bodily/kinesthetic

Musical

Interpersonal

Intrapersonal

People with *verbal/linguistic* intelligence are skilled with the spoken and written word. Although everyone has some degree of verbal/linguistic intelligence, Gardner believes that certain individuals demonstrate an ability to understand and manipulate words and language with greater ease. These people enjoy all forms of verbal and written communication: reading, writing, and speaking. Students with verbal/linguistic intelligence like to keep journals, read and write stories for pleasure, do crossword and jumble puzzles, talk aloud as they think, and recite poetry. Students with high verbal/linguistic skills often do well on the verbal portion of the SAT and other standardized tests. They seek careers in communications and become authors, journalists, teachers, and attorneys.

Those with *logical/mathematical* intelligence do well collecting, organizing, and interpreting data. They are also good at seeing numerical relationships, sequences (such as playing Sudoku), and patterns among discrete variables. *Logical/mathematical* individuals think both inductively and deductively. They use strategic logic in solving abstract math problems and games. Students with logical/mathematical intelligence are good in math and science and pursue careers in engineering, applied technology, statistics, computer programming, and the sciences. Students with high logical/mathematical skills often do well on the mathematical portion of the SAT and other standardized tests.

Visual/spatial intelligence involves the ability to construct concrete and mental models. People with visual/spatial intelligence are especially good at reading and interpreting maps, drawing, playing chess, and solving maze puzzles. Students with visual/spatial intelligence prefer to have lectures supplemented with PowerPoint slides, graphs, charts, illustrations, computer graphics, concept maps, and graphic organizers. Students caught doodling in class are often masquerading their visual/spatial intelligence. Individuals with high visual/spatial intelligence usually go on to careers in architecture, planning, and design.

People can also express their intelligence using *bodily/kinesthetic* channels. Students with bodily/kinesthetic intelligence are gifted with natural fine- and large-motor coordination skills and are very physical and tactile. They like observing and examining objects through physical and haptic sensations such as touching, feeling, and hands-on manipulation. Teachers often plan hands-on science activities to complement students' bodily/kinesthetic urges. Because this type of intelligence often is played out as squirming, wiggling, or acting out, teachers often mistake these behaviors as problems rather than habits to express one's physical needs. People with bodily/kinesthetic intelligence go on to become athletes, dancers, and performers.

Many of us are very familiar with *musical* intelligence, possessed by people with talents to carry a pitch or song, create and interpret rhythm, compose music, and write lyrics. Understanding sound, timing, and voice are aspects of someone with musical abilities. Students with high musical intelligence play in the school band or orchestra, sing in the choir at school or church, and perform in musicals. Many teachers often allow students with creative, musical intelligence to demonstrate their understanding about an academic concept by performing a song or rap.

Interpersonal intelligence involves interacting and communicating with others. People with interpersonal intelligence demonstrate an ability to read the moods and emotions of people around them. They excel when participating in group processes and cooperative learning situations, and they display compassion and empathy for the feelings of family members and friends. Descriptions such as *sensitive* and *sentimental* apply to individuals with interpersonal intelligence. These people often seek careers in counseling and social work. By providing opportunities for students to work in cooperative learning groups during science class, teachers promote and encourage interpersonal intelligence.

When one understands one's own emotions, motivations, strengths, and weaknesses, one demonstrates *intrapersonal* intelligence. People with intrapersonal intelligence seek opportunities to reflect on their thoughts and feelings. Students with intrapersonal intelligence like to connect new knowledge with preexisting knowledge. Teachers promote intrapersonal intelligence by having students write in journals and use self-assessment strategies. Children with high intrapersonal intelligence like to use their private time in such activities as taking solitary walks or building forts and tree houses, and they prefer secretive play places for reading or listening to music. They take extra time to contemplate actions and decisions that affect them personally, directly or indirectly.

In *Frames of Mind*, Gardner explains that each of us has one or more dominant intelligences that profile our human intellect, but he points out that all humans have varying degrees of all seven intelligences. He goes on to propose that each intelligence occupies a distinct and separate area of the brain and that injury to the brain can result in impairment to the intelligence associated with that affected section.

Gardner's theory, although not originally formulated for instructional use, has had a dominant place in education. Teachers who embrace his ideas apply multiple intelligence theory to classroom settings by designing lessons and assessments in which students can demonstrate competence through a variety of intelligences. To integrate inquiry-based instruction and multiple intelligences in the science classroom, consider setting up seven stations or learning centers for a particular unit of study, with each station emphasizing the need to use a different intelligence to complete the task. Other projects in this unit of study may involve students working in cooperative groups (interpersonal), doing hands-on activities (bodily/kinesthetic), writing in science journals (verbal/linguistic), classifying objects (logical/mathematical), completing remedial or enrichment excursions at their own pace (intrapersonal), listening to songs (musical), or creating a concrete model of the phenomenon observed (visual/spatial).

In 1999, Howard Gardner followed up his 1983 *Frames of Mind* with *Intelligence Reframed*. In this publication, Gardner added *naturalistic intelligence* to the original list of seven intelligences. People with naturalistic intelligence are gifted with the ability to see patterns and distinctions in the natural world. These individuals keenly recognize relationships among the flora and fauna in a community and focus on existing phenomena that others disregard. Naturalistic intelligence fosters caring and sensitivity to the environment.

Although little has been written on the connection between scientific inquiry and naturalistic intelligence, a natural link seems to exist. In inquiry, students can enhance their naturalistic intelligence through observing and recognizing patterns from the environment and surroundings. Thus inquiry becomes an ideal vehicle for students to explore their natural world, heightening the senses that allow them to discern similarities and differences in organisms. This exploration may lead to carefully observing and recording the behaviors of various species of plants and animals. In *Inquiry at the Window: Pursuing the Wonders of Learning,* Phyllis and David Whitin (1997) provide an excellent reading for a yearlong inquiry of primary-level students observing birds drawn to a bird feeder outside a classroom window. The authors weave a brilliant story wherein the teacher encourages students' naturalistic intelligences to observe patterns in nature and to record the various species and their frequent visits to the feeder while undergoing a school-year science project—in other words, learning to appreciate the world of nature. In *Taking Inquiry Outdoors* (Bourne, 2000), classroom teachers reflect on coming to understand science through reading, writing, and outdoor inquiry—the perfect blend of verbal/linguistic, bodily/ kinesthetic, visual/special, and naturalistic intelligences.

Teachers of environmental science can easily integrate scientific inquiry with naturalistic intelligence. Consider designing an ecology unit appropriate for your grade level and the district's content standards, a unit in which students have the opportunity to use their sensory skills to observe nature. In that unit, students may create collections of woodland organisms and make drawings of the specimens in their science logs or journals. Some students may be interested in making a scrapbook of their collection. Others may use the science references and field guides to identify the common and scientific names for the organisms.

One More Look at Defining Scientific Inquiry

In subsequent chapters, we will see examples of scientific inquiry as a process of active exploration by which we use critical, logical, and creative thinking skills to raise and engage in questions of personal interest. It is the dynamic collaboration between the individual investigator and the question being investigated. Driven by students' curiosity and wonder about observed phenomena, inquiry investigations usually involve

- generating a question or problem to be solved,
- brainstorming possible solutions to the problem,
- stating single or multiple hypotheses to test,
- choosing a course of action and carrying out the procedures of the investigation,
- gathering and recording the data through observation and instrumentation to draw appropriate conclusions, and
- communicating and justifying their claims and evidence through scientific argumentation.

As students communicate and defend their explanations, inquiry helps them connect their prior understandings to new experiences, modify and accommodate their previously held beliefs and conceptual models, negotiate meaning (Hand, Norton-Meier, Staker, & Bintz, 2009), and construct new knowledge. In constructing newly formed knowledge, students generally are cycled back into the processes and pathways of inquiry with new questions and discrepancies to investigate.

Throughout this book, you will read about students exhibiting the five essential features of scientific inquiry:

- Learners are engaged by scientifically oriented questions.
- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
- Learners formulate explanations from evidence to address scientifically oriented questions.
- Learners evaluate their experiences in the light of alternative explanations, particularly those reflecting scientific understanding.
- Learners communicate and justify their proposed explanations. (NRC, 2000, p. 29)

Finally, learning through inquiry and argumentation empowers students with the knowledge, skills, and dispositions to become independent thinkers and lifelong learners. The process encourages students to use communication, manipulation, and problem-solving skills to increase their awareness of and interest in science and guide them on their way to high school and eventually becoming scientifically literate citizens.

An inquiry approach requires a different teacher mind-set and classroom culture for creating a learner-centered environment. In Chapters 3 and 4, you will read more about becoming an inquiry-based science teacher and how a constructivist mind-set parallels inquiry-based teaching and learning.

Questions for Reflection and Discussion

At the end of a chapter in many professional development books, the author provides questions for further discussion. Contrary to this and to model good inquiry, the questions should come from you. So whether you are reading this book alone, collaborating in a small study group, or participating in a college course or summer institute, write three questions you presently have about inquiry. The questions may be about the challenges you face in implementing science inquiry in your school or a reaction to a section you read in Chapter 1. This exercise is designed to evoke thoughts, opinions, viewpoints, and, most of all, personal feelings about what you are reading. After you write your three questions, share them with others also reading this book. Set a few moments aside, maybe over coffee or pizza, to answer each question. Your questions, responses, and reflections will become beneficial as you progress on your journey.

Three Questions I Have

1.

2.

3.

Figure 1.11 T-Chart: What Science Inquiry Is and What Science Inquiry Isn't

T-Chart

What Science Inquiry Is	What Science Inquiry Isn't

If you cannot think of any questions to pose or do not have any questions this early in the book, you can start a journal to record your reflections over the next few months. Begin by writing your definition of *inquiry*. Prepare a written narrative, a set of bullet points, or even a concept map to capture your present understandings of science inquiry. Compare your understandings to the sections you previously read from the national organizations. Consider writing about how you think inquiry promotes scientific literacy and the kinds of knowledge, skills, and attitudes your students will need to succeed beyond their elementary and middle schools years.

As a supplement or alternative to the journal-writing exercise, consider the following questions and discuss your responses to a colleague.

1. Leon Lederman, renowned scientist and Nobel laureate, has said, "Scientific literacy may likely determine whether or not democratic society will survive into the 21st century." What do you think he meant by this?
2. What role do science literacy and inquiry-based instruction play in making our country and its citizens globally competitive?
3. Chapter 1 outlines 12 beliefs or misconceptions about inquiry-based teaching and learning. Can you think of other misconceptions teachers may have about scientific inquiry?

Lastly, here's an activity to try. It's called "What Science Inquiry Is and What Science Inquiry Isn't." Working with a partner or in a small group, place a poster-sized sheet of paper on a wall. Using a marker, make a T-chart such as the one shown in Figure 1.11. Label the left-hand column "What Inquiry Is" and the right hand column "What Inquiry Isn't." (For larger groups, you may want to use two separate poster sheets.)

Give each participant a pad of medium-sized adhesive notes. Tell each of the participants to write a statement on a sticky note that describes what inquiry is or isn't. Then place that sticky note on the appropriate column of the T-chart. After 10 minutes, the poster sheets should be filled with sticky notes. Next, read all the sticky notes aloud—one at a time. Take off any duplicate statements. Have a discussion about the statements. Were there any statements you would not agree with? Did the activity expose any misconceptions about inquiry? Compare the groups' postings with the statements about inquiry from the Exploratorium, the *NSES*, NSTA, the *Framework,* and the *NGSS* that you read earlier in this chapter.

Note

1. Excerpts from Exploratorium, Inquiry Descriptions. Reproduced with permission. © Exploratorium®, www.exploratorium.edu/ifi/about/philosophy.html