FOCUS ON INQUIRY

GUIDING INQUIRY

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From Books to Bears

When I began teaching, I was placed in a first-grade classroom. My materials included a set of small “science books.” We “read” from the science book once or twice a week. Because the reading level matched the reader, there was really no content, but after all, these were just first graders.

Sometime that next summer I went to a workshop about bears. When I began my unit in the fall, we were singing songs, reading poems, and doing worksheets and art projects all about bears. I distinctly remember a particular art project using a brown paper bag from a grocery store. We tore the edges instead of cutting them because “bears are mammals and have hair, boys and girls.” Those bears were so cute!
Introducing Inquiry
Later in my experience of teaching science to first graders, I realized that it would be a good idea for the children to do real observations of things we were studying. So during my spider unit I borrowed a tarantula from a friend who taught middle school and had a classroom full of creatures. I made sure I placed our visitor in a central part of the classroom so we could walk past it several times a day. We learned how to draw spiders anatomically correctly (two body parts, eight legs coming out of the head), that they ate bugs, and that they all made silk, which they used in different ways. To wrap up this unit, I dressed each child in black and positioned him or her for a photo on the climbing wall at P.E. Boy, this would make a great keepsake picture for their families! We returned to the classroom to eat insect gummies and drink juice with our spider fangs. I was sure I had helped the children achieve the ultimate science experience.

Inquiry Models
Last summer, I attended a weeklong teacher training that focused on using an inquiry model to teach science. My initial hesitation was based on my misconception that inquiry-based instruction was equivalent to a “free-for-all” in the classroom: the teacher attempting to direct each student on his or her independent learning quest, each child choosing his or her own area of learning interest. I was relieved to discover that inquiry can be ignited by common content and guided by questions posed by the teacher. I learned the value of student journaling to record and reflect on learning.

As we began our studies on environmental science, the children examined soils and I saw comments in their journals comparing the different samples. They wrote about their soil’s ability to pass through various sifters and funnels. They discussed the composition of their soil and made assumptions about its origin, “This reminds me of the beach,” “How did this one get so dirty?” In one of my lessons I gave the children materials including a soil sample, water, and a filter. They were instructed to design an experiment to see how much water their different samples could hold. On the first day Suzanna said that her soil seemed weak. When I asked her to explain, she said that it was not able to hold much water. The following day she said her next sample was stronger. I asked her how she knew and she said that not as much water was leaking onto the filter. This kind of discovery by a 6-year-old scientist was amazing to me. I knew the children were really solving problems and thinking about the world around them. Each day many asked me as soon as they saw me if we got to have science that day.

I know that I still have work to do when I hear Gregory say that the girl next to him has more pudding than he does. I take a deep breath and calmly say (again), “Gregory, remember, good scientists save their imaginations for the playground. The things they do in their labs are real. Tell me what you notice about your soil.” I am continually interacting with the children and pushing their thoughts. I do believe that as a teacher I have really begun to understand how to help children achieve the ultimate science experience.

As you infer from her Guiding Inquiry Focus on Inquiry vignette, Kelly’s first-grade children are actively engaged in science. Her class is really excited about exploring soil. The children seek to find explanations to the challenges presented by their teacher. This is the essence of inquiry. Inquiry represents the varied ways in which students develop their scientific process skills and their understanding of scientific ideas. Inquiry experiences help develop positive attitudes toward science, scientists, and how the world is studied from a scientific perspective.

As you read her Guiding Inquiry, do you notice how Kelly changed her teaching over time from the beginning of her career to her account of this year’s teaching? More important, what changes do you think are occurring with the nature of the children’s learning in her classroom? Do you visualize children passively memorizing facts? Are her students actively exploring and applying scientific concepts? Do you see less concern over the teacher’s instruction
based on a predetermined collection of discrete information to be taught—like a step-by-step recipe? Conversely, is your mind’s eye view of Kelly’s class a vision of students actively engaged in inquiry-based learning?

Web Discussion
Teacher Change

Kelly talks about how her teaching changed through the years in her Guiding Inquiry Focus on Inquiry. Google the National Academies Press site and then search for the book Inquiry and the National Science Education Standards (National Research Council [NRC], 2000a). Read the section on “Understanding the Change Process” in Chapter 8. What factors may have made it difficult for Kelly to change her teaching? What kinds of support may have been required?

As you explore this chapter, look back on the vignette and see if you can recognize aspects of Kelly’s teaching that you can adopt in your own classroom. Take the time to reread the vignette and identify her approach to teaching. For example, do you notice how she first thinks about the broad learning goals that she wants to accomplish? Can you detect her way of indicating that the children have learned or otherwise show that they have met the learning goals?

Consider how Kelly plans ways to engage the children in a series of activities that build on what they know and promote further curiosity into the unknown. In this chapter, we will be introducing a 5E model for inquiry teaching and learning. By this point, you may be asking yourself, “Why the overwhelming focus on inquiry?” In this chapter, we will answer that question and confer about the prevalence of inquiry—from the research scientist’s laboratory to a first-grade teacher who is just starting to think about this approach to teaching and learning.

A national focus on inquiry

Can you describe the inquiry method of teaching in your own words? Is your current idea of inquiry different from what you may remember from your own classroom experiences? Let us provide some background to how inquiry methods have evolved. In 1996, the National Research Council released the National Science Education Standards (NSES). In the NSES opening Call to Action, the president of the National Academies of Sciences states that “[a]chieving scientific literacy will take time because the Standards call for dramatic changes throughout school systems.” The NSES authors go on to say that this change is “a new way of teaching and learning about science that reflects how science itself is done, emphasizing inquiry as a way of achieving knowledge and understanding about the world” (p. ix).

The vision of the thousands of scientists, professors, teachers, and leaders who developed and promoted the NSES is to have K–12 science teaching and learning match the diverse process for discovery used by scientists. They see children observing phenomena; developing personal questions, predictions, or hypotheses to explore; gathering relevant information to see what has already been discovered; using various tools to collect, organize, analyze, and interpret data; proposing answers to the initial hypothesis; and finally, communicating the results.

A lot has been accomplished since the NSES were released, but the vision is not yet fully realized. Some aspects of how scientists operate may match the science taught when you were in a K–12 classroom, or how you taught during your practicum experiences. However, the full
Elementary school science activities are sometimes an open time to explore or play with a natural object or piece of equipment. Unfortunately, this type of activity may lack other critical aspects of the process such as communication of the hypothesis or question to explore and the subsequent identification, testing, confirmation, and communication of results.

Likewise, some middle and high school teachers offer activities, but they involve predetermined and explicit directives. In these situations, children repeat step-by-step instructions where someone else’s answer is already formed. They are expected to arrive at the same conclusion. In this case, there is not a pre-activity or post-activity discussion. Children do not make their own predictions or communicate their personal results other than the standardized lab report. Most important, there is not any teacher follow-up. Instructors do not identify individual misconceptions, erroneous ways of thinking, or conceptual misunderstandings.

What grade were you in when the National Science Education Standards were released in 1996? Think about what has happened in U.S. classrooms since that time. In your opinion, is the vision being realized? What about your own understanding and use of inquiry? Let’s explore our conceptions as we reconsider our opening vignette set in Gainesville, Florida, in relation to the national focus on inquiry.

WEB DISCUSSION
NSTA Position Statement on the National Science Education Standards

Google the National Science Teachers Association Position Statement on the National Science Education Standards. Comment on how you can help bring the vision to reality.

A Teacher Brings Inquiry into the Classroom

Can you identify what Kelly is doing that matches the vision provided in the NSES? Here is a likely scenario. Before the activity starts, she considers the applicable state standards in effect in her district. In this case it’s the Sunshine State Standards (SSS, Florida Department of Education, 1996–2008), the Florida equivalent to the NSES. You will have an equivalent set of standards in your state as well. In her Guiding Inquiry, Kelly addresses the standard that the child “knows that people use scientific processes including hypotheses, making inferences, and recording and communicating data when exploring the natural world” (p. 2). Also consistent with the NSES Content Standards that are reflected in the SSS, Kelly develops inquiry activities based on the concept that children will “know that environments have living and nonliving parts” (p. 2).

Inquiry is carefully considered even before the activity begins. Kelly contemplates the end result of each child’s learning as she plans the lesson. She also considers each child’s level of concept and skill formation related to the standard and what the children should know and be able to do as a result of the activity. She then contemplates ways to arrange materials so that children can develop questions and design activities with the soil. As her children complete their explorations, Kelly follows up to check individual and group understandings. She identifies misconceptions and reengages the class in further exploration as necessary. In short, she is modeling the inquiry approach.

Inquiry from the College Classroom to the Elementary Classroom

If you are not personally familiar with the inquiry approach to teaching, you are not alone. Kaitlyn Hood was in your situation while an undergraduate science methods teaching candidate at Drake University. She was first introduced to the inquiry method of teaching and
learning science in her science methods class. Later, in her Science and Children article, “Inquiring Minds Do Want to Know,” she recounts her own venture into inquiry instruction. She notes how it “changed the classroom atmosphere from presentation to discovery and application” (Hood & Gerlovich, 2007, p. 44). Kaitlyn highlights her own thoughts on inquiry as follows:

An inquiry-based lesson . . .

- Is more than the lesson idea or the proper equipment. It involves trusting your students to learn when you give them the time and responsibility to think on their own. Provide students the tools to know how to problem solve, give them guidelines on working with others, provide safety reminders, and let them explore. Our job as teachers is to circulate and guide students with questions as they discover the solutions.
- Is the kind of activity in which everyone in the class can be involved; it may turn out that this is where a struggling student can really shine.
- Can teach more than just about concepts. It gives students a process to use when they encounter other problems in and out of the classroom.
- Allowed me to see the students use information to create something. (p. 44)

In the end, Kaitlyn was excited to teach with the science-based method that matches what scientists do in their work. She notes, “Three years ago, if someone had told me I would be excited by teaching with a science-based method I would have rolled my eyes, but this experience has changed me and my approach to almost everything in my classroom” (p. 44). Our hope is that by the end of your science methods course, you will develop Kaitlyn's positive attitude and better understand inquiry.

A Child-Centered Perspective of Inquiry

What caught your attention with Kaitlyn’s view of inquiry? Are you thinking of the bigger question of why learning with this science-based method would be important in the first place? Please consider the following justification. By learning the scientific principles and processes, children start to develop the foundation to become scientifically literate and make sound societal decisions. This “mental workout” is as critical to future understandings as a physical workout would be for an athlete.

Scientific study helps children learn the scientific basis on which to evaluate the barrage of media reports they encounter each day. Consequently, they can have a meaningful debate, cast informed votes on issues, and contribute to important political decisions. They develop the background to knowledgeably discuss topics such as energy use as it relates to global warming, the potential controversy over the widespread use of biometrics as a deterrent to terrorism, or society's cost-benefit relationships related to health care and population life expectancies.

WEB DISCUSSION
NSTA Position Statement on Beyond 2000–Teachers of Science Speak Out

Google the National Science Teachers Association Position Statement on Beyond 2000–Teachers of Science Speak Out. Provide your own view as to why effectively teaching science at the elementary level is an important societal consideration.

Children also begin to make better personal decisions. They ascertain important understandings such as why they would want to stay away from non-prescription drugs, avoid high-risk drinking, and avoid unprotected sex. Children also begin to understand other personal issues like how their body functions and why it is important to have proper nutrition to avoid
obesity. Participation in inquiry helps children think about the multiple aspects of issues and know how to access information to remain informed. They can meaningfully consider things such as whether to participate in curbside recycling as a way to help society manage solid waste and resource use.

Consider an issue in your community such as green energy, spraying for mosquitoes, or public/private land use. How well can you think through the complex situation and apply your scientific skills to seek an answer or solve a problem? What could your teachers have done differently to prepare you for being elected to your city or county legislative body and having to make important decisions?

Another important aspect related to inquiry learning of science is simply having a better appreciation of the natural and designed world. Be honest—do you sometimes wonder about things like what causes a mirage, why some snails may estivate for years at a time, or why earthworms are hermaphroditic? Have you ever really considered the unintended consequences of not studying nature in elementary school? Would this affect the number of children going on to become scientists, engineers, or even entrepreneurs who discover the next important product?

Scientist Support of School-Based Scientific Inquiry

It is important to note that the inquiry movement is not just a phenomenon associated with K–12 teachers or the science education professors who prepare those teachers. In 1985, the American Association for the Advancement of Science (AAAS), representing 10 million individuals, launched Project 2061—to achieve scientific literacy for all by the year 2061. This timeframe is associated with Halley’s Comet’s last perihelion, or closest point to the sun during its elliptical orbit around the sun, and its return in 2061. Project 2061 is a long-term and all-inclusive initiative to advance scientific and technical literacy to cultivate a scientifically literate population by July 2061 when Halley’s Comet becomes visible on the Earth.

In their landmark Project 2061 publication Science for All Americans, the authors suggested that teachers do not need to teach more and more science content. Conversely, they should focus on what is essential to science literacy and how to teach it more effectively (AAAS, 1989/1990). Put another way, teachers should cover fewer topics but teach them in greater detail to promote deeper understandings. The Project 2061 authors go on to say that certain features of science give it a “distinctive character as a mode of inquiry” and “those features are especially characteristic of the work of professional scientists”. . . . “Everyone can exercise them in thinking scientifically about many matters of interest in everyday life” (p. 5). In other words, you can think like a scientist as you ponder and solve everyday problems.

WEB DISCUSSION
Scientific Literacy for All

Google the National Academies Press document Every Child a Scientist: Achieving Scientific Literacy for All (NRC, 1998). Read the section entitled “Why Do We Need Science Anyway?” What motive is there for America to have “science for all” as suggested in Science for All Americans (AAAS, 1989/1990)?
policy, the National Research Council (NRC). The NRC is responsible for the NSES. In the NSES, statements such as “Learning science is something students do, not something that is done to them” and “Science teaching must involve students in inquiry-oriented investigations in which they interact with their teachers and peers” echo the importance of engaging children with inquiry in the classroom (NRC, 1996, p. 20).

With such widespread support, it is hoped that inquiry teaching is becoming the norm in K–12 classrooms. Unfortunately, even today, there are discouraging reports coming out of the National Academies of Science. In a recent report from the Committee on Science, Engineering, and Public Policy titled Rising Above the Gathering Storm, Craig Barrett, then Chairman of Intel Corporation, makes the statement, “If I take the revenue in January and look again in December of that year 90% of my December revenue comes from products which were not there in January” (National Academies of Science, 2007, p. 17). Think about that for a minute. In one year 90% of the products are developed, marketed, and sold.

What does this testimonial say to you about the need to promote inquiry science? The authors of Rising Above the Gathering Storm also state the following:

There is a particularly strong need for elementary and middle school teachers to have a deeper education in science and mathematics. Many school children are systematically discouraged from learning science and mathematics because of their teachers’ lack of preparation, or in some cases, because of their teachers’ disdain for science and mathematics. In many school systems, no science at all is taught before middle school. Teachers who are not required to teach science have little reason to increase their knowledge and skills through professional development. No Child Left Behind requirements, however, will expand testing to the sciences in 2007. Elementary school teachers thus need training now in many areas of science; they need to see the relationships between mathematics and the sciences; and, most important if they are to excite young minds, they need the ability to integrate information across disciplines. In short, all teachers need to be scientifically literate and preferably excited about science. (National Academies of Science, 2007, p. 121)

The expectation is that by focusing continuously on the importance of quality science teaching and inquiry-based learning, the United States can remain a competitor in the emerging global marketplace. We can’t go on just teaching the facts of science since they can change at a pace like Intel’s products. Rather, we have to teach how to think, be able to find needed information within the glut of information being generated daily, and finally, evaluate the reliability of information found. Given the steadily declining number of U.S.-born scientists, there is also an ongoing concern to interest children of all ages in scientific study and possible future careers as scientists.

Your role will be to make sure that your elementary school classroom contributes to this effort. Similar to the account provided in Kelly Dolan’s chapter-opening Focus on Inquiry where she provides a vision of what first-grade inquiry would look like in harmony with the NSES inquiry standards, you will be challenged to implement inquiry. Her account is not isolated. The NSES Content Standard A calls for inquiry-based teaching. Let’s look at other classrooms where the “Abilities necessary to do scientific inquiry” and “Understanding about scientific inquiry” inquiry standard is being implemented (p. 105).
Inquiry in the Prekindergarten Through Sixth-Grade Classroom

First Grade

Candice Marshall, a first-grade teacher, also wondered about inquiry as she began her school year. In her Science and Children article “First Graders Can Do Science” (2006), she discusses how she had to rethink how she taught science in order to better promote inquiry. Instead of science being lessons involving just an activity to further represent a concept, she now begins her lessons with questions such as “Does black or white get hotter in the sun?” (p. 46). She suggests starting with a question as a way to engage children and provide an inquiry mindset.

Candice begins by having her class explore questions. She also builds in the time to develop further questions and follow activities with science conferences to communicate the findings of the inquiry activities. She begins her inquiry lessons by engaging children in larger group inquiry activities. Candice then starts individual inquiry projects with pairs of children. She reinforces that good activities begin with a testable question. Later, she assists children in making sure they have an appropriate question that could be explored and reported on during a closing conference. Candice also scaffolds equipment, supplies, and support for gathering background knowledge for her class by organizing materials, information resources, and reporting forms. The children proceed to make and test predictions as they organize their data and form conclusions. The class ends the experience with student conferences, complete with supporting PowerPoint slides and display boards.

Looking at the sequence of activity for Candice’s children, you find that it matches how a scientist will engage in scientific study throughout his or her career. Candice is forming scientific habits of mind so that children become increasingly familiar with the process of science. Children also build their content knowledge as they seek answers to their questions. What aspects of the portrayal of Candice’s inquiry teaching do you think remain similar as we change the focus to a third-grade or fifth-grade classroom?

WEB DISCUSSION

Scientific Habits of Mind

Google Science for All Americans from the American Association for the Advancement of Science. In your own words, describe the notion of “scientific habits of mind.” How does your explanation compare or differ from the one provided by the authors in Chapter 12 of Science for All Americans?

Grade 3

One example of the NSES inquiry standard being taught in a third-grade setting is described in Inquiry and the National Science Education Standards (NRC, 2000a). Ms. Flores’s class is transitioning from an earthworm activity to further instruction on the NSES “characteristics of organisms, life cycles of organisms, and organisms in their environment” and is exploring square-meter plots for earthworm density. They begin forming questions such as “Why are the worms different sizes?” and “Why didn’t I find earthworms in my study area?” (NRC, 2000a, pp. 40–41).

This activity presents an excellent opportunity to build on the children’s questions. Ms. Flores makes arrangements to purchase earthworms with egg cases and immature earthworms. She incorporates NSES for science and technology to build habitats to keep their worms. Her children also collect related information by returning to the original habitat to study where worms lived.
In order to further research earthworm environments, the children are also challenged to ask their parents and relatives about their understanding of worm habitats. As worms are distributed and studied, the children have further questions that are discussed and researched in the library. This leads to even more observation, discussion, and questioning. Throughout the activity, measurement skills are refined as balances and rulers are used to collect data. Children also communicate their findings and are challenged to use only personally observed data in their conclusions. How might inquiry learning be different in an upper elementary setting?

Grade 5
Teaching candidate Kim Bunton’s fifth-grade classroom is described in a Science and Children article “Indicators for Inquiry” (Townsend & Bunton, 1996). It is another example of the NSES inquiry standard in action. She is working with children on the NSES physical science standard “properties of objects and materials” (p. 106) by using homemade acid-base indicators.

• **Engage.** Kim begins by engaging the class in think-pair-share group sessions where they talk about acids and bases. This allows Kim to determine the children’s prior knowledge on the properties of the materials—specifically the acidity of the materials. Transitioning out of the discussion and before the children begin exploration on their own, Kim performs a simple titration demonstration with a cabbage juice indicator acting on vinegar (acid—turns red) and ammonia (base—turns blue). This excites children, and they now want to learn more about the topic.

• **Explore.** Kim arranges the student-centered time for children to explore guiding questions through observation and data collection. The class forms and tests predictions as students identify acid, base, and neutral substances through titration with the cabbage juice indicator.

• **Explain.** As children complete their activity, Kim provides time for the class to explain what they find during their explorations. Children share data and their conclusions, and it is at this time that Kim can identify if the children have grasped the concepts and resolved any misconceptions.

• **Elaborate.** Next, the children go on to elaborate on their experiences during the activity. The goal of this phase of the lesson is to take what was learned and make real-world connections to things in their everyday life. In this case, children apply their new acid-base knowledge to household items that claim to have a certain pH range. They can now test advertisements made by manufacturers and validate claims.

• **Evaluate.** The last part of Kim’s lesson is centered on evaluation. Kim, like her peer teachers, incorporates a performance-based assessment into this phase of the lesson. She challenges the children to apply their new knowledge in a different situation.

The sequence Kim uses in her inquiry lesson is commonly known as the 5E learning model. This widely used model is a refinement of earlier learning models, subsequently formalized by BSCS to use in its curriculum materials (Bybee et al., 2006). Have you facilitated a lesson using this model or observed a teacher using this model? Let’s explore this model in more detail.

Adapting the 5E Model
The 5E model described in the *Indicators for Inquiry* lesson represents an effective way to promote inquiry in the classroom. This model is well researched (Bybee, 1997). It continues to grow in popularity and is becoming infused into domains such as district and state science frameworks, textbooks, science curricular materials, and individual lesson plans in
traditional classrooms, college courses, and informal science education settings (Bybee et al., 2006). We also use this model in our own science teaching. Like Chessin and Moore (2004), we have adapted it to better reflect the need to infuse the growing influence of E-learning technologies in K–16 classrooms. The BSCS model is presented in Table 1.1. Although the sequence of the original model is retained, we adapted the BSCS model to infuse E-learning (Table 1.2).

In Chapter 2, we will further explore the 5E model. However, one underlying feature of the model to consider now is how the model matches the scientific enterprise. Is it representative of how a scientist would engage in her or his activity? Does the model help you to identify what the students know about science? Will the child be able to modify these notions as part of the conceptual change experienced during participation in the model? Please stop for a minute and take the time to think about your own knowledge of health and nutrition. Ask yourself how you developed that knowledge. Reflect on how you modified your theories of health and nutrition over time. In the following section, we will put these questions into context with an explanation of the nature of science.

### TABLE 1.1 5E Instructional Model

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<th>Stage</th>
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<tr>
<td>Engagement</td>
<td>The teacher or a curriculum task accesses the learners’ prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students’ thinking toward the learning outcomes of current activities.</td>
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<td>Exploration</td>
<td>Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation.</td>
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<td>Explanation</td>
<td>The explanation phase focuses students’ attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this phase.</td>
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<tr>
<td>Elaboration</td>
<td>Teachers challenge and extend students’ conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.</td>
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<tr>
<td>Evaluation</td>
<td>The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.</td>
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Source: Summary of the BSCS 5E Instructional Model in *The BSCS 5E Instructional Model: Origins, Effectiveness, and Applications* by Roger Bybee and others © 2006 by BSCS. Used with permission.
As you read the news or watch reporters on television, you probably hear about scientific reports that contradict each other, generally repealing earlier findings. Just think about the flurry of news reports and advertisements related to nutrition and healthy diets. *Nutrition Today* recently published an article entitled “Who’s the Average Joe Eater to Believe?” (Tillotson, 2006). The author states that billions are spent on researching nutrition. This research generates numerous reports and recommendations, yet the public has lost faith in nutrition scientists because of the ongoing contradictions. Unfortunately, compounding the issue we have many unresearched things that you hear about nutrition every day on television. These are not based in the same science undertaken by legitimate scientists. According to the author, this unfortunate public distrust comes at a time when legitimate nutrition science is actually becoming more evidence based.

The author goes on to discuss how the scientific study of nutrition is using better methodologies and researchers produce better data and interpretations. As a result, they are willing to replace older recommendations. He states that the new recommendations “are a strength, not a weakness of modern nutrition” (p. 114). Another author also discusses these flip-flops in nutrition science and suggests that

**E-Learning Adaptation to the 5E Instructional Model**

| E-Learning | This phase is infused throughout the model to enhance the technological skills of the learners as they do things such as gather information, engage in explorations, and explain and communicate their findings. E-learning is defined as computer-enhanced learning and may involve:
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<td>Discussion boards.</td>
<td>Educational animations.</td>
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<td>Electronic voting systems.</td>
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**WEB DISCUSSION**

**NSTA Position Statement on the Nature of Science**

Google the National Science Teachers Association Position Statement on the Nature of Science. In two or three sentences, summarize what the nature of science means to you.
When solid nutrition studies turn out differently than predicted, the science is doing what it is designed to do: subjecting dogma to the cold light of fact and experiment. Without a doubt this process is occasionally disruptive, but in the end, it means that the recommendations will be more firmly grounded in scientific evidence. (Dwyer, 2006, p. 98)

WEB DISCUSSION
Nutritional Recommendation

Research and present one example of a revised nutritional recommendation that is based on a new scientific finding.

Given this scenario on nutrition, your job as a consumer is to evaluate the scientific basis for the reports and, if applicable, act accordingly through your purchases, voting, or other activities. You will also have to decipher which are valid reports and which reports represent media hype to sell products. Have you personally taken a nutrition supplement or gone on a special diet? Fortunately, science inquiry helps to develop important skills to help make sense of the information to make sure you were not misled. In *Benchmarks for Science Literacy* (AAAS, 1993), the authors make the following point about the study of science:

> When people know how scientists go about their work and reach scientific conclusions, and what the limitations of such conclusions are, they are more likely to react thoughtfully to scientific claims and less likely to reject them out of hand or accept them uncritically. Once people gain a good sense of how science operates—along with a basic inventory of key science concepts as a basis for learning more later—they can follow the science adventure story as it plays out during their lifetimes. (p. 3)

Can you begin to see why developing inquiry skills with children will be so important in building the skills to think critically when interacting with the society and the media? How do you personally handle a change in position from the scientific community? Do you sometimes ask yourself why the scientific community cannot even agree among themselves? Let’s see, last year was it beneficial to have that one glass of red wine or maybe even a glass of beer? What will scientists say this year? Will it help your heart, cause cancer, or both? Doesn’t this change in position represent a weakness of science? Actually, scientific flip-flops are not seen as limitations of science.

Flip-flops are one of the most important strengths of science in that the entire scientific body of knowledge is subject to new empirical evidence or new ways of interpreting the existing data. Better ways to make observations such as newer technological advances may reinforce a theory or provide a correction to an existing theory. Sometimes there is a major breakthrough that will become the new paradigm, or commonly accepted best explanation that accounts for the observations. The changing nature of legitimate nutritional information is one important example of the nature of science—the varied ways in which scientific knowledge is developed and the values and beliefs that guide the process.

Another example of how science can change is exemplified as you think about how data on cell structure may have changed from the first microscope as compared to the modern optical microscope, the scanning electron microscope, the transmission electron microscope, or the emerging use of scanning probe microscopy. Ask yourself if you would want scientists to hang onto the original ideas about cell structure and function as observed through the early lenses. Wouldn’t this limit future medical breakthroughs?

If you were sick, wouldn’t you be asking the doctor for the latest breakthrough as opposed to an ancient treatment such as leech therapy? The etymology associated with the word *leech* is “to heal.” In fact, leeches were the treatment of choice in the past and doctors were actually
called “leeches.” Did you know that Egyptians believed that leeches sucking a patient’s blood could help cure fevers? Likewise, in medieval Europe, leeches were used extensively by physicians to treat patients. But, before you decide—in an interesting flip-flop—leeches may actually be making a comeback in medical treatments. Will you be able to make an informed decision concerning your own leech therapy?

WEB DISCUSSION

Scientific Flip-Flops

What are some other examples of how scientists have changed their position on something due to updated research?

The changes in theories should not be a reason for the public to disregard scientific knowledge or to lose faith in the scientific way of thinking. Scientific knowledge is self-correcting as new information and interpretation occurs. Collective scientific knowledge, although ultimately tentative, is based on extensive data that cannot and should not be disregarded. Disregarding this scientific knowledge would affect the quality of decisions that we make in everyday life. Think about the various theories related to global warming that you hear about from the media. What is the basis for these theories?

TEACHING TIP

The Nature of Science Activity

Although the current reforms in science education place a strong emphasis on students’ understandings of the nature of science, there are not abundant resources to help you share that concept. The following idea shared by Norm Lederman has been found to be successful for teaching students about the characteristics of scientific knowledge. This activity requires virtually no scientific background on the part of the students. Consequently, it is relatively risk free.

1. Re-create the tube pictured in Figure 1.1. I suggest that you obtain a mailing tube from the post office, the map room at a local library, or a store that sells posters. You may also use a piece of PVC pipe or an empty oatmeal container. Clothesline, twine, or rope from a local hardware store will do for the rope. The ring holding the ropes together is plastic; you can buy one at a craft store. If a ring is not available, the lower rope can simply be looped over the upper rope. The ends of the tube can be sealed with rubber stoppers or taped.

2. Make an overhead (and class set of handouts) of what is pictured in Figure 1.1.
Scientific Theories

We generally think of a theory as a hunch about something—"I have a theory about why that child did not study last night" or "What is your theory about who the secret lover is in that television series?" These theories are simply educated guesses based on limited circumstantial fact. You cannot further explore the situation. Science presents a different kind of denotation of a theory. Science involves a much richer meaning for the word theory. As indicated before, a scientific theory is a well-substantiated explanation based on systematic observation, data collection, and careful analysis of the data. Scientific theories help to provide an understanding of some aspect of the natural world and are based on a body of reliable facts. Furthermore, these facts are subject to repeated confirmation as other scientists make observations under the same conditions while repeating experiments.

WEB DISCUSSION

Improving Students’ Understanding of the Nature of Science

Google the National Association for Research in Science Teaching Research Matters to the Science Teacher on the topic of “Improving Students’ Understanding of the Nature of Science.” Briefly describe what a teacher would need to do in his or her teaching to promote an understanding of the nature of science.

This verification process provides reliability to the facts that are used in developing theories. You can think of theories as the building blocks of science. New data results in new theories. An abundance of new, compelling data will lead to changes in existing theories. These
new theories lead to new experimentation and verification, which results in new data being collected and analyzed. Sometimes theories are subject to widespread controversy, such as the case with the theory of evolution or the aforementioned global warming controversy.

Let’s use an example from another perspective. Does our current understanding of how cancer can be cured account for all possibilities? This is unlikely since this knowledge is limited by factors such as the amount of time and funding needed in order to research the causes and pharmaceutical or homeopathic approaches to cure cancer.

We continue to pursue the cure through new methods of scientific discovery that contribute to the ongoing development of knowledge about cancer, replacing older theories. Thinking back, what was your conclusion related to global warming? Why did you adopt this particular conclusion?

There is ongoing media controversy that surrounds global warming (i.e., Gore, 2006). You will continue to hear news accounts of groups of scientists debating the topic of global warming as they present competing theories—is the earth cooling with an upcoming ice age or warming due to the greenhouse effect? Reporters seek debate based on opinions if the current warming trend is a naturally recurring phenomenon or if the increasing climatic temperature is being accelerated by mankind’s burning of fossil fuels. The impression you get from the media is that this issue is a subject of much debate in the scientific community. This is not really the case. Yes, there are competing views based on actual data—which is expected in science as we attempt to explain this complex issue. However, the fact is that members of respected scientific societies who perform research in this area generally agree on the accepted scientific theory of anthropogenic climate change. As one author put it,

> Scientists publishing in the peer-reviewed literature agree with IPCC [Intergovernmental Panel on Climate Change], the National Academy of Sciences, and the public statements of their professional societies. Politicians, economists, journalists, and others may have the impression of confusion, disagreement, or discord among climate scientists, but that impression is incorrect. (Oreskes, 2004, p. 1686)

So what causes so much confusion surrounding the issue? This generally happens as politics becomes involved. When that happens, opinion can predominate over fact. The nonscientist or television or newspaper pundit presents a competing interpretation of scientific fact that does not follow the basic tenets of science. These naïve interpretations are not formed through empirical evidence and the testability of the evidence by others as is the case with established scientific theories. Often financial interests are behind the commentary.

What we should consider, however, is that NASA performs scientific research on the effect of greenhouse gases. They found that the surface temperature on Venus with its dense clouds is warmer than the temperature on Mercury, which actually orbits closer to the sun. What does this say about Earth as we continue to add pollutants to the atmosphere? In summary, personal interest can also become the impetus to blur scientific fact that may provide a competing interest.

**WEB DISCUSSION**

**Scientific Objectivity**

If you owned a factory that put a lot of pollutants into the air, explain how you might balance the good of the planet with the self-sufficiency of maintaining operations and the ability to provide work for your employees. What strategies would you use if you wanted to downplay or disregard competing interests that would prevent you from releasing the harmful emissions?
When subjectivism is introduced into science, science becomes corrupted, and theories are subject to error. Scientists must remain as objective as possible and not do things like disregard those observations that do not fit their personal expectation. When we engage in science, we attempt to eliminate all subjectivity and arrive at impartial explanations—explanations that are backed up by evidence, testing, and logical theory.

The goal of the scientific method is to eliminate personal opinion as we determine what is true and form applicable theories. These theories will become a foundation for how we take care of ourselves and interact with society. The goal of your classroom science teaching as seen in the NSES is to promote scientific literacy along these lines.

The Nature of Science and Its Applications to the Classroom

We understand that the ultimate goal of pure science is to generate new knowledge in the form of theories, laws, and other facts based on observations and data collection. We also appreciate that this pure science is not a goal of elementary science. During the elementary years, science instruction should not only help children learn about what scientists have found, such as facts, theories, and laws, but much more important, science instruction should also help children learn how science facts, theories, and laws are developed. Put another way, both the processes and the content of science will be important in your classroom, but the process is what will produce enduring understandings.

Why is it important to concentrate on the process? The children will not be developmentally ready to form scientific theories on their own, but they will be able to appreciate science as a way of knowing. They should come to know that science includes the array of organized inquiry approaches used by scientists to examine a situation, solve a problem, or find an answer to a question. Take a minute and think back to Kim Bunton’s fifth-grade classroom. Her class was forming and testing predictions related to acids, bases, and neutral substances. However, unlike scientists who complete precise titrations with a much higher level of precision, they were titrating with the cabbage juice indicator. The accuracy of the conclusions was not as important as the process of forming and testing predictions.

In your classroom, your principal attention will be on modeling and replicating with children the aspects of the process of science called scientific inquiry. By helping children engage in scientific inquiry, you assist them in constructing reality. Children will make sense of the world around them, with or without your influence. What you hope to do is help them to develop a more accurate understanding. You can help them to identify and remediate their own misconceptions as they participate in inquiry. Thinking about science as a way of knowing helps you to realize that, as an elementary teacher, you probably will not be concerned with children memorizing all of the scientific facts needed to participate in future game shows. Nor will children need to generate breakthrough novel theories in science. Rather, you will be involved in exploring the nature of science with children in a way that parallels the activities and thinking processes used by a scientist. Think of yourself as “uncovering” science and finding out about the world we live in as opposed to “covering” science in the form of discrete bits of information to be objectively tested. The common approach to uncovering science is a way of knowing that includes values and beliefs inherent to scientific knowledge and its development (Lederman, 2006).
Scientific Method

We often use the scientific method in the classroom as a way to illustrate the scientific process. You may remember memorizing the scientific method in middle or high school. But how does that match with what scientists do in their work? Although there is a general path for developing and testing hypotheses through experimentation consisting of observation and data collection, there is not a specific, one-size-fits-all, prescribed operating procedure followed by each scientist in each experiment (Lederman, 2006; NRC, 1996). In fact, serendipity while performing other testing has resulted in many scientific discoveries such as penicillin, X-rays, safety glass, superglue, and the current use for Viagra. What does that mean to you as a science teacher?

Obviously, we are not looking for serendipitous events in the elementary classroom. Your role will be to help children work through the pathway of identifying questions, exploring those questions so as to find ways to answer the questions, answering the questions, and sharing their answers with the class at large. This process may be slightly different each time depending on the circumstances. Sometimes the question may already be provided, much like the research performed in a lab of a major corporation. In other cases, the end result is there but the child questions the procedure used to manipulate the variables and wants to try to replicate the procedure similar to what may occur in drug testing. Learning the general way the scientific method is used benefits the child much more than memorizing the individual steps and related information. What are some other benefits that occur when science is properly taught?

HOW DO CHILDREN AND SOCIETY BENEFIT WHEN SCIENCE IS TAUGHT PROPERLY?

All children need a rich array of firsthand experiences to grow toward a full measure of science literacy. Quality science programs make it possible for advanced study, which can lead to many occupational choices and benefits to all society. As children become adults, knowledge of specific technical information may be considered when making purchases. For example, when buying a car, it is helpful to have some knowledge of horsepower, fuel economy, hybrid technology, and antilock brakes. A firm grounding in science will also help us to understand the more technical aspects such as variable torque distribution, vehicle dynamics control, and electronic brake-force distribution. To secure a job, we will be expected to know something about the nature of the position we are seeking. Our functioning and survival in our society are linked to science literacy.
Societal Benefits

It is important to educate people and to change any naïve understandings in order to cope with today’s challenges. Naturally, the public education system plays a major role in this societal conceptual change process. For example, K–12 science education opportunities to engage in inquiry help citizens develop the abilities to better understand and take appropriate voter action on such topics as reducing the use of fossil fuels to slow global warming and why society should invest in alternative energy exploration. Science education will produce citizens who better appreciate the natural world and understand why they need to conserve resources as explosive population growth and urban development further decrease the supply of fresh water to communities and increase the risk of unsafe food being distributed. Graduates of the system should also better understand how an individual member of society can become a burden on the health care system if he or she allows obesity to increase the incidence of diabetes or engages in unsafe personal practice that would contribute to the spread of AIDS, hepatitis, or other diseases. We want a graduate who understands flooding, hurricanes, droughts, the spread of disease, and other natural and man-made disasters and can vote appropriately to help minimize the effects on the community.

Every society wants its contributing members to be literate—that is, to have enough background knowledge and ability to make informed decisions, communicate, produce, and improve the general welfare. In a society as advanced and dynamic as the one we live in today, the amount of information increases at an accelerating rate. Developing the ability to better find, understand, analyze, and effectively use information is often as essential as the information itself. With limited national resources, we need to find cost-effective ways to remain globally competitive. The authors of Rising Above the Gathering Storm (National Academies of Science, 2007) provide the following perspectives:

- Starbucks spends more on health care than on coffee, and General Motors spends more on health care than on steel (p. 14).
- In 2001 (the most recent year for which data are available), U.S. industry spent more on tort litigation than on research and development (p. 16).
- There were almost twice as many U.S. physics bachelor’s degrees awarded in 1956, the last graduating class before Sputnik, than in 2004 (p. 16).

WEB DISCUSSION
Science in Everyday Life

Google the Nova or AAAS ScienceNow or the National Academies of Science in the Headlines website and read a current news story. What is the scientific credibility of the story? How will this story influence your life? What personal position will you take or change will you make related to the story?

Under such conditions, people need a common core of knowledge. A common understanding allows us to communicate more efficiently with one another and facilitates public policy. Science literacy is imperative in a society that leans heavily on science and technology. Literacy serves as the common ground for discussing and understanding diverse and complex issues. Issues such as toxic waste dumps, in vitro fertilization, nuclear proliferation, genetically altered foods, and bionic body parts are examined in our everyday encounters with the media. The AAAS (1993) views literacy in the following way:

Project 2061 promotes literacy in science, mathematics, and technology in order to help people live interesting, responsible, and productive lives. In a culture increasingly pervaded by science, mathematics, and technology, science literacy requires understandings and habits of mind that enable citizens to grasp what those enterprises are up to, to make some sense of how the natural and designed worlds work, to think
Reflection

1. Inquiry is seen as a way of teaching and learning about science that reflects how science itself is performed by scientists on a daily basis.
2. By engaging in inquiry activities, children learn the scientific principles and processes to develop the foundation to becoming scientifically literate and making sound societal decisions.
3. The 5E instructional model includes the phases of Engage, Explore, Explain, Elaborate, and Evaluate, and represents an effective way to promote inquiry in the classroom.
4. Theories are well-substantiated explanations based on systematic observation, data collection, and careful analysis of data and are seen as the building blocks of science.
5. The nature of science refers to the process of how science knowledge is constructed as well as the values and beliefs inherent to scientific knowledge or the development of scientific knowledge.
6. Society wants its contributing members to be literate so that citizens have the ability to make informed decisions, communicate, produce, and improve the general welfare of the community.

SUMMARY

1. Inquiry is seen as a way of teaching and learning about science that reflects how science itself is performed by scientists on a daily basis.
2. By engaging in inquiry activities, children learn the scientific principles and processes to develop the foundation to becoming scientifically literate and making sound societal decisions.
3. The 5E instructional model includes the phases of Engage, Explore, Explain, Elaborate, and Evaluate, and represents an effective way to promote inquiry in the classroom.
4. Theories are well-substantiated explanations based on systematic observation, data collection, and careful analysis of data and are seen as the building blocks of science.
5. The nature of science refers to the process of how science knowledge is constructed as well as the values and beliefs inherent to scientific knowledge or the development of scientific knowledge.
6. Society wants its contributing members to be literate so that citizens have the ability to make informed decisions, communicate, produce, and improve the general welfare of the community.

REFLECTION

1. What science content and/or skills should be taught in the elementary classroom?
2. What would exemplary science teaching look like in grades prekindergarten through grade 6?
3. Wiki Development: Log onto your instructor’s course wiki and create a page on the following topics:
   - Group 1: Inquiry and the Teaching and Learning of Science
   - Group 2: The National Science Education Standards and Project 2061
   - Group 3: The 5E Instructional Model
   - Group 4: The Nature of Science
   - Group 5: Scientific Theories
   - Group 6: Scientific Knowledge
   - Group 7: Scientific Method
   - Group 8: Societal Benefits of Science and Technology

What will you do to help promote scientific literacy?
Discovering Science through Inquiry

FOCUS ON INQUIRY

INQUIRY IN THE CLASSROOM

Ms. Pita Martinez-McDonald
Preschool & Elementary Level Director and Committee Chair,
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Initiating Inquiry

I find that the best inquiry science that my class of 4th graders in Cuba Elementary are involved in are those projects that begin with students’ questions or frustrations. A teacher’s practice of open-ended questioning with students is probably the first step in any inquiry we do in the classroom. Carefully thinking of responses to students’ questions can either spur a group on to further thinking or it can put an end to their questions. Because I have very little science background myself, I often don’t know the answers to students’ questions, thus we all step through the process of inquiry together. Never be afraid to say, “Gee, I have no idea! What can we do to find the answer?”

I often use literature to bait students into thinking scientifically. When we are reading stories, I think through some of the science that is an underlying component of the story and then think of open-ended questions that will help students think about a topic. Once the original question is out there, students brainstorm a process to follow, to learn about the questions I’ve asked.
Coyote and the Lizards

An example of this is when we read the Navajo folk tale *Coyote and the Lizards*. In the story, Mr. Coyote is watching the lizards slide down a steep hill on flagstone rocks. Mr. Coyote joins the game and begins by choosing a small rock where he is able to control his slide and is unhurt. Later he is warned not to choose a large, heavy rock because he’ll get killed. By asking my students, “Do you think the story is correct? Would Mr. Coyote be able to handle a small rock but not a large rock? Why?” there was a great discussion about the weight of a rock, and the lighter a rock, the faster it would slide. Other students stated that no, a heavier rock would end up going faster. Students have had lots of experiences with sliding down slides at school and in winter when sledding. When encouraged to recall these experiences, they remembered that their older, bigger siblings would go down a hill faster than they would. I then asked, “Could we test this?” And we launched into a huge unit on force and motion! We touched on Newton’s laws of motion and went through the entire scientific method. One surprise for me was students’ understanding of vocabulary. When we were discussing the surface Mr. Coyote was sliding down, students imagined the sandy hill to be smooth or soft. After testing several surfaces, smooth, rough, soft, and slick I realized that students thought the words “smooth” and “soft” were interchangeable, meaning the same type of surface. Nearly all the students in our school are designated English Language Learners, and I often forget that their understanding of a word may not be the same as mine. Be sure to clarify all vocabulary throughout any lesson.

Exploration and Explanation

Another crucial component of all inquiry lessons is taking the time to discuss the science in the lesson. Students must communicate their thinking orally or through journaling so that you know what they are thinking. It is often difficult to stop an engaging lesson to talk about science, but lessons must not only be hands-on, but minds-on as well.

Try to be courageous and venture into areas that you are not very sure of. Remember there are always high school science teachers in your district or a scientist within your community who is willing to help you out and answer questions you may have, or who would be willing to check the soundness of the science concepts you are teaching.

In her *Inquiry in the Classroom* Focus on Inquiry, Pita Martinez-McDonald points out how her children’s inquiry units often start with students’ questions or frustrations. She indicates that she often uses literature to initiate the questioning so that she can guide the students into developing a testable question on which to base her unit planning.

Although she does not use the specific labels in her Focus on Inquiry, we see that Pita is engaging her class, allowing them to explore, and providing time for explanations, elaborations, and evaluations. In this chapter, we will look deeper into inquiry and the phases of the 5E instructional model. Let’s begin with a review of the twofold aspect of inquiry.

**INQUIRY AND ITS ROLE IN PROMOTING SCIENTIFIC LITERACY**

The authors of the *National Science Education Standards* (NSES) define inquiry in the following way.

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. (National Research Council [NRC], 1996, p. 23)

You may recall from the discussion of nature of science in Chapter 1 that science is a way of knowing that includes the values and beliefs inherent to scientific knowledge and its
development (Lederman, 2006). Nature of science is reflected in the first part of the NSES inquiry definition concerning scientists. Did you happen to notice that we do not use the term “the” nature of science above? The reason for this is that there is not a single way of developing scientific knowledge. This is consistent with the inquiry definition above that includes the term “diverse” in describing the ways that scientists may pursue knowledge.

In addition to the work done by scientists, the NSES authors also describe inquiry as the activities that children will undertake in your elementary classroom to help them understand scientific ideas and the process scientists use in forming these ideas. As with the scientists, there is not a single way of engaging in science that should dominate activities. There is, nevertheless, a changing emphasis for teaching that focuses on student understanding as the teacher guides children in scientific inquiry. The focus on understanding in science teaching and learning coincides with the paradigm of how a scientist would engage in his or her own pursuits.

**WEB DISCUSSION**

**Other Paradigms**

Paradigms are often referred to as common patterns of thought. The usage of the term paradigm is not unique to science. For example, the “well-connected customer” is a paradigm example in business. Generally, it refers to customers who use the Internet to exponentially increase their ability to find out about and compare competitive products and services. They also have the ability to share positive and negative product and service experiences with numerous other potential customers. What are other examples of paradigms?

**INQUIRY AS A PARADIGM FOR TEACHING AND LEARNING**

Teachers should be aware that science is not just a body of knowledge but a paradigm through which to see the world (American Association for the Advancement of Science [AAAS], 1998, p. 202).

Does this quote suggest to you that there is a commonly accepted method for engaging in the study of scientific phenomena? Remember that a paradigm is a typical viewpoint or ideal example that provides a model for all related processes or systems. Where did the idea of paradigms begin? Thomas Kuhn (1962) first defined a paradigm as a commonly accepted viewpoint. He distinguished a paradigm shift as a radical change in this common viewpoint. For example, the paradigm of a sun-centered solar system replaced the paradigm of the earth-centered solar system.

Paradigm shifts occur because scientists use experimentation and new technologies to better explain observed scientific phenomena. Scientific discussion, experimentation, and publication generally center on current paradigms. Deviating from the common paradigm is apt to place a scientist’s research funding and acceptance of scholarly publications in scientific journals in jeopardy. Ideas that are inconsistent with current paradigms are generally dismissed. Even as paradigms in science change our perspectives and understanding of how the world works, they also transcend science education and our understanding of how to better teach science.

**Paradigms of Science Education**

Take a minute to study the Changing Emphases for Teaching found in the NSES (NRC, 1996, p. 52). We find that looking at the research related to the NSES, an inquiry approach to teaching and learning predominates as the current paradigm. Statements such as how teachers
should be “Guiding students in active and extended scientific inquiry” support this assertion. Let’s look at the aspects of inquiry from a scientist’s and student’s perspective.

**INQUIRY AND SCIENTISTS**

Scientists are constantly trying to improve their understanding of the living and nonliving world. They continuously investigate the natural and designed systems that function all around. Using their own skills and techniques, as well as personal and historical scientific knowledge, they conduct investigations. From these investigations, scientists generate empirical data used to construct explanations that can be shared and tested by others. Occasionally, scientists are simply repeating the work of another scientist to confirm a result. Other times, they are testing their own predictions or working on a problem posed by their employer. Frequently, scientists develop a new technique for collecting data, analyzing the information, or sharing it with others. Mathematics guides the process of inquiry as questions are introduced and data are then collected, analyzed, and shared in response to the guiding question. New processes are often the result of advances in technology or in a creative application of existing technology. Communication is an important step of the inquiry process and, by necessity, results are clearly explained, logically connected to current data and past scientific knowledge, and completed in such a way as to promote repetition or expansion of the current activity.

**WEB DISCUSSION**

Scientists’ Metaphors for Scientific Inquiry

Go to [www.nsela.org/publications/scienceeducator/14article4.pdf](http://www.nsela.org/publications/scienceeducator/14article4.pdf) or Google Putting the Puzzle Together: Scientists’ Metaphors for Scientific Inquiry from NSELA (Harwood, Reiff, & Phillipson, 2005). Develop your own metaphor for a scientist and briefly explain the metaphor and why you chose that metaphor.

As we learned in Chapter 1, there is a logical progression of the activity as opposed to a stringent adherence to a single approach for scientific inquiry that is historically defined as the scientific method. Do you remember learning a version of the scientific method similar to: (1) begin with an observation, (2) state a predictive hypothesis in the form of an if-then proposition, (3) test the hypothesis, (4) analyze data to support or refute the hypothesis, and (5) communicate this conclusion? This approach is still highlighted in some schools today. Absolute use of this approach is an authoritative and impersonal way to think about science and often leads to a negative view of the scientist. This way of thinking generally contributes to the unfavorable view of science as an inhuman activity and discourages children from...
participation in the scientific enterprise. It is true that scientists may generally proceed along these lines. But, as with the varied approaches the members of your group would take in answering a question such as “Does all wood float and all metal sink?” there is as much diversity in conducting inquiry as there is with the scientists themselves. What they do agree to is not the exact steps, but the fundamental suppositions such as data are carefully and systematically collected and their results are replicable, based on evidence, and determined through the logical conclusion of data. How does this relate to the inquiry that you will foster with your own class?

INQUIRY AND CHILDREN

The NSES authors define a successful science classroom as one where “teachers and students collaborate in the pursuit of ideas, and students quite often initiate new activities related to an inquiry” (NRC, 1996, p. 33). This is analogous to how scientific colleagues work to generate new ideas and build research programs. The NSES authors go on to say that, in the successful classroom, teachers “guide, focus, challenge, and encourage student learning” as well as “continually create opportunities that challenge students and promote inquiry by asking questions” (NRC, 1996, p. 33). Once more, we see the focus on inquiry.

That is not to say that every child is engaging in his or her own segment of classroom scientific tumult. It will be your role to guide the activity and intervene as needed to promote full understanding as indicated in the Guiding and Facilitating Learning Teaching Standard B. Sometimes, the class will be engaged freely in open inquiry, but your skillful intervention will move this activity into a focused pursuit of a definable question and accompanying pathway to an answer.

You will also mediate whenever necessary to assess the child’s progress related to the learning goals by allowing the student to clarify his or her personal understanding. It will also be your role to intercede if the activity begins to impede that child’s ability to make sense of the inquiry. It is a constant balancing act, but keep in mind that the ultimate goal of the inquiry you facilitate is not to make every child into a future scientist, but to produce a scientifically literate society; understanding is the key.

CONVERGENCE OF IDEAS

The essence of NSES Science as Inquiry Content Standard A (see page 7) is the joining of ideals. The processes scientists use to understand our world and inform colleagues about their work are characteristic of the behaviors children in your classroom will use as they work to understand their world and express ideas to others. Like scientists, children begin with a question they want to explore, carry out an investigation, and communicate what they found. An inquiry approach to the child’s acquiring scientific knowledge, process skills, and positive attitudes and beliefs is not standardized. To quote the NSES, the inquiry standard “should not be interpreted as advocating a ‘scientific method’” “This standard cannot be met by having the students memorize their inabilities and understandings. It can be met only when students frequently engage in active inquiries” (NRC, 1996, pp. 144–145). Research suggests that the 5E model and other 5E extended models are a way to promote inquiry (Bentley,
To review at this point, we have discussed the overall benefits of using an inquiry approach to teaching elementary science, we explored how an inquiry approach to teaching can be used to promote an understanding and appreciation for nature of science, we examined what inquiry looks like in some representative elementary classrooms, and considered the 5E instructional model as a framework for what inquiry might look like in your future classroom. Now let's turn our perspective to a child's point of view. What is the child's role in learning and how can we support his or her learning? The authors of the NSES suggest the role of the child in the following passage.

When engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills. (NRC, 1996, p. 2)

WEB DISCUSSION
Goals for School Science

Review the goals for school science from the NSES cited below. Reflecting back on your own science experiences, give your past teachers a collective A, B, C, D, or F grade on how well-prepared you feel in relation to the goals for school science. Provide a brief comment to justify your grade.

The goals for school science that underlie the National Science Education Standards are to educate students who are able to

- Experience the richness and excitement of knowing about and understanding the natural world.
- Use appropriate scientific processes and principles in making personal decisions.
- Engage intelligently in public discourse and debate about matters of scientific and technological concern.
- Increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers.


What does this excerpt mean to you? From an operational standpoint, it suggests things you should do to help the student, such as provide opportunities for students to ask questions, explore their ideas, and communicate what they find. From the child's vantage point, though, it suggests how the child will learn, identify his or her previous assumptions, use thinking skills to test those assumptions, and consider alternative assumptions as the child modifies previous understandings and creates new knowledge about the world. The underlying learning theory in this quotation is called constructivism. In the following section, we will investigate what constructivism is and how it relates to inquiry teaching.

CONSTRUCTIVISM AND SCIENCE TEACHING AND LEARNING

Constructivism is the belief that knowledge is not passed on from the teacher to the student. Rather, it is constructed by an individual as he or she creates his or her own world view (Colburn, 2000; Tobin & Tippins, 1993). Constructivism is not a specific pedagogy. However, when using constructivism as a referent for science teaching, student learning is maximized...
Ms. W. encourages students to engage in an investigation initiated by a question that signals student interest. The context for the investigation is one familiar to the students—a pet in the classroom. She teaches some of the important aspects of inquiry by asking the students to consider alternative explanations, to look at the evidence, and to design a simple investigation to test a hypothesis. Ms. W. has planned the science classes carefully, but changes her plans to respond to student interests, knowing the goals for the school science program and shaping the activities to be consistent with those goals. She understands what is developmentally appropriate for students of this age—she chooses not to launch into an abstract explanation of evaporation. She has a classroom with the resources she needs for the students to engage in an inquiry activity.

George is annoyed. There was plenty of water in the watering can when he left it on the windowsill on Friday. Now the can is almost empty, and he won’t have time to go to the restroom and fill it so that he can water the plants before science class starts. As soon as Ms. W. begins science class, George raises his hand to complain about the disappearance of the water. “Who used the water?” he asks. “Did someone drink it? Did someone spill it?” None of the students in the class touched the watering can, and Ms. W. asks what the students think happened to the water.

Ms. W. encourages students to engage in an investigation initiated by a question that signals student interest. The context for the investigation is one familiar to the students—a pet in the classroom. She teaches some of the important aspects of inquiry by asking the students to consider alternative explanations, to look at the evidence, and to design a simple investigation to test a hypothesis. Ms. W. has planned the science classes carefully, but changes her plans to respond to student interests, knowing the goals for the school science program and shaping the activities to be consistent with those goals. She understands what is developmentally appropriate for students of this age—she chooses not to launch into an abstract explanation of evaporation. She has a classroom with the resources she needs for the students to engage in an inquiry activity.

Marie has an idea. If none of the children took the water, then it must be that Willie, their pet hamster, is leaving his cage at night and drinking the water. The class decides to test Marie’s idea by covering the watering can so that Willie cannot drink the water. The children implement their investigation, and the next morning observe that the water level has not dropped. The children now conclude that Willie is not getting out of his cage at night.

“But wait,” says Kahena. “Why should Willie get out of his cage? Willie can see that the watering can is covered.” So the class decides to leave the cage in the middle of the sand table and take the cover off the watering can. The water level begins to drop again, yet there are no footprints in the sand. Now the children dismiss the original idea about the disappearance of the water, and Ms. W. takes the opportunity to give the class more experiences with the disappearance of water.

At Ms. W.’s suggestion, a container of water with a wide top is placed on the windowsill and the class measures and records changes in the water level each day using strips of paper to represent the height of the water. These strips are dated and pasted on a large sheet of paper to create a bar graph. After a few days, the students discern a pattern: The level of water fell steadily but did not decrease the same amount each day. After considerable discussion about the differences, Patrick observes that when his mother dries the family’s clothes, she puts them in the dryer. Patrick notes that the clothes are heated inside the dryer and that when his mother does not set the dial on the dryer to heat, the clothes just spin around and do not dry as quickly. Patrick suggests that water might disappear faster when it is warmer.

The children’s experiences with the disappearance of water continue with an investigation about how the size (area) of the uncovered portion of the container influences how fast the water disappears and another where the children investigate whether using a fan to blow air over the surface of a container of water makes the water disappear faster.

A CONSTRUCTIVIST APPROACH TO TEACHING

What did you notice about the “Willie the Hamster Vignette” that is included in the NSES Standards box? The students in Ms. W.’s class are investigating water evaporation in a relevant context. Notice how Ms. W. used an everyday classroom event as a transition into an inquiry activity where the class develops an experiment. When that activity fails to provide a satisfactory answer, she guides the children into subsequent rounds of inquiry based on her questioning and their ideas. What is interesting to note is that Ms. W. did not start with a curriculum guide entry that outlined when to introduce content, often in the form of an unfamiliar textbook section. Nor did she start with a definition of evaporation. Instead, she started with an event that was familiar to the class and built on that experience.

Throughout the entire inquiry-based episode, Ms. W. engages the children in individually meaningful learning experiences as they think about their own knowledge. She helps them to change prior beliefs as necessary. Ms. W.’s children change in some way as a result of the learning and will readily recall the information in the future and apply the processes they learned in this and other situations. What else did you notice concerning the “Willie the Hamster Vignette”? Did Ms. W. direct her initial response to George’s question back to him or did she involve the class? Think about how the role of others is important to learning.

Vygotsky and Social Constructivism

Lev Vygotsky’s theory of constructivism includes the role of culture and society in mental development. Vygotsky thought that behavior must be studied in a social and historical context, giving rise to the term sociohistorical. Vygotsky theorized that children do not simply reproduce what is said or shown to them. Instead, they undergo socially mediated cognitive constructions. As an example, take a minute to deliberate on the situation in Willie the Hamster. Do you see how each of Ms. W.’s children could develop an individual understanding that water evaporates faster when it is warmer? Except, do you notice that they develop their ideas through interaction with other members of the class?

Put another way, Vygotsky’s cognitive development is a matter of an individual’s social interaction within the environment. The mechanism of social behavior and the mechanism of consciousness are the same, according to his theory (Vygotsky, 1978). That is to say, we know ourselves because of our interactions with others. That is a powerful concept. Consciousness, according to Vygotsky, can only be explained in terms of socially meaningful activity. Sound confusing? We can look at it another way by comparing Vygotsky’s theory with the more familiar theory about learning provided by Piaget.

Like Piaget, Vygotsky believed that learners construct their own knowledge and that a deeper meaning goes beyond perception. A major difference does exist between the two theories. Piaget was a developmental constructivist. In other words, Piaget saw the child’s development as leading learning. He described how advances in development, or stages of development, facilitated new abilities in learning, such as conservation.

As a classic example, think about the ability of a child to understand that the amount of mass in a ball of clay does not change when it is rolled out. In this scenario, the child would need to already be at the concrete operational stage to understand that the mass is unrelated to the arrangement. Likewise, scientific classification is difficult before this stage because the child can only arrange things according to one attribute. Piaget also placed an emphasis on the child’s internal processes.

Converse to Piaget’s theory, Vygotsky saw learning as leading development. This is opposite of Piaget’s view. For Vygotsky, students first engaged in learning spontaneous concepts with their peers. Students would later individually restructure these same concepts into scientific concepts within their own cognitive structures. In other words, children did not need to have already arrived at a developmental level to perform a task or develop a concept as with Piaget. Instead, the interaction with peers helped the child to learn in order to actually reach that new developmental level. What is it that we as teachers do to help in this process?
Our role in a child's development is to facilitate the development of scientific concepts. We do this by helping the child communicate better and learn within the social context. Let's back up and look at this from a child's perspective. As a child grows, words begin to take on meaning and communication begins to develop (Vygotsky, 1986). The child finds names for objects, and informal, spontaneous concepts continue to develop as a result of the verbal exchange with others.

These concepts are often vague and tend to be illogical and unsystematic, but they are further developed through the use of psychological tools or signs. The tools and signs are used much like the tools that any craftsperson uses to perform tasks better. Mental tools allow us to improve our communication and better adapt to our environment. They can be either external or internal.

Writing notes in a notebook is an example of external psychological tools; these notes help us augment the mind's capacity. Internal psychological tools, like a mnemonic rhyme or acronym, assist us in mental development. Do you remember tools like "Kings Play Chess Or Feed Growing Sparrows" to assist in remembering the classification hierarchy of Kingdom, Phylum, Class, Order, Family, Genus, and Species?

WEB DISCUSSION
Psychological Tools

Psychological tools are the culturally developed signs used in mental and social activities that help mediate our actions. They include things like “various systems for counting; mnemonic techniques; algebraic symbol systems; works of art; writing; schemes, diagrams, maps, and technical drawings; all sorts of conventional signs, and so on” (Vygotsky, 1981, p. 137, cited in Cole & Wertsch, n.d.). Provide a short list of some other examples of psychological tools.

The Teacher's Role in Cultural Mediation

Our role as teachers is also to promote cultural mediation. So how do we do this? Vygotsky observed that mental tools, such as our tools and signs, are representative of our culture and are unique to humans. He proposed that although all animals share mental behaviors such as attention and perception, which are lower or biological forms, it is cultural mediation that provides a level of understanding that separates human thoughts from those of other animals. This higher order thought process is thought of as cultural mental behavior, as opposed to the natural mental behavior common to all animals (Vygotsky, 1981).

Vygotsky explained that the specific knowledge gained by children occurred through social interactions with teachers, parents, and other adults. These interactions represented the shared knowledge of a culture. It is cultural mediation that accounts for the child's construction of his or her knowledge, such as our system of symbols, speech patterns, and writing that represent our language the habits of the culture that guide our everyday behavior, and tasks such as the ability to use a balance beam. The specific individualized knowledge gained by children is reflective of the societal knowledge in this process is known as internalization. It is at this point of internalization that tools can take on a less societal and more individualized nature—much like an artist who uses a paintbrush “tool” to paint an image.

We now see that the main difference between lower biological forms and higher social forms is the shift that occurs from outside control (teacher and peer-supported activity) to self-directed (autonomous) control. Social collaboration is gradually lessened as a child takes on more responsibility for her own learning. To put it another way, the development of higher forms of mental processes occurs through a child's enculturation into society as a result of the educational process. Instruction is a principal source of the child's concepts. For Vygotsky, the stages of concept development reflect a maturation process. Table 2.1 illustrates the stages of concept development from simple labeling of objects to abstract and systemized knowledge of scientific concepts (Dixon-Krauss, 1996).
A Constructivist Approach to Teaching

The Zone of Proximal Development and Scaffolding

The bottom line of our discussion of Vygotsky's theory is its application to science teaching and learning. Can we, as elementary science teachers, maximize science learning by taking advantage of social collaboration? Is group work important in the classroom? Vygotsky noted that when children were placed in groups that were under the guidance of an adult, or when they collaborated with a more experienced peer, they could perform at levels higher than were possible when working on their own. Furthermore, what was possible in the group situation now (i.e., teacher and peer-supported activity) would be possible on an individual basis later (i.e., internalization or autonomous control). Have you experienced this when working with children?

You may have already seen the principles of Vygotsky's theory in action. You notice a child struggling with something, like understanding the metric units of measurement for length on an independent measuring activity. But when placed in a small group, the child is able to work with the team to achieve the desired results. Later on, when completing a subsequent assessment, that child can now measure on his or her own.

Implications for Science Teaching

Social constructivists indicate that the only good kind of instruction is that which marches ahead of and leads development. Instruction must be aimed not so much at the ripe as at the ripening functions (Vygotsky, 1962). So with group or teacher assistance, a child's instruction should always be slightly ahead of what was possible for that child on her own level. If the student can already complete a classification based on two properties, but not on three, instruction should be directed at classifying with three properties under the guidance of the teacher or learning group.

For example, a student may be able to perform a dichotomous classification of representative species that are either animals or plants. This same child may not be able to classify representative species into plants, vertebrate animals, and non-vertebrate animals unless assisted by peers or the teacher. This type of situation is common since elementary-school students view only vertebrates as animals, a much more restricted meaning than biologists have for the word animal. The important thing to remember is the positive influence of another person or group in the learning process.

The term zone of proximal development is used to indicate the difference between what a child can do with the help of a more knowledgeable person and what the child can do independently (Vygotsky, 1978). The goal of instruction is to actively engage the student in solving problems within the zone of proximal

### TABLE 2.1 Vygotsky's Stages of Concept Development

<table>
<thead>
<tr>
<th>Heaps</th>
<th>Child groups objects into random categories.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complexes</td>
<td>Traits of objects are analyzed and concrete factual relationships among diverse objects are established.</td>
</tr>
<tr>
<td>Potential Concepts</td>
<td>Transition from the concrete and spontaneous to the abstract and scientific concept.</td>
</tr>
<tr>
<td>Genuine Concepts</td>
<td>Abstract and systematic concepts that are common to culture.</td>
</tr>
</tbody>
</table>

Source: From Table 1.1, p. 12, *Vygotsky in the Classroom* by Lisbeth Dixon-Krauss. Copyright © 1996 by Longman Publishers USA. Reprinted by permission of Addison-Wesley Educational Publishers Inc.

TEACHING TIP

The Cooperative Learning Center

Google the "Cooperative Learning Center at the University of Minnesota" for an overview of cooperative learning.
development. The teacher’s role is that of a facilitator or mediator. The teacher provides an environment where learning in the zone of proximal development is maximized. The teacher acts as a scaffold and provides just the right amount of support to accomplish the developmental goal.

Alternatively, the teacher can arrange a cooperative learning group in which another student will be the knowledgeable other. The “scaffolding” support that a teacher provides is analogous to the scaffolding that painters use. The painter may reach many areas independently, but when he cannot reach an area on his own, he requires a scaffold to assist in performing the task. Correspondingly, painters would not use scaffolding to paint a baseboard or lower wall. The implication here is that the teacher should not provide more guidance than is needed for developmental support; too much support will not promote the development of independent thought in children.

Let’s look back at our example with Willie the Hamster. Notice how Ms. W. guides the discussion as she involves the class in forming questions and designing investigations. What does she do when the class initially covers the watering can and then determines that Willie did not drink the water? Ms. W. is cognizant of the misconception and guides them into thinking about the results of the activity in another way. Later, she again guides them into an activity on the effect of warmer air as a way to reinforce the concept of evaporation. In these situations, Ms. W. is scaffolding the activity. The students are able to learn by working in their optimal ability level; their zone of proximal development. All of the students are involved in a collaborative way and each student was given equal opportunity to learn and contribute to the discussion and activity.

Without explicitly stating it in the story of Willie, Ms. W. was also building positive attitudes toward science and scientific inquiry. This is evident in her children’s wanting to investigate and derive answers to their questions. The NSES reflect your role in developing this type of classroom environment in Teaching Standard E.

Collaborative learning and thinking, as seen with the Willie the Hamster activity, is the foundation of Vygotsky’s theory but is also consistent with the scientific community’s approach to investigations. Think about how scientists, engineers, physicians, computer technicians, and other professionals carry on activities within the workplace. Do they work independently or as a team? Could a particle physicist work independently or does he rely on teams of scientists, computer programmers, and mathematicians from many countries designing, building, and operating particle accelerators, collecting, storing, and transmitting data generated, and developing algorithms to analyze the tremendous amount of data stored in huge computer farms? Likewise, does your family physician imply that to be effective, she must know the answer to every question and not rely on others?

Teamwork is an important aspect of learning. It is also a twenty-first-century skill. The Partnership for 21st Century Skills (2004) identifies “working creatively with others,” “interacting effectively with others,” “working effectively in diverse teams,” and “collaborating with others” as some of the essential skills to succeed in work and in life during the twenty-first century.

Collaboration is the very means by which a child learns the fundamentals of society. It is the method of moving from lower learning to higher learning and is the system by which activities within a child’s zone of proximal development are successful. Scientific experimentation and problem-centered activities, or those that have multiple solution paths, provide the
Much like scientists and engineers engaged in collaborative research, your interactions with students will promote learning. Like the physician who must consult on many cases, you will not be an expert in all areas and will rely on others, including students, to assist you in knowledge acquisition. Also similar to the doctor who cannot be available at all times for every patient and employs the help of nurses, technicians, and others, you cannot be available at all times for every student and will need to get assistance. This may be in the form of a room mother, cross-age tutor, or even the students themselves. These knowledgeable others will assist in the scaffolding process, communicating the terminology and processes to their peers.

The Role of Language

We know collaboration is important, but what is the role of language? Because language is central to Vygotsky’s theory, it is important that students understand and use the “language of science.” Constructivists generally agree that discourse is especially important in negotiating meaning and developing socially agreeable constructs. Therefore, open-ended questioning is important before, during, and after activity periods. This can be especially difficult for English Language Learners (Fathman & Crowther, 2006; National Science Teachers Association, 2001).

Science itself is likened to a foreign language—one with comparatively more new terms than found in a Spanish, French, or German language text. Social constructivist theory suggests that a child constructs an understanding of language from the whole to its parts. If this is the case, then the elementary classroom should surround children with stories and trade books on science topics so that the children are exposed to the content of science through a whole language or integrated approach to learning. Vocabulary should remain in the context of what is read; it should not be encountered as a separate, out-of-context, memorization drill. We will discuss ways to augment your teaching for English Language Learners (ELL) in the section on linguistic diversity on page 120.

Learning science can also be especially difficult for minorities who do not have a strong command of the language. As Jay Lemke (1990) puts it,

It is not surprising that those who succeed in science tend to be like those who define the “appropriate” way to talk science: male rather than female, white rather than black, middle- and upper-middle-class, native English speakers, standard dialect speakers, committed to the values of Northern European middle-class culture. (p. 138)

WEB DISCUSSION

Science Buddies

Read the Science and Children article on “Science Buddies” (Potenza, 2003). Comment on the success of using science buddies to promote the language of science.

If science is truly to be for all children, we need to be deliberate in making sure activities promote social interaction and encourage language development related to science. We cannot overemphasize that presenting facts and vocabulary out of context will be detrimental to science achievement and positive attitudes toward science. Science instruction should be a model of how science is performed by scientists. Table 2.2 presents further suggestions for teaching within a social constructivist framework.
Driver, Asoko, Leach, Mortimer, and Scott (1994) sum up the learning of science as follows:

[Science learning] involves being initiated into scientific ways of knowing. Science entities and ideas, which are constructed, validated, and communicated through cultural institutions of science, are unlikely to be discovered by their own empirical enquiry; learning science thus involves being initiated into the ideas and practices of the scientific community and making these ideas and practices meaningful at the individual level. The role of the science educator is to mediate scientific knowledge for learners, to help them to make personal sense of the ways in which knowledge claims are generalized and validated. (p. 6)

As you can see, this approach to teaching and learning has important implications for you as a teacher. You will need to plan in a way for your students to construct new knowledge within a sociohistorical framework.
**Curricular Models**

Constructivist curricular models describe the learning process in terms of the student—not the teacher or content. As you can imagine, it is not possible to prescribe an individual curriculum for every child, or even for every teacher. Notwithstanding, when students are actively engaged, they are constructing knowledge. Learning is taking place, not as a result of the transference of knowledge from teacher to student via text or a personal knowledge base, but as students interpret and make sense of their surroundings. This new interpretation is influenced by their prior knowledge and present activities.

It is the teacher’s role to facilitate activities that will guide the learner into developing meaningful concepts. Our way of facilitating the learning process is through the use of the 6E instructional model. In Table 2.3 we see how the 6E model promotes inquiry-based science consistent with how children learn.

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**TABLE 2.3 Inquiry and the 6E Model**

<table>
<thead>
<tr>
<th>Engagement</th>
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<tbody>
<tr>
<td>• The children are presented an interesting question to explore with their peers.</td>
<td></td>
</tr>
<tr>
<td>• Children develop their own questions to explore based on the group’s activity.</td>
<td></td>
</tr>
<tr>
<td>• Spontaneous concepts and other prior knowledge are recalled as a bridge to new activity.</td>
<td></td>
</tr>
<tr>
<td>• Initial assessment by the teacher can identify the level of scaffolding required related to the forthcoming exploration.</td>
<td></td>
</tr>
<tr>
<td>• Children’s curiosity is promoted, not subdued, thus gaining their attention and willingness to accept your invitation to learn.</td>
<td></td>
</tr>
<tr>
<td>• There are distinct improvements in cooperative learning since children are enthusiastic about learning.</td>
<td></td>
</tr>
<tr>
<td>• Children are encouraged to try out new ideas that are generated.</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>E-learning</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Online collaboration with other school children, scientists, or others, can be used to generate questions to explore.</td>
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</table>

<table>
<thead>
<tr>
<th>Exploration</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cultural mediation helps children to form new concepts or modify existing spontaneous or scientific concepts.</td>
<td></td>
</tr>
<tr>
<td>• Children work within the zone of proximal development as they explore questions developed in the engagement phase.</td>
<td></td>
</tr>
<tr>
<td>• Children may view themselves as scientists who are engaging in the scientific process, thus promoting positive dispositions.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>E-learning</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Technology such as Internet chats and simple podcasts can be used to guide children in designing and conducting an inquiry activity or in bridging prior knowledge to the new ideas.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Explanation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Students individually restructure spontaneous concepts and prior scientific concepts to form new Vygotskian scientific concepts.</td>
<td></td>
</tr>
<tr>
<td>• Verbal exchange promotes psychological tools and signs to help students to understand concepts and internalize.</td>
<td></td>
</tr>
<tr>
<td>• Positive attitudes toward science are developed as students demonstrate understanding of the answers to personal, peer, and teacher-developed scientific questions.</td>
<td></td>
</tr>
<tr>
<td>• Enhanced skill development also contributes to the child’s self-efficacy.</td>
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</tr>
</tbody>
</table>

(continued)
As a historical context, the 6E model is based on the work of Dewey (1910/1971), who had an approach to science education that generally followed that taken by scientists engaging in their work. Students experienced a perplexing situation, developed questions in the form of a hypothesis as a way to clarify the problem, tested the hypothesis, retested if needed, and then acted on solutions.

Later, the learning cycle approach to teaching science was introduced as part of the Science Curriculum Improvement Study (Barman, 1989; Karplus and Their, 1967). They used the idea of a sequence of "exploration, invention, and discovery." The expression invention was later changed to term introduction and then again to explanation. The term discovery was changed first to concept application and then to elaboration.

Subsequently, The Biological Science Curriculum Study group added a step before the exploration called engagement. They also added a step at the end of the original learning cycle called evaluation (Bybee et al., 2006). The resulting sequence was the 5E Instructional Model of "engagement, exploration, explanation, elaboration, and evaluation" that is consistent with constructivism and the constructivist learning model (Yager, 1991). In order to better see the linkages of inquiry and Vygotsky’s theory to the 6E model, let’s look at the model as it relates to your classroom.

PREPARING FOR INQUIRY IN YOUR CLASSROOM

The 6E model is not only inquiry based, it is also grounded in all of the aspects of Vygotsky’s theory. Think about the headings “Engagement,” “Exploration,” “Explanation,” “Elaboration,” “Evaluation,” and “E-learning.” These are stated in terms of what the student will be doing, not...
a play-by-play for you the teacher. Understanding of this phrase is key, as it is with student learning. The 6E model promotes understanding because it provides a model for in-depth learning as children progress through the stages.

The progression, although not always linear, takes the child from sharing of prior experience, to concept development gained from exploration, to conversations leading to concept development and refinement, to reapplication of the concept in new situations. Throughout the sequence, ongoing assessment is provided by the teacher. Students should also have the opportunity to use technology to support learning and assessment. Let’s look at the stages and some of the key considerations for teachers.

Engage

Were you ever at home working on a project with the radio or television in the background and all of a sudden found yourself stopping what you were doing to divert your attention to an advertisement or special programming? This is the goal of the engagement stage. We want this stage to include attention grabbers. We ask ourselves what discrepant events, curiosity about natural disasters, or interesting problem to solve will engage the child’s reticular activating system—the part of the brain that controls attention. These attention activities do not have to be elaborate.

For example, a student standing with her heels against the wall and her feet together tries to pick up a dollar bill placed about a foot in front of her feet and finds that she cannot pick up the dollar without bending her knees or moving her feet. Or, the entire class is drawn to your demonstration when you fill a glass tumbler with water, place an index card on top of the glass and then while keeping your hand on the card, quickly invert the glass and remove your hand (try it with someone to see if it catches his attention).

Although the initial dialog may start out almost mundane from your perspective, you will lead the class into an edge-of-their-seat attention as the curiosity culminates and you transition into the exploration phase. Keep in mind that children should have ample time to share experiences for two reasons. First, you want them to activate their own prior knowledge base, which will become the foundation on which they will mentally build the new experiences. Second, you will informally assess their knowledge so you know how to better scaffold the experiences in the exploration phase.

Explore

You have just discussed the children’s thoughts about air and grabbed their attention by blasting an air cannon that blew out a candle placed on the other side of the room (see: www.mcrel.org/whelmers/whelm01.asp or Google “MCREL Air Cannon”). It is now time to proceed with an activity that will help develop the NSES Physical Science Content Standard B to understand the properties of objects and materials (NRC, 1996). You want the children to become directly involved in learning that air does have volume and takes up space. You challenge the class to try to put a tissue underwater in the classroom sink without getting the tissue wet. After discussion and brainstorming, they realize that by placing it in a cup and submerging the cup upside down, they are able to put the cup underwater in the sink and the tissue will remain dry.
At this stage, it is important to link any new explanations or terminology to the activity that students have just experienced. They now have a kind of mental hook on which to store the new information such as the term *raptorial* in a description of the front legs of the praying mantid. As you facilitate communication, you also check for misconceptions and assess the children’s level of understanding so you can plan additional experiences as needed or further discuss what occurred during the explore stage. Specific unresolved questions that would lead to new exploration are typically deferred to the elaboration stage.

**Explain**

Today your class is very excited. Despite being several states away, they used the Environmental Scanning Electron Microscope (ESEM) at the University of Illinois at Urbana-Champaign, otherwise known as the Bugscope (Hadley & Korb, 2007) to view some of the bugs they had collected while researching beneficial bugs (http://pests.ifas.ufl.edu/software/det_predators.htm). This was part of a unit based on the NSES Life Science Content Standard C to understand the characteristics of organisms. Your class has discovered the sophistication of the insects as well as some of the unique features of the “beneficial bugs” they were studying.

Your students are now aware of the intricate details of bugs such as the piercing and sucking mouthparts of assassin bugs, the bearded appearance of robber flies, and the prey-grabbing front legs of the praying mantid. It is at this stage that you introduce new vocabulary such as *setae* to describe the hair that forms the beard of protection to the face of the robber fly. Children articulate their thoughts related to observations, newly formed ideas, and answers to their previous questions as you promote discussions.

**WEB DISCUSSION**

**Inquiry Assistance**

The role of the knowledgeable other can extend beyond the classroom. In Kathryn Hadley and Michele Korb’s article *Through the Bugscope* (2007), they discuss how they used the Environmental Scanning Electron Microscope (ESEM) at the University of Illinois at Urbana-Champaign. “Bugscope” is available for teachers to incorporate into their classroom curriculum (see: http://bugscope.beckman.uiuc.edu/ or Google “Bugscope”). You sign up for the program, students catch bugs and mail them to the facilitators, and then the scientists place the bugs on the ESEM and allow the students to control the ESEM while viewing the images online. What other resource people outside of the classroom could act as knowledgeable others?

**TEACHING TIP**

**Kentucky Critter Files**

The Kentucky Critter Files is an online guide to many common insects, spiders, and other arthropods (Google “Kentucky Critter Files”). The University of Kentucky Department of Entomology also has teaching resources for bugs, including a beneficial bug scavenger hunt lesson plan (Google “Kentucky Bug Connection Teaching Resources”).

At this stage, it is important to link any new explanations or terminology to the activity that students have just experienced. They now have a kind of mental hook on which to store the new information such as the term *raptorial* in a description of the front legs of the praying mantid. As you facilitate communication, you also check for misconceptions and assess the children’s level of understanding so you can plan additional experiences as needed or further discuss what occurred during the explore stage. Specific unresolved questions that would lead to new exploration are typically deferred to the elaboration stage.
Elaborate

Your unit started rather unusually. It had been a full moon and one student had noticed that the inside of her Oreo® cookie looked like the moon that night. The students continued to talk about it, and with a little guidance from you, other children were able to scrape parts of the frosting off a few more cookies to resemble different images of the moon they remembered from the past. Taking advantage of the learning opportunity, you extend the discussion into an exploration where the class keeps a daily journal. They record how the moon appears each night (see Figure 2.1).

Each following day, you spent time discussing their observations, recording information on a classroom chart, and confirming their information by checking in with the U.S. Naval Observatory (see: http://aa.usno.navy.mil/data/docs/RS_OneDay.php or search “moon” at the www.usno.navy.mil/ site). After the observations are complete and you have ample information, you discuss the findings with the class. Now you can introduce terminology such as new, waxing crescent, first quarter, waxing gibbous, full, waning gibbous, last quarter, and waning crescent. You also discuss data patterns and compare them to what occurred the previous
month with information you downloaded from the Naval Observatory. You put the new information in context by using the LCD to project the interactive “moon phaser” on the screen (see: www.spaceday.org/index.php/The-Phaser.html or Google “Space Day moon phaser”). From the discussions, new questions have been raised and recorded. It is now time to elaborate on those questions. You start with the prediction of when the next full moon will occur. Students go back to their collected data and look for trends to help answer that question. You show them how to confirm their prediction with other predictions by scientists (http://aa.usno.navy.mil/data/docs/MoonPhase.php).

The elaboration stage of the 6E model is when you expand on concepts and make connections to related concepts such as the phases of Venus (see: http://apod.nasa.gov/apod/ap060110.html or Google “phases of Venus”). You can connect to other content areas such as social studies and full moon names like Full Harvest Moon (see: www.farmersalmanac.com/full-moon-names or Google “Full Moon Names”). The elaboration stage ultimately allows you to validate understandings as children apply what they have learned.

Evaluate

Think back to Pita’s unit on force and motion at the beginning of the chapter. When did she evaluate the children? When did assessment occur in the Willie the Hamster lesson on page 26? What you find with many inquiry activities is ongoing and embedded assessments. The teacher is continually assessing understanding, mainly through active questioning. You will assess the class and often change directions to make sure that your children accomplish the necessary skills and gain the key understandings. This can occur at any time and does not need to follow a linear sequence and just occur after activity.

There may be opportunities for a formal evaluation after the lesson. This is usually a way to determine grades and provide a culminating evaluation of the knowledge, skills, and dispositions that the children have achieved. Oftentimes, the evaluation closely matches the engagement and elaboration activities. That is to say, these assessments can be traditional objective or essay tests or more authentic assessments as will be discussed in Chapter 4.

E-learning

As you can see, E-learning was incorporated throughout the discussion of each of the five phases of the model. Much like assessment, it is most effective when used on an ongoing basis and within context. There will be occasions, though, when you will want to focus on E-learning, such as taking time out to review software, discuss appropriate Internet searching, or provide skills in using productivity software. We will see other possibilities for E-learning as we investigate more about planning for inquiry in Chapter 3.

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SUMMARY

1. The zone of proximal development is the gap between a child's current level of development and the child's potential level of development when supported by collaboration with a more capable peer. Scaffolding is when an adult first structures a learning task and then provides the dialogue needed to guide a child's successful participation in that task.
2. Peer tutoring, when a high-achieving student tutors a lower-achieving student, is an excellent application of Vygotsky's theory.
3. A constructivist approach implies that the use of a variety of activities in the classroom promotes a child's making sense of the world and developing scientific concepts.
4. The 6E model can help you to prepare for inquiry in your classroom.

REFLECTION

1. Briefly describe a recent lesson that you have taught as part of your field placement. Was the lesson in keeping with the theory of the zone of proximal development? Explain why or why not.
2. Using the 6E instructional model, describe a science lesson for a kindergarten class.
3. Wiki Development: Log onto your instructor's course wiki and create a page on the following topics:
   - Group 1: Inquiry as a Paradigm for Teaching and Learning
   - Group 2: Inquiry by Scientists as Compared to Inquiry by Students
   - Group 3: Overview of Constructivism
   - Group 4: Vygotsky's Theory of Constructivist Learning
   - Group 5: Spontaneous and Scientific Concepts
   - Group 6: Psychological Tools
   - Group 7: Zone of Proximal Development
   - Group 8: Scaffolding
As this is my first year of teaching, my children are in a Title I school struggling to meet No Child Left Behind Annual Yearly Progress, and that science is now being tested as part of the Florida Comprehensive Assessment Test (FCAT), I knew it was imperative that I plan successful activities in science that would be engaging to students and optimize their learning and progress toward meeting the Florida Sunshine State Standards. Today I am having a body bubble festival (see Barber & Willard, 1992; Wiebe, 1990). It sounds like fun from a student’s point of view, but for me it is the culmination of planning based on the Grade Three Big Idea of “The Practice of Science” and the subsequent benchmark “infer based on observation” (Florida Department of Education, 2008). Our challenge will be to make a body bubble that will enclose a student completely. The objective is to have the students observe bubbles and infer the effect of adding glycerin to our bubble base solution that is formed by adding 3 liters of warm water to 200 ml of non-glycerin-based dishwashing detergent.
To begin my planning, I first thought through the learning goal. In this case, I wanted the students to understand the difference between observation—accurately and repeatedly using the senses and instruments to examine and measure an object in order to describe an object’s attributes and any changes in that object—and inference—interpretation of the observations and patterns of change based on prior knowledge, experience, and the current observations. At this point, I asked myself, “What is it that the students should know about an observation and an inference?” and, more important, “What is the difference between observations and inferences?” The key understanding would be that observations are simply pieces of collected information and that an inference is new knowledge based on interpretation of current observations and one’s prior understandings. In assessing students on a previous activity, I also knew it would be important to include development of prediction skills along with inference skills.

Next, I thought about how I would know that the students know. What ways could they show me that they understood the concepts and could perform the skills? First, I would want the students to be able to explain, in their own words, what it means to observe something and how an inference could be formed based on those observations. Likewise, they should be able to differentiate an inference from an observation with a prediction and accurately provide an inference and prediction based on the activity. I also reflected on a way they could independently reproduce the activity and check for transfer of their knowledge.

**Engagement**

I then set about designing the activity based on the objectives and assessment plan that I already developed. I first considered what type of inquiry activity would be useful to help students discover the difference between observation and inference and came up with making bubbles. We would begin with a small plastic pool of the bubble solution without glycerin and see if we could form a bubble that lasted long enough to surround the child. Having tested this at home, I knew that we would need glycerin to produce a lasting bubble. As an engagement, the children would be challenged to use the bubble solution and hula hoop to produce a bubble that would be able to surround them.

**Exploration**

Ultimately, I would guide them through the exploration based on the engagement challenge. I would set out the materials that the class could use in their experiment and guide them into the development of a research question and related procedure that would include adding increasing amounts of glycerin (such as 25, 50, 75, and 100 ml) and observing the height that the forming bubbles reached when we used a hula hoop lifted straight up from the pool.

**Explanation**

As we reached the bubble goal, we would stop and provide an explanation as to what was occurring. We would also discuss qualitative observations of the bubble as well as quantitative observations of increasing heights. At this point, we would also check for understanding of inferences based on the observations.

**Elaboration**

The elaboration activity would be to place the students individually on a step stool in the center of the pool and form a bubble around them. They would observe what it was like to be in a bubble and comment on the experience while I noted whenever they would describe an inference or prediction as opposed to an observation.

**Evaluation**

To further provide evidence that the students understood the concepts, I also thought of an evaluation application question that they could try at home. I provided an empty milk jug to measure equal amounts of water and a small amount of glycerin and non-glycerin-based dish detergent in a small, labeled, plastic bag. I asked the students to design an activity to demonstrate the effectiveness of a bubble solution when washing their dishes at home. I was looking for evidence of their ability to “infer based on observation” as they described their observations. I anticipated statements such as “with a gallon of warm water and the non-glycerin soap, the soap
bubbles lasted for washing dishes for 5 minutes” or “we began with one centimeter of suds when we used the glycerin soap” versus inferences like “not having glycerin in my soap only allowed me to wash dishes for 2 minutes” or predictions such as “if I put glycerin in the car wash, it would last longer when washing the car.”

**E-learning**

As an extended activity to infuse E-learning skills and further have the class think about their observations, inferences, and predictions, I would have them form their own teams and research dishwashing soap and bubbles on the Internet at a classmate’s house, the local community center, or branch library. They could explore substitutes for glycerin such as corn syrup, reveal some novel uses for dish soap such as the use of Dawn® to save wildlife after San Francisco’s oil spill, and generally find out about the properties of bubbles from sources such as the Exploratorium (see: www.exploratorium.edu/ronh/bubbles/bubbles.html or Google “Exploratorium bubbles”).

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**PLANNING INQUIRY EXPERIENCES**

In the Inquiry by Design vignette, Matt guides his class through a lesson on body bubbles. Think about how you would plan for a similar inquiry activity in your own classroom. You would probably ask yourself questions similar to what Matt considers as he prepares for an inquiry activity. “Why is this lesson important?” “What standard do I need to address with my class?” “Will the students have an opportunity to learn a meaningful concept and/or skill through this inquiry?” “How will I know that the children understand the concepts?”

In order to optimally promote inquiry-based learning, Matt plans his bubble activity consistent with the 6E model that was introduced in earlier chapters (Engage, Explore, Explain, Elaborate, Evaluate, and E-learning). There is one significant twist, however. Matt does not jump right into planning the actual engagement portion of the lesson. Despite the fact that starting from the beginning may be the way you would intuitively think to plan, there is actually a better way. Matt uses the backward design process highlighted by Wiggins and McTighe (2005). This method of preparation naturally complements the 6E model and involves three stages:

- **Stage 1: Desired Results**
- **Stage 2: Assessment Evidence**
- **Stage 3: Learning Plan**

Let’s consider each of these stages in more detail, beginning with the desired results.

**WEB DISCUSSION**

**A Backward Approach to Inquiry**

Look up and read Sher Hendrickson’s January 2006 *Science Scope* article titled “A Backward Approach to Inquiry.” Summarize the successes and difficulties that were associated with the use of the backward design model.

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**Desired Results**

Working backward may not be a novel idea when you put it in a different context. Think about when investors want to build a new building. Do they begin the planning by hiring the concrete contractors to start to lay the foundation? Rather, they hire an architect who can envision the resulting building based on his or her knowledge of overall engineering and construction standards and local regulations. The architect begins by checking with the investors to see what they want as an end use result for the structure and available resources.
Likewise, your first step in planning is to consider what you want students to understand as a result of the inquiry opportunity you will create for your class. Similar to the construction codes adhered to by the architect, you will be guided by the state and local educational standards. Your locally used standards will be reflective of the NSES as suggested by the authors of the *Practice of Science Education Standard*.

You will probably begin to plan by asking yourself, “Why spend time on this particular standard?” and “Will it really help the class to study this topic?” Again, this is the big picture of what you want to happen in the classroom. Keep in mind that, as Matt mentioned in the start of his account, you will ultimately need to address a set of standards that are in place to guide your school’s curriculum since these standards are linked to the state’s assessment system under *No Child Left Behind Act* (NCLB, 2002).

Architects find that building codes vary by state and city. Likewise, the level of detail, use of knowledge and/or performance indicators, and timing or progression of educational standards varies among the states. Even within a state, the use of the standards can deviate among school districts. You should know that there may be districts that leave almost all of the curriculum sequencing and lesson planning up to you. On the other end of the spectrum, some districts are so specific that every classroom may be working on the same topic, and even the same lesson, on any particular day.

Whichever standards are used in your school, what you are ultimately looking for in Wiggins and McTighe’s desired results stage are ways to build the enduring understandings that are at the core of science education. You will want to sort out what the class already knows and those understandings and skills that still require additional exposure for your class to better attain the standard and be successful on the related assessment.

Also consider the match between the standard and your children. Would an architect design a 100-floor-plus skyscraper for a suburban neighborhood or a sprawling ranch house in the middle of a large city business district? Consistent with the NSES Appropriate Program of Study Standard, you are looking for those understandings and skills that your class will be developmentally ready to learn; those that you will ultimately be able to use to actively engage your class in learning as part of the 6E model.

How did Matt specifically determine what his children needed to learn? Even before he planned the first lesson, he became familiar with his state’s standards and reviewed information related to the state assessment. He found that, under the *No Child Left Behind Act of 2001* (2002), science was required to be administered at the elementary level beginning in the 2007–2008 academic year. Matt also looked for other information such as the test design information, sample items, and if the test corresponded to the standards.

Again, narrowing the focus to the lesson described in Matt’s chapter-opening *Focus on Inquiry*, we see that he begins his planning with the big idea standard of “The Practice of
Science.” This overarching standard could have many meanings, so further refinement is needed. One of the benchmarks for this standard is “infer based on observation.” This is exactly what he needs to stress with his class. With this benchmark in mind, he then asks himself what big-picture understandings, essential questions, and potential misconceptions are related to the benchmark (Wiggins & McTighe, 2005).

Next, Matt contemplates what his children will need to understand in order to discriminate between an observation and inference, noting that a prediction may also be important to the understanding since there is generally some confusion between inferences and predictions. He also wants the children to understand the connections between observations, inferences—that look backward to explain observations that have already occurred—and predictions—which look forward to predict a future observation.

As part of the desired results in Wiggins and McTighe’s Stage 1, Matt first considers some big-picture questions as to why it is important to study this topic, such as:

- What scientific skills are essential in “The Practice of Science”?
- Why would it be important for my students to know what an observation is or how to use tools to extend the senses and make more accurate observations?
- Is the ability to make careful observations important in other areas such as mathematics?
- Is it important to the scientific enterprise to be able to interpret observations in the form of an inference?
- Are inferences important outside of science, such as inferring meaning from a selected reading passage?

From these questions he develops some more refined benchmark-related essential or guiding questions. For example:

- What is the scientific process of observation?
- What is scientific process of inference?
- What is scientific process of prediction?

He may restate the questions in the form of related understandings, such as:

- The students will be able to understand that observation, inference, and prediction are related but separate processes.

Matt also identifies one or two essential skills that the children should be able to perform, such as:

- The students will be able to measure the size of a bubble with a meterstick.
- The students will be able to accurately record their observations on the chart provided.

In summary, the desired results stage of planning provides the basis for determining what students will know and be able to do as a part of the lesson. In this case, as a result of the body bubble inquiry, Matt’s children should ultimately know what an observation is, what an inference is, and why observations are needed in order to form inferences and predictions. They should also be able to use their senses and metersticks to collect observational data related to bubble height and then use observed data to form valid inferences and predictions.

Now let’s move on to the next stage of backward design. We will consider the assessment evidence that will tell us if students have achieved the desired results.
Assessment Evidence

Following Wiggins and McTighe's Stage 1 of desired results is Stage 2 of the backward design model where the teacher develops the assessment evidence (2005). This is not unlike what an architect must do in his or her predesign or planning role. Throughout the period when the building is built and ultimately when it is completed, there will be ongoing checks related to adherence to zoning laws, compliance with fire safety standards, tests for structural integrity, and an evaluation of the ongoing cost to be sure that it is built efficiently and within budget. How these checks will be performed is considered before construction begins and after the initial client discussion of the objectives, requirements, and fixed budget of the project.

WEB DISCUSSION
Professional Planning

How does the proposed assessment evidence suggested above fit our education backward design planning? This is where we again refer back to the 6E model. Although generally illustrated as a linear model from engagement, to exploration, to explanation, to elaboration, to evaluation, to E-learning, we know that it is advantageous to begin by planning the evaluation criteria much like our architect would with the building.

We then work backward to plan how to engage the learners and explore new concepts. There is a benefit in clearly defining final learning outcomes assessed in the evaluation phase of the 6E model. As you plan, you can refer back to the standards and outcomes to be sure the lesson you are developing is consistent.

It is also beneficial to establish ways to incrementally assess the child throughout the other phases of the model. For instance, in the engagement phase, it is important to assess the learner's prior knowledge. By beginning with the ending learning goal in mind, we can better orchestrate an activity. Subsequently, we will promote curiosity with the children as they engage in meaningful activity. Likewise, we will elicit prior knowledge that can be assessed in light of the ultimate learning goal. Developing questions to explore, or activities in which students can develop their own questions to explore, is easier when you know where you are trying to guide the exploration in terms of a final learning outcome.

Let’s look back at Matt’s lesson to better understand the notion of starting with the resulting assessment evidence when planning a lesson. He wanted his students to be able to explain, in

TEACHING TIP
Developing Questions to Explore Through Children’s Literature

Children’s literature can be an excellent source for interesting and developmentally appropriate questions to explore. Check with your school’s media specialist or the local library. Oftentimes they have books or a pre-established list of potential books on hand, or they will actually create a list to help you narrow your focus. The National Science Teachers Association publishes an annual list of outstanding trade books (go to www.nsta.org and search “outstanding trade books”).

Science Class is another source for literature ideas. This monthly e-mail newsletter delivers theme-based content to teachers in elementary, middle level, and high school. Included are news articles, SciLinks, journal articles from the NSTA archives, and appropriate books to support each theme.
their own words, what it means to observe something. As part of this, the children would indicate that they use their senses to observe and that measurement can extend the senses in information gathering. He also wanted them to make an inference as to what effect the glycerin had on the bubbles, keeping in mind that the inference would be an interpretation of existing data. Finally, he wanted the class to be able to develop a prediction based on data. The prediction would indicate a future possibility based on current data such as “if the amount of glycerin in the bubble mixture were to be doubled, the bubble would be much larger.”

At this point, Matt begins to formalize his thoughts and draft out a little assessment rubric. He lists essential components of the skills as seen in Figure 3.1. This rubric will be used on an ongoing basis throughout the lesson.

Along with the assessment rubric, Matt would also use the activity that was assigned to be done at home during the 6E evaluation phase. This would be a final assessment to check if students could accurately describe observations and form inferences and predictions. Children’s self-assessment would also occur as they compared measurements and observations throughout the lesson.

### Learning Plan

Stage 3 of the Wiggins and McTighe backward design model is to create the learning plan based on the desired results and predetermined assessment evidence (2005). This is where we plan out the Engage, Explore, Explain, and Elaborate phases of the 6E model and supplement
the lesson with appropriate E-learning opportunities. Before we start with our planning though, let’s think about what might be different about the plan based on the synergy of the backward design and 6E models.

WEB DISCUSSION
6E and WHERE TO

The Wiggins and McTighe backward design model (2005) includes the WHERE TO elements of instructional planning.

- W – Ensure that students understand WHERE the unit is headed, and WHY.
- H – HOOK students in the beginning and HOLD their attention throughout.
- E – EQUIP students with necessary experiences, tools, knowledge, and know-how to meet performance goals.
- R – Provide students with numerous opportunities to RETHINK big ideas, REFLECT on progress, and REVISE their work.
- E – Build in opportunities for students to EVALUATE progress and self-assess.
- T – Be TAILORED to reflect individual talents, interests, styles, and needs.
- O – Be ORGANIZED to optimize deep understanding as opposed to superficial coverage (pp. 197–198).

Compare Wiggins and McTighe’s elements of instructional planning (WHERE TO) to the 6E model (Engage, Explore, Explain, Elaborate, Evaluate, E-learning). Provide examples of similarities and differences between the two approaches to planning.

By focusing first on the learner’s achievement of the standards, and then carefully planning ongoing assessments, we place our emphasis on the learner. This approach eliminates simply following a predefined yearly curriculum from the beginning to whatever point we may reach at the end of the school year. Likewise, using backward design and the 6E models prevents the content of textbook chapters from arbitrarily driving the planning process. The once predominant “read the chapter—complete the worksheet—take a test” method does not take into account the children’s developmental levels, their interests, and, most important, their successful learning of the primary enduring understandings. Given the very limited amount of time you will have in the classroom, it is important to target what students actually need to know.

We realize that changing the focus from the teacher to the learner has implications. The amount of teacher direction and control of the outcomes will be reduced in proportion to the amount of student control and outcomes of their self-directed activity. In short, they are in control of their learning.

Does the idea of a loss of control make you a little nervous? We understand that this is often a philosophical shift for many teaching candidates, as well as some experienced teachers. What many teachers find is that, by enthusiastically engaging the children, classroom management actually becomes much easier. Students truly want to learn when they are actively engaged in inquiry.

At this point you may be asking yourself what a lesson might look like from a student’s point of view. What changes when the process of planning shifts from our teaching to the child’s learning? The National Research Council’s Inquiry and the National Science Education Standards (2000a) lists some essential features of classroom inquiry as reflected in Table 3.1. Does this illustration help show how the focus is not on what you are doing, that is, lectures, demonstrations, or chapter read-alouds, but what the child is undertaking? Again, this approach reconfigures your role in the classroom to that of a facilitator and coach who is there to provide an opportunity to learn.
CHAPTER 3  Planning for Inquiry

### TABLE 3.1 Essential Features of Classroom 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 explanations in light of alternative explanations, particularly those reflecting scientific understanding.
- Learners communicate and justify their proposed explanations.

*Source: From Inquiry and the National Science Education Standards: A Guide for Teaching and Learning (p. 25). Copyright © 2000 by the National Academies of Sciences, Courtesy of the National Academies Press, Washington, DC.*

### A Learner’s Perspective

Put yourself in a child’s role and let’s wander through some classrooms where students are observing the classification of leaves. First you encounter a classroom where the teacher is telling the class about the properties of leaves such as simple leaf patterns or compound leaf patterns. She holds up a picture of a leaf to represent each category. You stay for a minute but then wander to the next room.

Here, you find the same lesson from a little different perspective. As you look around the classroom you see your classmates busily sorting leaves in small groups. They have a sorting grid in front of them that was carefully labeled by the teacher according to predetermined properties of ovate, obovate, elliptic, or oblong shapes. Occasionally, the teacher asks a small group why they placed a certain leaf in a particular section. This looks interesting but you move on to another classroom.

After taking a nature walk to collect leaves and draw images of how the leaves appeared on the branches, the teacher simply challenges the class to “sort them out.” Later she will guide them into thinking about why they chose particular characteristics to sort the leaves and if there could be other ways to sort. Once they are familiar with the properties of the leaves, the teacher begins to introduce the vocabulary. She connects the vocabulary with the pictures (i.e., simple and compound leaf patterns; pinnate, bipinnate, palmate, trifoliate leaf patterns; alternate, opposite, whorled leaf arrangements) and the student grouping of leaves according to properties (i.e., ovate, obovate, elliptic, or oblong shapes and entire, dentate, serrate, compound serrate, erose, or crenate margins).

Can you think of how these same teachers might approach the study of earthquakes? Which scenario will optimally involve the students in inquiry?

What you experienced in these imaginary classrooms was the continuum of what inquiry would look like from a learner’s perspective. The first example clearly has the teacher leading the way. In the third example, the class is steering the direction of the lesson. As seen in the NSES Inquiry Teaching Standard, the teacher’s role is to design and facilitate the explorations that will promote conceptual change.

Table 3.2 provides examples of how increasing the amount of learner self-direction, as seen in moving left on the chart, decreases the amount of guidance provided by the teacher. We realize that it would be very difficult to immediately move all classroom activities to the left of the chart; often called *open inquiry*. Analogously, we would not want to consistently maintain increased control over the lesson; generally referred to as *guided inquiry*.
Inquiry Teaching Standard

Teaching Standard D

Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science. In doing this, teachers

• Structure the time available so that students are able to engage in extended investigations.
• Create a setting for student work that is flexible and supportive of science inquiry.

• Ensure a safe working environment.
• Make the available science tools, materials, media, and technological resources accessible to students.
• Identify and use resources outside the school.
• Engage students in designing the learning environment.

Source: NRC, 1996, p. 43.

TABLE 3.2 Essential Features of Classroom Inquiry and Their Variations

<table>
<thead>
<tr>
<th>Essential Feature</th>
<th>Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner engages in scientifically</td>
<td>Learner poses a question</td>
</tr>
<tr>
<td>oriented questions</td>
<td></td>
</tr>
<tr>
<td>Learner gives priority to evidence in</td>
<td>Learner determines what constitutes evidence and collects it</td>
</tr>
<tr>
<td>responding to questions</td>
<td></td>
</tr>
<tr>
<td>Learner formulates explanations from</td>
<td>Learner formulates explanation after summarizing evidence</td>
</tr>
<tr>
<td>evidence</td>
<td>Learner independently examines other resources and forms the links to</td>
</tr>
<tr>
<td>Learner connects explanations</td>
<td>explanations after summarizing evidence</td>
</tr>
<tr>
<td>to scientific knowledge</td>
<td></td>
</tr>
<tr>
<td>Learner communicates and justifies</td>
<td>Learner forms reasonable and logical argument to communicate explanations</td>
</tr>
<tr>
<td>explanations</td>
<td></td>
</tr>
</tbody>
</table>

Source: From Inquiry and the National Science Education Standards: A Guide for Teaching and Learning (p. 29). Copyright © 2000 by the National Academy of Sciences, Courtesy of the National Academy Press, Washington, DC.
What is needed is to match the desired results and evidence from the backward design model to an appropriate level of fully open through mostly guided inquiry.

Now, let's mentally go back into Matt's classroom from the chapter opening Focus on Inquiry. Do you notice how Matt guided his class through the challenge to “use the bubble solution and hula hoop to produce a bubble that would be able to surround you” to begin his activity? Looking at Table 3.2, where would this fit on the chart? At one point, he stops the activity and allows students to provide an explanation as to what was occurring. Where does this fit in the continuum?

### DEVELOPMENT OF A 6E LESSON

Now that you are more familiar with the desired results, assessment evidence, and learning plan stages of the backward design model, let's look at how an actual lesson would be planned in the 6E model. We are going to use the *Bartholomew and the Oobleck* story as a basis for our lesson (Geisel & Geisel, 1949/1977). Take a few minutes to carefully look over the lesson before we break it down into the 6E parts.

#### LESSON PLAN

**Exploring a Mixture**

- Children can become scientists as they explore the world around them. When they encounter a new situation, they can observe, classify, measure, infer, predict, communicate, and experiment to solve problems and gain new information or ideas. Children's curiosity is stimulated as they complete activities.
- This activity is designed to acquaint children with a substance that does not behave similarly to other substances. Specifically, the mixture gets harder as it is manipulated and softer when it is left alone. This is in direct opposition to materials such as Play-Doh or a similar mixture.

### Backward Design Stage 1: Identify Desired Results

**Science Themes**

- **Systems**: Mixtures are physical/chemical systems made up of molecules that interact with each other and the environment. To understand the nature of the substance, we must consider its behavior as an integrated system composed of interacting parts and energy.
- **Models**: In considering the way molecules or atoms are arranged in the mixture, students can create pictorial or mental models of the structure of particular types of matter.
- **Consistency**: Although we can cause temporary changes in a substance by inputting energy in one form or another, students will often notice that the system tends to maintain its properties and reorganize itself into the same physical consistency and structure as before the system was disturbed.
- **Patterns of Change**: Patterns of change are represented through the study of the properties of matter.
- **Scale**: The behavior of a mixture may be caused by scale. Sizes of molecules may allow them to interact in ways that a larger substance cannot.

### Benchmarks for Science Literacy

By the end of fifth grade, students should know that:

- Heating and cooling cause changes in the properties of materials, but not all materials respond the same way to being heated or cooled.
- Things can be done to materials to change some of their properties, but not all materials respond the same way to what is done to them. (AAAS, 2009)
National Science Education Standards
As a result of the activities in Grades K–4, all students should develop

• Abilities necessary to do scientific inquiry.
• Understanding of properties of objects and materials. (NRC, 1996, pp. 121, 123)

Scientific Skills
• **Classification:** Students will compare this substance and other materials in an attempt to classify it according to its properties.
• **Observation:** Students will use all their senses to observe the substance.
• **Inference/Prediction:** Students will infer what the substance is made from by using the collected data of observable properties.
• **Communication:** Students will communicate their findings to the group. They will also communicate with each other when developing theories of why it behaves the way it does.
• **Experimentation:** Students will design and carry out experiments to alter the mixture, to find its properties, and to explain its behavior.

Backward Design Stage 2: Determine Acceptable Evidence

Required Assessments
• Report the findings of your group related to the behavior of the mixture, including your group’s hypothesis, data collected, a summary of collected data, and conclusions using pictures, graphs, and charts.
• Work with your upper grade partner to develop a poem, such as, cinquain or diamante, which describes the substance and its properties.

Optional Assessments
• Take a small amount of a mixture home and ask a parent or friend to provide his or her thoughts on the properties of the mixture.
• Leave a mixture out for 1 week to observe the effect on the substance. Explain what happens to the substance using descriptive adjectives.

Backward Design Stage 3: Plan Learning Experiences and Instruction

6E Model: Engage
• Read *Bartholomew and the Oobleck* (Geisel & Geisel, 1949/1977) and end by discussing what happens with the substance falling from the sky.
• Demonstrate to the class what happens as you knead the premixed substance.
• Materials: Two or three boxes of cornstarch; green food coloring; water; small objects such as marbles, coins, rubber stoppers; other common substances or materials that can be used to explore; thermometers, a safe heat source such as a microwave; a balance; and graduated cylinders.
• Prepare the mixture by placing one or two boxes of cornstarch in a mixing bowl and adding small amounts of green-colored water. Continue until the consistency is like a thick plaster.
• The engagement question is, “What do you notice about the substance?”

6E Model: Explore
• Provide a warning to keep the materials on newspapers on the lab tables. Also provide a caution against tasting the material due to possible allergies.
• Pass out a small amount of the substance to each group in a plastic sandwich bag.
• While students explore, walk around the room and question students about what they are doing, why they are doing it, and what else they can do to gain information about the mixture.

6E Model: Explain
• Halt activity and ask close-ended questions with predetermined answers such as, “What happens to the mixture as you continue to squeeze it in your hands?” (It hardens.)
• Ask open-ended questions such as, “What did you find out about the mixture?”
LESSON PLAN continued

6E Model: Elaborate

- Continue exploration with the cornstarch and water mixture and facilitate a discussion where the children develop a theory to explain why the mixture behaves unusually.
- Alternative Activity: What possible explanations do you think scientists give for the behavior of the substance?
- Discuss scientific theory and why scientists cannot completely agree on why it behaves as it does. Discuss the tentative nature of science theoretical models and their use, and the scientific search for explanations.

6E Model: Evaluate

- See Backward Design Stage 2: Determine Acceptable Evidence.
- Incorporate concept maps if needed.

6E Model: E-learning

- Complete a WebQuest looking for materials that behave the same way as the mixture.
- E-mail a local scientist to ask his or her thoughts on the substance.
- Go online to an “Ask a Scientist” website and seek an explanation for Newtonian and non-Newtonian fluids.
- Go online to Wikipedia and explore Newtonian fluids and non-Newtonian fluids.

Children interact with a cornstarch and water mixture. (Cary I. Sneider/Great Explorations in Science and Math)

Source: Reprinted from the Great Explorations in Math and Science (GEMS) teacher’s guide entitled Oobleck: What Do Scientists Do?, copyright by The Regents of the University of California, and used with permission. The GEMS series includes more than 70 teacher’s guides and handbooks for preschool through eighth grade, available from LHS GEMS, Lawrence Hall of Science, University of California, Berkeley, CA 94720-5200. (510) 642-7771.
Development of a 6E Lesson

Backward Design Stage 1: Identify Desired Results

What things stand out in the lesson plan for you? After reviewing the plan, does it make sense for you to use the backward model to plan a lesson? Will it help to review the steps? We begin the lesson plan with the end—more specifically, the end result. Keep in mind that we would not have the title yet or the overview statement. We save those for last.

Our starting point is Backward Design Stage 1 and our initial focus is, “What do we want the student to achieve as a result of the lesson?” Recently, we noticed that the students are not as familiar with the properties of materials as we would like them to be in accordance with the standards. Additionally, we are concerned that they have not had a consistent engagement in scientific inquiry and need some additional work on their skills.

The Project 2061 themes that we are concerned with are from Chapter 11 of Science for All Americans (AAAS, 1989/1990). These represent what we have identified as additional experiences needed by students based on their past lessons and assessments. Here we have included five of the six themes leaving out the evolution theme, which better fits in other lessons. Although we provide these examples, you will generally have only one or two themes, or, if you are working directly from state standards, you may find yourself not specifically stating themes at all.

Benchmarks for Science Literacy (AAAS, 2009) are the next category. These will closely align with your state standards or may actually be used in your district or school. This is where we begin to focus on what understandings are desired as a result of the lesson. We want students to comprehend that heating a material will cause change in the properties of matter. The NSES are also presented. Again, these will align with your state, district, and/or school standards, or may be the actual guidelines that you use.

Remember that a primary focus is on the children’s ability to engage in inquiry. We are also emphasizing the properties of matter. Finally, our students’ scientific skills are also a concern, and we list some appropriate skills to concentrate on as a result of prior interactions with students. In sum, we have built this section of the lesson plan based on what we saw as the key knowledge and skills needed for our students.

Backward Design Stage 2: Determine Acceptable Evidence

Once we have identified the results, we proceed with how we will know the results have been achieved. This is the Backward Design Stage 2 section of the lesson plan. We brainstorm ways that we can “know that the students know.” What performance tasks or other assessments will we ask students to do to see if they have achieved the desired results or if we need to continue exploring the stated objectives? We start with several assessments that we feel will satisfy our goals from Design Stage 1. Also included are some optional assessments that we can use with individuals or groups depending on how the lesson proceeds.

Notice we did not suggest a standard test here. Since one of our objectives is “abilities necessary to do scientific inquiry,” we want a more realistic measure of our students’ understanding of inquiry. That way we will know what to include in future inquiry lessons. As an aside, we will discuss various, appropriate assessment techniques in Chapter 4.

Backward Design Stage 3: Plan Learning Experiences and Instruction

With the objectives and assessment measures in place, we are ready to plan the actual lesson. We want to start thinking about the engagement since this is how we will mentally hook the students. Asking ourselves what mixture or other matter has an unusual property to catch their attention, we remember the cornstarch and water mixture. We also remember that there is a good resource associated with this mixture that will help in the lesson planning. From here the lesson begins to fall into place.
CHAPTER 3  Planning for Inquiry

Engagement
Our engagement is in two parts. First, we start with a story to prompt students’ prior knowledge and build a foundation for the subsequent activities. Since our story involves an unusual substance, the narrative will begin the thinking process on properties of substances. The actual engagement hook comes as we demonstrate the properties of the cornstarch and water mixture. It looks like a fun substance to play with at first and draws students into the activity.

WEB DISCUSSION
Convergent and Divergent Questions
Convergent questions have predetermined answers and converge on a common, single response. Questions can also have many possible correct answers. These are called divergent questions because they lead to a wide variety of responses and produce divergent thinking. The engagement question in the Bartholomew and the Oobleck lesson plan is, “What do you notice about the substance?” Would you classify this as a convergent or divergent question? Why? Provide one additional convergent and one additional divergent question that could be used as engagement questions in this lesson. Of your two additional questions, which one appears to be more appropriate to the activity—the convergent or divergent question?

Exploration
Although the exploration section in the lesson plan appears to be short, this is really the heart of the lesson. Since we are encouraging inquiry, we do not want to delineate each step of the process or otherwise overly direct the activity. We just start the inquiry session and strategically guide the children. Soon, they will realize the unusual properties. Remember the essential features of classroom inquiry from Table 3.2. We want more learner self-direction.

With the learners in charge of the activity, our role of guide is to move around the classroom, prompting discussion and further inquiry. This type of activity can be described as open inquiry or problem-centered learning. It is opposed to a teacher-centered, well-structured approach to teaching referred to as direct instruction where the teacher employs lectures, worksheets, recitations, demonstrations, or specific-answer type questions in a prearranged sequence. A very detailed exploration section of the lesson plan is generally used for a direct instruction experience since the teacher is very much in control of the lesson.

Explanation
As the students complete their initial explorations, it is time to check for understanding. At this point, we ask a variety of questions that will ultimately guide the elaboration. We are seeking to resolve any remaining misconceptions and reinforce the appropriate concepts. When we look for specific key knowledge points of information, we ask convergent questions that have specific answers, such as, “What do you think is in the mixture?” If we want to have the children explain their overall inquiry activity and related skills, we will ask divergent questions, such as, “What can you conclude about the properties of the cornstarch and water mixture?”

Depending on your level of familiarity with the content, you may want to take some time before the lesson to practice the activity. While doing this, you can develop a set of questions that you can draw from throughout the actual lesson. Try to have a mix of questions that will help focus attention on specific content and skills as well as questions to expand the thought process. Do not forget to incorporate some attitudinal questions that will explore areas such as interest, curiosity, objectivity, flexibility, openness, skepticism, and creativity.
TEACHING TIP

Direct Instruction

Direct instruction is a teacher-centered, well-structured approach to teaching. One advantage of direct instruction is that the teacher can arrange the sequence of activities ahead of time and thus reduce the number of teaching decisions to be made during a lesson. This is especially helpful for teachers who are preoccupied with management issues or who want to be sure they cover a certain curriculum. It is also helpful when introducing a new skill such as classification or learning to use a new piece of equipment.

A disadvantage to direct instruction is that students construct their knowledge at different paces. Therefore, the teacher’s pace may not match the students’. The students are not free to explore topics further on their own when they are interested. They are subject to what the teacher selects as themes or important concepts. Problem-solving and higher-order thinking skills are better developed through a more independent learning situation.

Another disadvantage of direct, or teacher-centered, instruction is that the teacher may have gender, cultural, or other biases that will limit learning for some students. In other words, the students are subject to everything from the teacher’s point of view—not their own. For example, if the teacher unconsciously believes that boys are better suited for science than girls, he may call on boys more often to answer a question or to assist in a demonstration. This behavior reinforces the cultural disadvantage girls have in the sciences (Kahle & Meece, 1994).

Elaboration

Based on the children’s explanations provided in this stage, we will continue the engagement with the mixture. The focus will be on developing enduring understandings. It is helpful to have some alternative activities listed in this section in case you need to substantially change the nature of the inquiry that occurred in the exploration stage.

It is important to use the elaboration stage to resolve any remaining misconceptions. In the cornstarch and water activity, the children may feel that the substance changes because the moisture is absorbed or released by their hands. You will want to guide the children in an activity that will allow them to discover the inconsistencies with their erroneous explanations. What would happen if they wore latex gloves and repeated the activity without any contact with the moisture in their hands?

Evaluation

Evaluation is used to identify those students who have achieved the key knowledge and skills. It is also the basis for determining whether your lesson planning was effective and the direction of future planning. Note that the assessment of this experience should be in keeping with its constructivist nature. Students should be assessed on the product (knowledge), process (skill), and attitude (value) of the experience.

Literature/language activities can become an assessment exercise as students write (or orally present) a creative story. Stories can also become the basis for assessment of attitudes as you transition the questioning from fictional characters to the children in your class. Think back to the lesson on Bartholomew and the Oobleck. Students can be asked how they feel about the fact that even scientists cannot agree on why the mixture acts the way it does. Students should also be challenged to come up with their own explanation as to why the Oobleck material behaves the way it does and engage in a class skeptical debate over the validity of the explanations.

TEACHING TIP

Teacher Self-Assessment

Do not forget to assess your own performance when teaching. Videotape or audiotape the lesson and review the tape with the following questions in mind:

- How did the students react to the investigation?
- Do I provide enough “wait time” after I ask a question?
- What percentage of the time was I dominating the discussion and how often were students actively discussing the mixture?
CHAPTER 3  Planning for Inquiry

Concept maps would be an appropriate way to determine content knowledge in this case. Students can be provided a key word such as *mixture* and asked to develop links based on what they know.

**E-learning**

For our lesson, we identified some possible activities in the lesson that could be integrated as needed during the other stages of the lesson. E-learning should not come as a supplement only when it is convenient for students to use technology. It should be included whenever possible so that all children become comfortable using the twenty-first-century technological tools critical to workforce development.

**WEB DISCUSSION**

**TPCK**

How comfortable are you with technology? Matthew Koehler describes Technological Pedagogical Content Knowledge (TPCK) as a form of knowledge that goes beyond the technological, pedagogical, and content knowledge of the teacher (Koehler, 2009). It is an understanding that emerges from an interaction of all of these elements. TPCK involves representation of concepts using pedagogical techniques that rely on technology in constructive ways (Koehler & Mishra, 2008).

Web 2.0 tools are the second-generation Internet technologies that promote collaboration. Some examples include social networking, video broadcasting, social messaging, photo sharing, Wikis, and Google Apps.

**Describe a situation where you will use Web 2.0 tools to effectively teach a concept.**

To put the need for integrating E-learning in perspective, think about the works of John Dewey, the quintessential educational reformer. He wrote about how traditional education was too concerned with statically delivering knowledge and not enough with understanding students’ actual experiences and how education was important to society (Dewey, 1938). He is also quoted as saying, “if we teach today as we taught yesterday, then we rob our children of tomorrow” (Dewey, 1916). Integrating the tools that the children will use in their future careers is every teacher’s job.

To complete the lesson planning, we provide the optional statement of the overview of the importance of the content. This helps to frame the overall purpose for the lesson. This also helps others decide the appropriateness of this lesson for their own needs. Finally, we provide a title for the lesson plan.

**TEACHING TIP**

**Inquiry Resources**

Google the “National Academies Press” and search the “Inquiry and the National Science Education Standards” to locate *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (NRC, 2000a) for resources for inquiry teaching and learning.

**NATIONAL STANDARDS AND PLANNING**

To help you think about planning and your classroom activities in a different way, envision yourself working in a manufacturing company that makes hybrid boats. Your job is to assist in developing a new hybrid boat with solar cells on the top deck to help produce additional power on clear days. As you think about your job, consider the following:

- You cannot talk with any other employees throughout the day.
- More experienced employees do not help you in any way.
- You also have to separate the workday into time periods. First, you will complete all the scientific undertakings, then the mathematical duties, some people-related responsibilities, and finally the language-type assignments. You spend the same amount of time each day on the four categories of tasks, regardless of how successful you are with any one type of task.
- You never spend very much time on reflection. You do not consider why the new type of boat even needs to be built, whom it is being built for, or how it can be made differently.
Nor do you spend any time trying to make the process or product better. You just want to meet a minimal standard for the construction of a new hybrid boat.

How successful will you be in your job with the above constraints? Now, think how successful elementary students will be with similar constraints. As a teacher, you are assisting children in constructing new knowledge. A big part of this process is planning.

Good planning will produce a better product just as it worked to promote inquiry with the students in the opening Focus on Inquiry. The authors of the National Science Education Standards (NRC, 1996) provide specific guidelines for how you can plan a science program. These are introduced in the Inquiry Planning Standard shown in the NSES Links box.

As you may infer from reading the Inquiry Planning Standard, the NSES, like state and district standards, provide a flexible framework for the year-long and short-term goals. Your challenge is to balance the immediate short-term needs with the year-long framework provided by the standards. One point to keep in mind is that in order for meaningful learning to occur, topics must be studied in detail. U.S. science curriculum is often negatively described as "a mile wide and an inch deep" (Schmidt, McKnight, & Raizen, 1997). There is no set answer to the curriculum planning challenge. It will depend on the profile of your students (i.e., prior knowledge and experience with inquiry learning) and other factors (i.e., your familiarity with topics), some of which are external to your class (i.e., district-mandated curriculum or a directed program of study related to a high-stakes assessment system).

### Teaching Standard A

Teachers of science plan an inquiry-based science program for their students. In doing this, teachers

- Develop a framework of year-long and short-term goals for students.
- Select science content and adapt and design curricula to meet the interests, knowledge, understanding, abilities, and experiences of students.
- Select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners.
- Work together as colleagues within and across disciplines and grade levels.


### SUMMARY

1. The backward design process involves three stages, including (1) the desired results stage of planning, which provides the basis for determining what students will know and be able to do as a part of the lesson; (2) the assessment evidence stage, where assessment methods are matched to the desired results; and (3) the learning plan, where the activities are developed to enable the students to achieve the desired results from stage 1.
2. Classroom inquiry is characterized by learners engaging in scientifically oriented questions. The amount of learner self-direction is in ratio to the level of teacher control.
3. The backward design model works in synergy with the 6E model when planning inquiry lessons.

### REFLECTION

1. Beginning teachers often employ very teacher-directed lessons. What is the advantage of this approach for the beginning teacher? What are some disadvantages of this approach for the beginning teacher?
2. Other courses in your professional preparation focus on lesson planning. Did any of these include backward design? Explain how this method enhanced—or had the potential to enhance—planning in other content areas.
3. Explore John Dewey’s Pedagogic Creed. In what ways are his declarations consistent with the NSES?
4. Wiki Development: Log onto your instructor’s course wiki and create a page on the following topics:

   - Group 1: Why Use the Backward Design Model?
   - Group 2: The Desired Results Stage of the Backward Design Model
   - Group 3: The Assessment Evidence Stage of the Backward Design Model
   - Group 4: The Learning Plan Stage of the Backward Design Model
   - Group 5: Essential Features of Classroom Inquiry
   - Group 6: WHERETO Elements of Instructional Planning
   - Group 7: Why Integrate E-learning?
   - Group 8: The National Standards and Planning