Seamless Assessment in Science

A Guide for Elementary and Middle School Teachers

Sandra K. Abell & Mark J. Volkmann

Foreword by Rodger W. Bybee
Seamless Assessment and the 5 Es

Assessment and instruction are logically linked. We set goals for learning that we translate into instruction from which we hope students will learn. We assess the degree to which students have learned the goals we defined. Yet assessment can be much more; assessment can provide incoming diagnostic information about students’ science knowledge. Assessment can let us know what students understand or do not understand so that we can refine our instruction. Assessment can help students learn from each other and from the assessment itself. Assessment can help us determine what students learned. And, assessment can help students reflect on their own learning. Seamless assessment is aimed at accomplishing each of these assessment purposes across a unit of instruction.

Our model of seamless assessment uses current views of inquiry-based instruction as a starting point. Classrooms in which inquiry occurs are characterized by five essential features (National Research Council 2000). According to the National Research Council, inquiry occurs when

1. learners are engaged by scientifically oriented questions
2. learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions
3. 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 (28)

One instructional model that incorporates these features of inquiry is the 5E model.

The 5E Model

We have several reasons for choosing the 5E model (Bybee 1997; 2002; National Academy of Sciences 1998) to guide our science instruction and seamless assessment. First, the 5E model is a useful tool for designing science lessons. It helps us focus on important concepts that we want students to learn and helps us think about an appropriate series of learning opportunities that will best help them learn those ideas. Second, the 5E sequence is based on what we know about how people learn (Bransford, Brown, and Cocking 1999). The 5E model recognizes that learners learn best when they are engaged in doing and thinking, when they have a chance to build new ideas after exploration, and when they can apply their learning to familiar and new contexts. Third, the 5E model directly addresses the research about student misconceptions in science (Driver et al. 1994; Wandersee, Mintzes, and Novak 1994). In a 5E unit, teachers (1) help students make their science conceptions explicit, (2) challenge those conceptions with new evidence, and (3) facilitate student building of scientifically accurate concepts. These strategies have the potential to create deep and lasting understanding in students. Last, but certainly not least, the 5E model is consistent with current views of inquiry. Throughout the five phases of the instructional sequence, students engage in science questions, collect and use data to formulate explanations, and evaluate and communicate their explanations. In other words, the 5E model captures the essential features of inquiry.

The instructional model is composed of five phases: Engage, Explore, Explain, Elaborate, and Evaluate. Each phase aims at a slightly different purpose for science learning (see Table 2-1). In the Engage phase, students encounter a scientific question, idea, or natural phenomenon. Teachers might introduce a unit with a field trip, demonstration, or discrepant event, a problem to solve, a current event, a local issue, a discussion, or some other strategy to engage students' attention and get them thinking about the scientific questions they will encounter in the unit. During the Explore phase, students have firsthand experience with a phenomenon. They might carry out investigations using laboratory equipment, make
Table 2-1 The 5E Model of Science Instruction

<table>
<thead>
<tr>
<th>Model Phase</th>
<th>Learning Purposes*</th>
</tr>
</thead>
</table>
| Engage      | • Initiates the learning task.  
              • Introduces the major ideas of science in problem situations.  
              • Makes connections between past and present learning experiences.  
              • Focuses student thinking on the learning outcomes of the upcoming activities.  
              • Mentally engages students in the concept to be explored.  
              • Motivates students. |
| Explore     | • Provides opportunities for students to test their ideas against new experiences.  
              • Provides opportunities for students to compare their ideas with the ideas of their peers and the teacher.  
              • Provides a common base of experiences in which students actively explore their environment or manipulate materials. |
| Explain     | • Provides opportunities for students to develop explanations.  
              • Introduces formal language, scientific terms, and content information to make students’ previous experiences easier to describe and explain. |
| Elaborate   | • Applies or extends students’ developing concepts in new contexts.  
              • Provides opportunities for students to develop deeper and broader understanding. |
| Evaluate    | • Encourages students to assess their understanding as they apply what they know to solve problems. |

*From Bybee 2002; National Academy of Sciences 1998

Observations in nature, or collect data using the Internet. Often students work in teams to build a common base of experience about the phenomenon under study. The purpose of the *Explain* phase is for students to formalize their understanding of the concepts under investigation. Students invent explanations and use evidence from the *Explore* phase to support their ideas. Teachers introduce formal ways to represent these ideas—terms, formulas, diagrams, and so on. In the *Elaborate* phase, students build on their understanding by solving new problems in new contexts. Teachers design ways for students to extend what they know by transferring their understanding to these problems. The *Evaluate* phase provides opportunities for students to reflect on and demonstrate what they know. Students communicate their learning to various audiences.
Five Es and an A

Each phase of the 5E model has implications for assessment. For example, during the Engage phase, if instruction is to be effective, teachers must identify what students already know about the phenomenon under study. This will include understanding commonly held misconceptions and diagnosing their own students’ views. In the Explore phase, teachers will use formative assessment to understand the progress that students are making in understanding concepts. Finding out what students do not yet understand helps guide the design of new instructional interventions. During the Explain phase, teachers listen carefully to student explanations and determine what ideas need further instructional attention. In the Elaborate phase, teachers see how well students can use their new understandings and formal representations to solve problems. During the Evaluate phase, there is an opportunity for summative evaluation. In addition, in the Evaluate phase, teachers can help students be metacognitive about what they have learned and what they still need help in understanding. In Table 2-2, we link each 5E phase with a particular assessment purpose.

These different assessment purposes can be connected with a set of concomitant assessment strategies. For example, diagnosing students’ incoming ideas during the Engage phase can be accomplished through discussion, by using a KWL chart, by asking students to draw a concept map, or through interviews with selected students. Formative evaluation during the Explore phase might take the form of student science notebooks or a demo memo. Summative evaluation in the Evaluate phase might include a postconcept map, constructed-response test items, or a presentation. Oftentimes the same activities that are planned to carry out instruction within a phase can be used to carry out assessment. When this happens, assessment has become seamless.

Assessment Strategies for Each Phase

The rest of this chapter highlights commonly used assessment strategies, linking them to the 5E phases and assessment purposes displayed in Table 2-2. We present a description and a practical example of each strategy and discuss which vignettes (from Chapters 3 through 5), if any, demonstrate the strategy. The Appendix provides a list of these same assessment strategies with accompanying websites where more detailed descriptions and additional examples can be found. Although we list the strategies by 5E phase, they are meant to be used flexibly. Some can be used in a variety of 5E phases for
Table 2-2 Assessment Purposes and the 5E Model

<table>
<thead>
<tr>
<th>Model Phase</th>
<th>Assessment Purposes</th>
</tr>
</thead>
</table>
| Engage      | • For teachers to identify students' incoming science ideas and misconceptions.  
              • Helps teachers determine what students need to explore in the next phase. |
| Explore     | • For teachers to determine how students are progressing in their conceptual understanding.  
              • For teachers to understand what students do not understand and determine instructional interventions that need to occur.  
              • Helps teachers determine what needs to be explained in the next phase. |
| Explain     | • For students to demonstrate their current understanding.  
              • For teachers to determine what ideas need further instructional attention.  
              • Helps teachers determine what elaborations will help scaffold learning in the next phase. |
| Elaborate   | • For students to demonstrate their ability to apply and transfer their understanding to new contexts.  
              • For teachers to see how students use formal representations of science knowledge (terms, formulas, diagrams).  
              • Helps teachers determine what will be important to evaluate in the next phase. |
| Evaluate    | • For teachers to determine what students learned from the unit.  
              • For students to be metacognitive about their learning.  
              • Helps teachers make decisions about new 5E learning cycles. |

Various assessment purposes. For example, notebooking, predicting, and concept mapping are versatile forms of assessment that can occur throughout the 5E cycle. The following list includes assessment strategies that are illustrated in the vignettes as well as some that are not. Furthermore, the vignettes include other assessment strategies not in the following list. The assessment strategies listed below, together with Tables 2-1 and 2-2 and the vignettes, constitute a toolbox for designing seamless assessment in science. The committed reader will be creating new assessment strategies to add to this list in no time!
Assessment Strategies for the Engage Phase

KWL chart (Ogle 1986). This assessment strategy helps students think about what they Know about a topic, what they Want to know about it, and after they have finished, what they Learned. The teacher begins by asking students to complete the first two columns of the KWL chart either in small groups or as a whole class. The list of responses identifies students' existing science ideas and helps the teacher plan instruction. For example, students list that they know the moon is visible only at night. In response, the teacher plans daytime observations of the moon during the Explore phase. As the unit progresses, evidence-based ideas are added to the third column of the KWL chart. See “Toiling in the Soil” in Chapter 5 for an example of how this strategy can be used during the Engage and Elaborate phases.

Concept mapping (Novak 1998; Novak and Gowin 1984). Concept maps help students develop a visual representation of their network of knowledge. A network consists of nodes and links. Nodes represent concepts and links represent the relations between concepts. Teachers often begin the strategy by giving each student a topic and a list of nodal terms. Students arrange the terms into connected nodes and label the connecting links. For example, in a unit on water quality, the teacher might provide terms such as temperature, turbidity, conductivity, tolerance, and macroinvertebrates and ask students to connect the terms. If a student's map indicates that he thinks that water temperature is not related to turbidity, then the teacher can plan explorations of the relationship. This assessment strategy is useful in the analysis of student learning at a variety of 5E phases, and it is often used in a pre/post manner. See “It's Volcanic!” in Chapter 5 for an example of how this strategy can be used during the Engage and Evaluate phases.

<table>
<thead>
<tr>
<th>BOX 2.1. ASSESSMENT STRATEGIES FOR THE ENGAGE PHASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>KWL chart</td>
</tr>
<tr>
<td>concept mapping</td>
</tr>
<tr>
<td>card sort task</td>
</tr>
<tr>
<td>memoir</td>
</tr>
<tr>
<td>brainstorming</td>
</tr>
<tr>
<td>interview</td>
</tr>
<tr>
<td>questionnaire</td>
</tr>
<tr>
<td>Venn diagram</td>
</tr>
<tr>
<td>science notebook</td>
</tr>
<tr>
<td>predicting</td>
</tr>
<tr>
<td>scientists' meeting</td>
</tr>
<tr>
<td>observation</td>
</tr>
</tbody>
</table>
**Card sort task** (Friedrichsen and Dana 2002). Card sorts help students distinguish between two or more potentially confusing ideas. Students examine a number of examples written or drawn on cards. They sort the cards and write a description of the properties of each sorted pile. For example, students often confuse the ideas of melting and dissolving. The teacher can supply cards with pictures of melting and dissolving for students to sort. When she inspects a student’s pile and finds cards misplaced, she can use this information to plan an exploration of the phenomena of melting and dissolving. See “Seeds and Eggs” in Chapter 3 and “May the Force Be with You” in Chapter 4 for variations on this strategy.

**Memoir** (George 2005). This strategy prompts recall of prior learning experiences and demonstrates to students what they currently know about a topic. Thus, it is useful for stimulating prior knowledge at the beginning of a unit or prompting metacognition near the end of a unit. For memoir writing, teachers ask students to think about a topic, what they used to know, and what they now know. For example, at the beginning of a unit a teacher might ask students to think about their magnet history, make claims about magnet behavior, and describe where they learned this information about magnets. If a student claims that magnets can attract hair, because she has noticed the way her hand attracts fur when she pets the family cat, then the teacher might plan an exploration of magnetism and static charge. See “It’s Volcanic!” in Chapter 5 for an example of how a memoir can be used as an Elaborate phase activity.

**Brainstorming.** This strategy focuses students on a problem and asks them to generate multiple solutions. Ideas are developed as fast as possible, and judgment is suspended. For example, students observe a burning candle and generate as many properties as they can in two minutes. The teacher does not evaluate the responses, but he encourages students to build on each other’s responses. If some of the students say that the wick alone is burning and the wax is simply melting, the teacher might use this information to plan an exploration of the role of wax in burning. See “It’s Volcanic!” in Chapter 5 for an example of brainstorming in connection with concept mapping.

**Interview or questionnaire** (Osborne and Freyberg 1985). Face-to-face interviews or written questionnaires about instances or events probe students’ understanding of a specific concept. For example, in an interview or questionnaire about living things, a kindergarten teacher might ask students which things are living things (e.g., person, animal, tree, fire, bicycle). In an interview or questionnaire about the event of light and vision, a sixth-grade teacher might ask students to explain how light helps a person see a tree. Their responses can be used to plan follow-up explorations.
“Misconceiving the Moon” in Chapter 5 uses a questionnaire about moon phases to begin the unit.

**Venn diagram.** This strategy exposes how students organize their knowledge. Large circles represent properties of different groups, with properties shared across groups at the intersection. For example, students might use a Venn diagram to represent the similarities and differences among mammals, reptiles, and birds. The teacher may use this information to plan lessons about animal groups or evaluate how student understanding has progressed. See “What’s the Anther?” in Chapter 3 and “May the Force Be with You” in Chapter 4 for examples of how Venn diagrams can be used at various 5E phases.

**Assessment Strategies for the Explore Phase**

*Science notebook* (Campbell and Fulton 2003). The science notebook reveals how students respond to field trips, laboratory activities, and problems throughout a unit of study. The science notebook has many uses, including keeping an accurate set of observations, recording quantitative data, describing the context or procedures for a lab or field experience, writing and drawing ideas to clarify thinking, making connections, wondering, and contemplating. For example, in response to a field trip to a canyon, a student may write: “Today, I was climbing in Big Cottonwood Canyon. The rock there is pinkish. The geologist said it was quartzite. What is quartzite? It feels smooth like limestone. There are white veins in it and it is very blocky. The edges are almost square.” This assessment strategy gives ongoing information about how students are building conceptual understanding and enables the teacher to assess progress. See “What’s the Anther?” and “Water You Know” in Chapter 3, “Shocking News: Static Electricity” in Chapter 4, and “Tilling in the Soil,” “Rock On!” and “Misconceiving the Moon” in Chapter 5 for examples of how science notebooks can be used.

<table>
<thead>
<tr>
<th>BOX 2.2. ASSESSMENT STRATEGIES FOR THE EXPLORE PHASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>science notebook</td>
</tr>
<tr>
<td>conceptual cartoon</td>
</tr>
<tr>
<td>think, pair, share</td>
</tr>
<tr>
<td>drawing completion</td>
</tr>
<tr>
<td>predicting</td>
</tr>
<tr>
<td>demo memo</td>
</tr>
<tr>
<td>scientists’ meeting</td>
</tr>
<tr>
<td>chart</td>
</tr>
<tr>
<td>observation</td>
</tr>
</tbody>
</table>
**Conceptual cartoon.** This strategy applies a science concept to a real-world situation depicted by a cartoon drawing and forces students to make a choice. The conceptual cartoon is designed to intrigue, to provoke discussion, and to stimulate scientific thinking. For example, a teacher might present a cartoon of a snowman with several students standing around it with cartoon bubbles above their heads. One is saying, “Don’t put the coat on the snowman, it will melt him.” Another is saying, “Leave the coat on, it will help the snow stay cold.” And a third is saying, “I think it doesn’t make any difference.” The teacher presents the cartoon and the students discuss the various claims and provide evidence for their choices. The discussion provides information about the students’ understanding of heat transfer and helps the teacher decide what kinds of investigations might help students solve the conceptual cartoon.

**Think, pair, share** (Victor and Kellough 2000). This strategy provides a quick check of student thinking about the concepts being taught. The teacher poses a challenging question and gives students a short time to think about the question individually; then they discuss their thoughts in pairs. Finally students share their answers with the class. For example, the teacher might ask, “Do you think a seed is alive? Why do you think that?” This strategy samples ongoing student understanding as part of a discussion and tells the teacher what needs further exploration and explanation. See “What’s the Anther?” in Chapter 3 for an example of how this strategy can be used.

**Drawing completion.** Drawing helps students visualize and develop understanding of a phenomenon. The teacher poses a challenge and may provide a partial diagram. Students draw or complete the diagram and use the drawing to help solve a challenge. For example, the teacher may ask, “What is the smallest mirror you can use to see your entire body?” He gives students a drawing of a boy standing in front of a wall and asks them to draw a mirror on the wall and the lines of sight the boy would use to see his entire body. Student responses help the teacher decide what needs further exploration or explanation. See “What’s the Anther?” in Chapter 3, “Mirror, Mirror on the Wall” in Chapter 4, and “Toiling in the Soil” and “It’s Volcanic!” in Chapter 5 for examples of how this strategy can be used.

**Predicting activities.** This strategy requires students to make evidence-based predictions about a demonstration or a hypothetical situation. The instructor provides a context and asks students to make a prediction about what will happen next or what will happen if some variable is changed. For example, after introducing pendulums with a story of Tarzan swinging on vines, the teacher asks, “What will happen to the swing of the vine if Jane joins Tarzan on the
vine?” Student responses influence next steps. See “Mirror, Mirror on the Wall” and “Will It Float?” in Chapter 4 for examples of how this strategy can be used.

**Demo memo.** Demonstrations can help all students witness and discuss the same phenomenon. The demo memo requires students to write a brief summary of the essential features of a student- or teacher-conducted demonstration. After a demonstration is completed, students describe what happened and how the demo provided an example of the underlying principle. For example, after demonstrating pitch by using bottles with different amounts of liquids and both blowing into the bottles and tapping them with a metal spoon, the teacher asks students to write about what happened and why they think the pitch was different in the two cases. See “Mirror, Mirror on the Wall” in Chapter 4 for another example of how this strategy can be used.

**Assessment Strategies for the Explain Phase**

**Exit sheet; exit ticket; minute paper.** These assessment strategies reveal (to teachers and to students) what is clear and unclear about a given concept. The teacher asks students to write brief responses to a few questions at the close of the class period (e.g., What is one thing you learned? What is one example of? What is one thing that was unclear? Can you explain how?). The teacher collects all responses and reads them prior to the next class. For example, the teacher might ask, “What is something you learned about sinking and floating and something that was unclear about sinking and floating?” Student responses provide information about possible instruction needed in subsequent classes. See “It All Goes Back to Plants” in Chapter 3 and “May the Force Be with You” in Chapter 4 for examples of this strategy in use.

**Box 2.3. Assessment Strategies for the Explain Phase**

- exit sheet; exit ticket; minute paper
- discrepant event
- Concept Test
- making a model
- making a claim; theory choice
- meaningful paragraph
- science notebook
- KWL chart
- labeled drawing
- predicting
- letter to the teacher
**Discrepant event** (Liem 1987). The discrepant event is a demonstration or activity with an unexpected outcome. It challenges students to use newly formed concepts to revise their explanations to account for this outcome. The teacher asks students to predict what they think will happen, to observe what actually happens, to revise their explanations, and to think about possible tests of their new explanations. The sequence of prediction, observation, and explanation is critical. In a study of density, many students think that big things sink and little things float. The teacher brings out a massive log from an oak tree and a huge tub of water and asks the students to predict if the log will sink or float. The surprise the students experience when they witness the log floating causes them to reevaluate their theories of sinking and floating. Student responses help the teacher select an appropriate elaboration activity. See “Will It Float?” in Chapter 4 for another example of how discrepant events can be used in seamless assessment.

**ConcepTest** (Mazur 1997). The ConcepTest consists of well-posed multiple-choice questions positioned at critical points in a unit and presented aloud to the entire class. These questions probe depth of understanding of important science concepts without invoking equations or formulas. A ConcepTest question focuses on a single concept and provides obvious and counterintuitive foils. Once students have made their individual choices, the teacher asks for a show of hands supporting each foil. Pairs of students then discuss the reasons for their choices. The teacher asks for a second show of hands, which often results in more correct selections. The teacher then provides the correct choice and asks students to write their explanation for why that choice is correct. For example, the teacher poses the following buoyancy question to the class: “A boat carrying a large boulder is floating on a lake. The boulder is thrown overboard and sinks to the bottom of the lake. Will the level of the water in the lake with respect to the shore (a) go up, (b) go down, or (c) stay the same?” (correct choice is b). Depending on how students respond, the teacher will decide how well students understand buoyancy and what elaboration activity might help them increase the depth of their understanding.

**Making a model.** This strategy uses three-dimensional models to help students visualize and explain aspects of the natural world that are otherwise impossible to see or difficult to imagine. The teacher can assign small groups of students to design a three-dimensional model of the phenomenon or can present her own model. Students discuss the models and provide explanations for how a model helps explain evidence collected in the *Explore* phase. The teacher can then quiz students on aspects of the model. For example, the teacher may assign students to make a scale model of our solar system, using analogies to
represent relative planetary size. One student group uses musical notes for their model, representing planetary size by the length of the note (e.g., sixteenth notes versus whole notes). The accuracy of the model is a good way to assess student understanding and to select elaboration activities that build on what they know. See “Misconceiving the Moon” in Chapter 5 for another example of how models can be used.

Making a claim. This strategy challenges students to make evidence-based claims about how something will behave in accordance with concepts they have been learning. The students work together in teams to construct their claims. The class evaluates each claim based on the concept under study and the evidence that was gathered during the Explore phase. For example, after investigating sinking and floating, students write claims on overhead transparencies. One group writes, “Objects with a density greater than one will sink.” The teacher invites students to the front to present their claim and invites the class to agree or disagree based on evidence from earlier investigations. The quality of the claim and of the audience critique helps the teacher decide next steps. See “Sounding Off” in Chapter 4 and “It’s Volcanic!” in Chapter 5 for other examples of how this strategy can be used.

Meaningful paragraph. This strategy is used at the close of the Explain phase to assess the depth of students’ understanding of terms that are related to a central concept. The teacher provides these terms and students use them to construct a meaningful paragraph. For example, the teacher may assign the students to write a paragraph about the water cycle using the following terms: rain, lake, evaporate, condense, cool, and heat. Students use the last few minutes of class to create their paragraphs and then hand them in. The teacher assesses each reply with a ✓+, ✓, or ✓−, depending on accuracy. Ideally, students learn how well they understand the material and the teacher finds out how well students can communicate the technical terms and the relations among concepts.

Assessment Strategies for the Elaborate Phase

Application problem. Application problems exercise analytic reasoning skills as students make connections between a new phenomenon and a recently learned concept. The teacher introduces the phenomenon to small groups of students. The students use the concepts they have learned to develop an explanation. The students either present verbal explanations (to the class) or written ones (to the teacher). For example, after studying the motion of pendulums, the teacher asks students to solve the following problem: “How many ways can you come up with to fix the swing in my backyard, which swings crookedly?”
BOX 2.4. ASSESSMENT STRATEGIES FOR THE ELABORATE PHASE

- application problem
- pair problem solving
- puzzler
- thought experiment
- debate
- writing and analyzing fiction
- design activity
- science notebook
- identification game
- team report
- data table and graph
- predicting

The students think about the question and try to solve it using what they know about center of mass. Their solutions provide evidence that they do or do not understand the concepts well enough to apply them to real-world phenomena. Application problems are used as assessment strategies in “Seeds and Eggs” and “It All Goes Back to Plants” in Chapter 3, “Sounding Off” and “Mirror, Mirror on the Wall” in Chapter 4, and “Tolling in the Soil” in Chapter 5.

**Pair problem solving** (Pestel 1993). This strategy involves pairs of students communicating how to solve a problem. The teacher poses a problem and provides time to solve it. The two students take on the specific roles of problem solver and listener. The problem solver reads the problem aloud and talks through the solution. The listener follows along and asks questions if the problem solver’s thought processes are unclear. Students switch roles for each problem. Presenting one’s problem solution aloud to a partner helps make reasoning skills explicit. For example, students are given two electricity problems. The first problem asks which set of batteries will last longer—the set powering one bulb or the set powering two bulbs in series. The second problem asks which set of batteries will last longer—the set powering one bulb or the set powering two bulbs in parallel. The resulting discussion helps students think aloud and to listen to how others reason and helps the teacher understand the quality of student thinking.

**Puzzler.** Puzzlers (Abell, George, and Martini 2002) tease students with a beguiling problem about the topic they are studying. The teacher poses a question and students individually write an answer. Time may be provided for actual experimentation if needed. A few students might be selected to read their answers out loud. Finally, the teacher leads students in a whole-class discussion. For example, during a levers unit, the teacher may pose this question at the
start of class: “How could I weigh a heavy object if I did not have a scale that measured that much?” Student responses help the teacher decide what, if anything, needs further elaboration. See “Misconceiving the Moon” in Chapter 5 for an in-depth example of how this strategy can be used.

**Thought experiment.** The thought experiment reflects the history of science and engages student imagination to investigate nature. Galileo and Einstein were, arguably, the most impressive thought experimenters in the history of science. The teacher frames a problem and students work through a logical solution without actual materials. The students work individually or in teams to approach the problem by thinking (and drawing) possible solutions. For example, after studying levers, students are asked to build a contraption for the zoo that will lift the smelly elephant off its favorite blanket to give it a bath. The students use what they know about force and distance in levers to draw a solution and explain how it will work. This activity challenges students to think deeply about and transform science concepts into useful solutions. “Misconceiving the Moon” in Chapter 5 discusses a thought experiment presented to students in the form of a puzzler (see previous strategy).

**Debate.** Debate engages students in examining two sides of an issue by adopting the role of a stakeholder. The teacher provides a controversial issue, debate guidelines, resources, and time limits. Students review appropriate debate behavior, research various perspectives, gather pertinent evidence, develop a position, and represent that position in an appropriate format (e.g., town meeting). In a variation called **structured controversy** (Johnson and Johnson 1985), students have to prepare and defend both sides of the issue. For example, the teacher may pose this statement: “Hunting is a necessary tool for wildlife management.” Students must use what they have learned about predator-prey relations and carrying capacity to effectively debate the issue.

**Writing and analyzing fiction.** Trying to write stories that incorporate science concepts is a creative way for some students to synthesize their learning. Teachers generate the story-writing context and young authors take off. For example, near the end of a unit about erosion, students might write stories in which a time traveler witnesses the before and after scenarios of various landforms. “Water You Know” in Chapter 3 uses eco-mysteries as a form of seamless assessment. In addition to writing fiction, students can also be asked to analyze works of fiction for the accuracy of the science concepts displayed. For example, near the end of a unit on sinking and floating, the teacher might read aloud the picture book *Who Sank the Boat?* (Allen 1982) and ask students if they think the story is an accurate representation of the science concepts under study. “Misconceiving the Moon” in Chapter 5 provides an example of this
Elaborate phase strategy, while "It's Volcanic!" in Chapter 5 uses literature to Engage students in the topic.

Design activity. A design activity is an engineering challenge that requires students to use science concepts to develop new products. Scale models or working prototypes are often included in the project. The teacher provides guidance, deadlines, and an audience for the final demonstration. The students work in teams or individually to design something that addresses the challenge. For example, after learning about force and motion, students design a roller coaster that is artistic, technically feasible, and safe. This activity challenges students to be creative while using their science knowledge. "Shocking News: Static Electricity" and "Will It Float?" in Chapter 4 use design activities as summative assessments in the Evaluate phase.

Assessment Strategies for the Evaluate Phase

Poster. Asking students to make a poster invites them to tell a story that includes a statement of the problem, a description of the method, a presentation of results, and a summary of the work in an engaging format. The poster is one refreshing alternative to the laboratory report. The teacher provides materials, project guidelines, a due date, and an audience for the final presentation. Students work singly or in groups to present findings. For example, after studying growth and nutrition in plants, students make posters about their investigations on the effects of various chemicals on plant growth. This activity challenges students to think creatively as they integrate their understanding into the poster. See “What's the Anther?” in Chapter 3 for an example of how posters can be used during the Explore phase.

<table>
<thead>
<tr>
<th>BOX 2.5. ASSESSMENT STRATEGIES FOR THE EVALUATE PHASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>poster</td>
</tr>
<tr>
<td>constructed response</td>
</tr>
<tr>
<td>presentation</td>
</tr>
<tr>
<td>comparison essay</td>
</tr>
<tr>
<td>final reflection</td>
</tr>
<tr>
<td>self-evaluation</td>
</tr>
<tr>
<td>one-page memo</td>
</tr>
<tr>
<td>scenario exam</td>
</tr>
<tr>
<td>concept mapping</td>
</tr>
<tr>
<td>Venn diagram</td>
</tr>
<tr>
<td>science notebook</td>
</tr>
</tbody>
</table>
**Constructed response.** The constructed-response test item consists of an open-ended, short-answer question that measures application skills as well as content knowledge. The questions often draw upon authentic, real-world examples. The teacher may include constructed-response items as one part of a unit test. Students’ answers demonstrate their understanding in greater depth than would multiple-choice responses. The teacher typically generates rubrics to score responses in terms of specific goals of instruction. For example, after studying ecosystems ecology, the teacher asks students to draw and explain a food chain that includes three levels. The constructed response challenges students to recall facts, understand concepts, and report in a logical way. Since many standardized tests use the constructed-response format, this assessment helps prepare students for high-stakes testing. See “Seeds and Eggs” in Chapter 3 and “May the Force Be with You” and “Sounding Off” in Chapter 4 for other examples of constructed-response items.

**Presentation.** This strategy challenges students to organize a presentation (using PowerPoint or other visual aids) that demonstrates what they have learned. The teacher provides presentation guidelines, tutorials on how to use technology, and a due date. The students use their ingenuity to develop an interesting presentation that demonstrates the most important points of their learning. For example, students might create seven PowerPoint slides demonstrating what they have learned about heat and temperature. See “It All Goes Back to Plants” and “Water You Know” in Chapter 3 for examples of how this strategy can be used.

**Comparison essay.** This assessment strategy requires students to compare and contrast the similarities and differences between two categories of things. The teacher provides a written description of the assignment and the deadline for completion. Individually or in pairs, students write an essay comparing two things or two aspects of something the class has been studying. For example, after studying reproduction in flowering plants, students are assigned to compare tomato and corn reproductive parts (e.g., stamen, pistil, pollen, and eggs), giving equal attention to the two plants. An example of a class comparison strategy appropriate for younger students, using a comparison chart instead of an essay, is illustrated in “Seeds and Eggs” in Chapter 3.

**Final reflection.** The final reflection requires students to summarize their current understanding of the topic or concept, using diagrams, verbal explanations, formulas, and/or data from class observations. The teacher provides guidelines of what to include in the final reflection and encourages students to use their science notebooks as resources. Students work individually to write reflections on their learning. For example, after a study of current electricity,
the teacher assigns students to use their electricity notebooks to explain how electricity is involved in making bulbs light and how series and parallel circuits are formed. She asks students to include diagrams, written explanations, and data from class activities to substantiate their ideas. See “Misconceiving the Moon” in Chapter 5 for an example of how this strategy can be used.

Self-evaluation. In self-evaluation, students reflect on their work and the depth of their understanding, often comparing their current ideas with their incoming ideas. The teacher provides prompts such as: “Before I thought _____; now I think _____” or “I could have done better if I had ______.” Students respond in writing and the teacher remarks on the self-evaluation. The teacher’s comments help students develop new learning goals. For example, at the end of a unit about plant reproduction, students complete the self-evaluation by writing one idea they had about plants that changed during the unit and one question they still have. Thus self-evaluation requires students to be metacognitive about their understanding and to make plans to improve their learning. “Misconceiving the Moon” in Chapter 5 illustrates the use of self-evaluation within a final reflection activity (see previous strategy).

One-page memo. The memo provides a more authentic form of assessment than the traditional lab report. The teacher creates a challenge based on the concept under study and provides guidelines for memo writing. Students write a one-page memo to a fictitious boss to report the findings of an investigation. Synthesizing their procedures and findings into a short piece of writing requires students to find the most important ideas in their work to report. For example, after completing a unit about mixtures and solutions, the teacher says, “It is time to compose a report to your boss at Acme Chemicals. Your boss is a busy woman and does not have time to read a ten-page laboratory report. Instead, she requires you to write a one-page memo in which you highlight your research question, procedures, findings, and conclusions and tell how your findings will benefit Acme Chemicals.” See “Will It Float?” in Chapter 4 for another example of how this strategy can be used.

Seamless Assessment in Action

These assessment strategies, linked to the 5E phases, illustrate the myriad of options available to science teachers who want to integrate assessment more fully into inquiry-based science instruction. In the following chapters, seamless assessment comes alive in the stories of classroom teachers, grades 1–8, who have used many of these strategies to plan instruction and examine student understanding.