Assessing for Achievement

Formative assessments are woven throughout a series of lessons structured upon the 5E Instructional Model.

By Kathleen Adair Creghan and Casey Creghan

Nothing satisfies a teacher more than seeing a smile of delight on students' faces when they turn over their test paper to reveal a successful score. In today's world of standardized testing, some elementary science teachers may struggle to help students move from active engagement in hands-on science experiences to high levels of achievement on paper-and-pencil tests. Consequently, that smile of delight is not seen often enough. However, I have discovered that one key to raising achievement scores is to carefully weave formative assessments throughout each phase of the 5E Instructional Model. The 5E Model is a lesson cycle based on inquiry and constructivism. The 5E Model phases are engage, explore, explain, elaborate, and evaluate (Bybee et al. 2006). The 5E Instructional Model is relevant to all age levels, as is the process of using formative assessments at every phase of the model. Specific examples of formative assessments given in the following 5E model are appropriate for grades 2 through 5, although the audience for the mixture and solution activities would be grades 4 and 5.

Engage

Those who have successfully used the 5Es realize the power of engaging students with activities such as a powerful visual or a discrepant event. However, the engagement phase is just as important in ascertaining students' prior knowledge and any misconceptions that may interfere with students' attainment of new content (Bybee et al. 2006). When beginning a new lesson cycle, my fifth graders loved to play the game "Top Five." I presented some type of scientific phenomenon through a video clip or a short demonstration, and then my students would record the top five ideas they knew about the subject. When we were beginning our study of mixtures and solutions, I brought several examples of common mixtures and solutions to display for the class. Displaying trail mix, fruit salad, and soda pop was a fast and easy way to get students engaged in the lesson. In Texas, students in grade 4 are asked to "compare and contrast a variety of mixtures and solutions" (TEA

2009, TEKS 4.5C). This state standard corresponds to *Next Generation Science Standards (NGSS)* disciplinary core idea PS1.B: Chemical reactions, which states that "when two or more different substances are mixed, a new substance with different properties may be formed" and performance expectation 5-PS1-4, which states that students who demonstrate understanding can "conduct an investigation to determine whether the mixing of two or more substances results in new substances" (Achieve Inc. 2013; see Connecting to the Standards). By asking my fifth graders to share what they knew about the mixtures and solutions, I could determine their relevant knowledge from the prior grade.

Whether students recorded their top five in their journals or on an ever-popular sticky note, they loved sharing their ideas with a partner. Students also loved reporting to the class from their lists as I recorded the results on chart paper. Recording the class ideas helped me to track areas where I would need to address misconceptions in our upcoming investigations. If students had difficulty coming up with five ideas then I knew this was probably new or more difficult content for them. It also let me know if they were struggling with vocabulary terms. Special needs and ESL students were expected to participate in our top five activity, but they were encouraged to draw examples of mixtures vs. solutions to assist in communicating their thoughts. This activity became the signal for a new topic in our class, and students frequently asked when we would be having another top five day. Throughout the upcoming 5E lesson, we revisited the charts and added to or revised information. It was surprising how many times the children would remind me to add to or correct information on our charts!

Explore

The Explore phase of the 5E Instructional Model allows students to share common experiences in order to begin to formulate ideas or to solve problems (Bybee et al. 2006), so I realized my formative assessments would need to reflect this type of experience as well. Rather than trying to take a participation grade or a lab grade on the Explore activity, I realized I needed to relate my assessments to the types of work my students were doing (Marzano 2006). What did I need to know to be able to tell if they were focused on the problem or question at hand? How could I tell if they were engaged in the learning and not just going through the motions of the activity? I determined my students should be asking the following critical questions:

- What is the problem or question I am trying to solve?
- What do I need to know to find out?
- What do I already know?

A checklist to survey each student group while they were working on their explorations was the answer to my assessment dilemma. As I circulated about the room, I would ask the groups these types of open-ended questions. At first my students struggled to answer the questions, but after a few investigations they began to volunteer the information when I came to their groups. More importantly, they began to ask questions prior to our activities when they weren't sure about the purpose. I noticed when they were clear on their purpose the results of the investigation began to be much more targeted. If my students could not answer these types of questions, then I knew they were just blindly following the lab procedures. It was important that I not require students to have all the answers, but rather be able to know what they were trying to discover. What a difference this checklist made in both their experiences and mine! I could see very clearly when I needed to redirect their focus for the investigation or let them continue to work.

One amazing example of this clarity for me was an activity in which the class was to "Demonstrate that some mixtures maintain physical properties of their ingredients" (TEA 2009, TEKS 5.5C). This type of exploratory activity aligns with *Next Generation Science Standards* crosscutting concept Cause and Effect: "Cause and effect relationships are routinely identified, tested, and used to explain change" (5-PS1-4, Achieve Inc. 2013; see Connecting to the Standards). This activity addressed the *NGSS* science and engineering practice Planning and Carrying Out Investigations.

I questioned several groups about what problem or question they were investigating and recorded comments based on their responses (see Figure 1 and NSTA Connection). The group members were quick to report that they were "looking for changes in properties when they created mixtures." I was pleased they were using their science words. One group looked a bit confused and remarked they were supposed to "mix some stuff together and draw a graph of the mixtures they made." It was apparent this group would not be able to make critical connections to the content if I could not clarify the purpose for the activity right away. A few guided questions later, they were on their way to a successful Exploration experience. For example, if the groups could not articulate the problem or question they were investigating, I would ask them a few basic questions to ensure they understood the basic vocabulary terms related to the investigation. In this case, recalling the meaning of the terms *property* and *mixture* might help the group to understand they were determining which properties would remain the same and which would change when creating their mixtures.

FIGURE 1.

Checklist for Explore phase group questioning.

Lab Activity: *Mixtures Exploration Lab*

Purpose for the Lab: *"Demonstrate that some mixtures maintain physical properties of their ingredients…"*

Date/Class Period:

Questions	Group 1:	Group 2:	Group 3:	Group 4:	Group 5:	Group 6:
What is the problem or question we are trying to solve in this activity? **Sample student reply:** *We are looking for changes in properties when we create mixtures.*	**Sample teacher comment:** *Group1 has a good grasp of the purpose for the activity.*					
What do we need to know to find out? **Sample student reply:** *We need to know what the properties of the ingredients are before we make the mixture and then after we make it.*	**Sample teacher comment:** *Group 1 understands properties of materials can remain the same or change in creating a mixture.*					
What do we already know? **Sample student reply:** *We already know several properties of the ingredients of the mixture by just making observations. We can predict what some of the changes will be because we have already made mixtures before.*	**Sample teacher comment:** *Group 1 understands they have previous knowledge of the properties of the ingredients and are ready to predict the properties of the mixtures they will create.*					

Explain

Many teachers have become masters of guiding students to formulate big ideas in science from their Explore phase experiences. Asking students to post their data on the board and then using the data to guide my students to the big ideas was one way I helped my students to make important connections during the Explain phase. Some teachers use group sharing and whole-class discussions to engage students grasping key concepts. With this method, regardless of the activity chosen, it is difficult to know if all your students have made these important connections. In the case of our mixtures and solutions example, I chose to create a table on the board for groups to post their data. Each group posted their ingredients, properties observed, and then the properties of their mixture. In our following discussion, students categorized those mixtures that retained properties of its ingredients, such as sand and water, versus those whose properties had either partly or completely changed, such as sugar and water. We also worked together to define and discuss relevant terms such as *mixture* and *solution*. It is at this point that a quick formative assessment is needed. I have learned never to let an Explain phase end without using some type of assessment or screening instrument to poll the results of our session. This idea may sound rather time-consuming, but I found using an exit ticket strategy (see Internet Resources) is an easy way to find out which students are ready to go on to the Elaboration and which students need a bit of extra help.

As an exit ticket, I gave my fifth graders an index card (see Figure 2) to record the main concept or concepts for the lesson, and it took just a few minutes at the end of the class period. In our mixtures unit, I had the students draw and label one of the mixtures they had created on the front of the card. On the back of the card they listed the ingredients that went into the mixture and the original properties of each ingredient. Then they listed the properties of the mixture, circling those properties that remained the same. As students filed out of the room, I sorted the cards in order to create groups for the following day's lesson. Whiteboards are also a fun way for students to demonstrate mastery of

FIGURE 2.

Explain phase exit ticket sample.

Activity: Mixtures Exploration Lab Explain Phase Discussion

Purpose for the Assessment: "Demonstrate that some mixtures maintain physical properties of their ingredients…"

<table>
<tr><th>Front of index card:</th><th colspan="2">Back of index card: (Students circle those properties that remained the same.)</th></tr>
<tr><td rowspan="10">Labeled drawing of a mixture your group created:

Mixture:
Sugar and Water</td><td>Ingredients</td><td>Properties</td></tr>
<tr><td>sugar</td><td>solid, white, granular, sweet*</td></tr>
<tr><td>water</td><td>liquid, clear, tasteless*</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
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*Be sure to remind students we do not taste materials in the science lab, but we may use prior information to list properties in this case.

concepts, but teachers will need to keep track of which students need assistance on a checklist. For example, you could have students categorize examples of mixtures and solutions on mini-whiteboards to conduct a fun but helpful formative assessment. Other times, some concepts may be better suited to a summary statement or a labeled drawing (such as a cycle or process) completed in a science notebook. Regardless of the type of formative assessment completed, I made sure the assessment I chose was quick and easy for me to see who has mastered the main concept of the day.

Another helpful way I found to move students from the hands-on experience of the Exploration phase was to provide students with examples of how assessment items would look on paper-and-pencil tests. Students do not necessarily have to practice these types of problems in the Explain phase but should have an opportunity to be ex-posed to the formatting of questions and to discuss how these questions might be approached in order to solve. Two examples of assessment items we could use in this learning cycle are as follows:

- Name two materials or substances that you predict will dissolve in water and two that you predict will maintain their physical properties in water. Explain your reasoning.
- Describe how separating a mixture into its ingredients can demonstrate how its properties have not changed.

Elaborate

At this point in the 5E Model, it is critical to differentiate instruction based on the level of content attainment for students (Duran et al. 2011). I used the index cards from the exit ticket in the Explain phase to determine who needed additional assistance and who was ready to move on. For those students who had not yet drawn appropri-ate conclusions in the Explain phase assessment, moving on to using the concept in a new way or in a new context may not be the best way to proceed. If students did not understand the basic concepts from the Explain phase, it will be difficult for them to use the information in a new way or a new context. For my students, the solution to this dilemma has been to create two types of activities for the Elaborate phase. Students who are ready to move on were given directions to complete a typical Elaborate ac-tivity. An Elaborate phase activity might allow students to develop and investigate a new choice of variable from the Explore investigation or allow students to conduct research on a real-world scenario using the original con-cept. In my classroom, I allowed my students to create a favorite snack recipe with mixtures that would retain the properties of their original ingredients and those that would have new properties. They were asked to first predict the outcomes of the mixtures based upon the properties of the original substances they had chosen. Be sure to review safety procedures with students prior to allowing them to create their own mixtures. For example, remind students not to put anything in their mouths in the science lab and to wear safety goggles.

CAUTION

Those students who were not successful on the Explain phase formative assessment were given more basic work to clarify concepts. Examples of these remedial assignments included participating in a more limited version of the Elaborate activity; participating in a small-group session with the teacher; creating vocabulary cards with pictures, examples, and non-examples (Steele and Mills 2011); or even reading and discussing related text materials. For our mixtures activity, my remedial group completed the same Elaborate phase activity as the students who mastered the exit ticket assessment, but with fewer choices of materials and specific guidance to help them determine the original properties and outcomes of the mixtures. Most remedial activities need guidance from the teacher, and this type of additional support can make an important difference in achieving mastery for struggling students. By stopping mid-lesson cycle to address the needs of students who had gaps, more of my students gained mastery by the end of the 5E cycle. If I waited to provide support or

FIGURE 3.

Assessing for achievement.

Within the 5E Instructional Model, many types of assessments can be used interchangeably. Here are some examples for each phase of the learning cycle.

Engage Phase: (Elicit prior knowledge, misconceptions, or possible gaps in content or vocabulary)

- Top five (students record their "Top Five" ideas pertaining to a topic)
- Open-ended questioning; guided questioning
- Partner discussion and followed by large group sharing
- Formative probes(1)
- KWL or KLEW(2) charts

Exploration Phase: (Monitor readiness for exploration, and active participation)

- Group checklist for questioning (purpose for the activity; what do I need to know, what do I already know)
- Open-ended questioning; guided questioning
- Class data tables and discussion of data
- Science notebooking reflections

Explain Phase: (Introduce vocabulary; clarify concepts)

- Exit-ticket strategy (3)
- Open-ended questioning; guided questioning
- Vocabulary cards (4) (examples and non-examples and non-linguistic representations)
- Mini whiteboard reflections or practice
- Practice problems (reflecting paper/pencil assessment items)
- Summary writing of main concepts (science notebooking reflections)

Elaborate Phase: (Use of newly gained vocabulary and concepts)

- Various products related to Exploration concepts
- Open-ended questioning; guided questioning
- Essay questions (science notebooking reflections) illustrating how Elaboration activity relates, connects, or extends main concepts
- Practice problems (reflecting paper/pencil assessment items)
- Concept mapping (5)

Evaluate Phase: (Students and teachers evaluate concept understanding)

- Student reflections of learning (part of Evaluation rubrics)
- Demonstrations/performances
- Open-ended questioning; guided questioning
- Concept mapping (5)
- Science notebooking written or illustrated reflections

Resources for More Information:

1. Formative assessment probes: *http://uncoveringstudentideas.org/*
2. KLEW charts: *www.nsta.org/publications/news/story.aspx?id=51519*
3. Exit-ticket strategy: *www.edutopia.org/blog/formative-assessment-exit-slip-rebecca-alber*
4. Vocabulary cards/strategies: *www.learnnc.org/lp/pages/7079*
5. Concept mapping: *www.stanford.edu/dept/SUSE/SEAL/Reports_Papers/Vanides_CM.pdf; example: www.vanides2.com/conceptmaps/conceptmap-example.doc*

tutorials for struggling students until they were unsuccessful in the Evaluate phase, then this contributed to students receiving lower scores at the end of the unit.

Evaluate

In the final phase of the 5E Model, it is imperative for students to take part in evaluating their own learning. Research has shown when the Evaluation phase is appropriately emphasized mastery of concepts increases (Bybee et al. 2006). In order for students to take a more active role in their evaluation, I added a student comment section to rubrics (see NSTA Connection). When I encouraged my students to reflect on their own work, they focused on areas of strengths and also areas where they needed to improve (Marzano 2006). Tracking their own progress on a chart in their science notebooks also helped my students focus on how well they were progressing. The tracking chart can be very simple in nature (see NSTA Connection) but should include concept information rather than just dates and grades. In this way students will be able to see areas of progress and strengths as well as areas where additional work might be needed. Actively participating in the Evaluation phase helped my students make connections from their hands-on experiences to standardized tests that were administered after the Evaluate phase. Weaving assessments throughout the 5E Instructional Model (see Figure 3) assisted me in developing targeted instruction as well as increased my students' scores on the Texas state test by an 11 percentage point increase in commended rates over the prior year's scores. Although student groups often had questions during the Elaborate phase, I learned to empower my students to work with their groups to make decisions as a majority. Establishing clear guidelines for materials and safety precautions was a key to the process. Additionally, the more autonomy I gave my students to problem solve, the more confident they grew in their own investigations. This confidence, in addition to a great deal of hard work by my students, resulted in improved scores on the state test. ■

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Connecting to the Standards

Standard: 5-PS1 Matter and Its Interactions

Performance Expectation:
5-PS1-4 Conduct an investigation to determine whether the mixing of two or more substances results in new substances.

Science and Engineering Practice:
Planning and Carrying Out Investigations

Disciplinary Core Idea:
PS1.B: Chemical Reactions

Crosscutting Concept:
Cause and Effect

NGSS Table: 5-PS1 Matter and Interactions
www.nextgenscience.org/5ps1-matter-interactions

Internet Resources

Concept Mapping Example
www.vanides2.com/conceptmaps/conceptmap-example.doc

Edutopia: A Favorite Formative Assessment: The Exit Slip
www.edutopia.org/blog/formative-assessment-exit-slip-rebecca-alber

Uncovering Student Ideas: Formative Assessment Probes
http://uncoveringstudentideas.org

Vocabulary Cards and Strategies
www.learnnc.org/lp/pages/7079

NSTA Connection

For the Explore phase checklist, the rubrics, and tracking chart, visit *www.nsta.org/SC1311*.