Embedding Formative Assessment into the 5E Instructional Model

By Page Keeley

Formative assessment and instruction are like two sides of the same coin; they are inextricable. An instructional model should seamlessly embed formative assessment throughout the stages of instruction. One of the most effective and highly utilized elementary science instructional models to do so is the 5E Model. Developed in the late 1980s by BSCS, the 5E model mirrors the way children learn science and provides opportunities to formatively assess student learning throughout the teaching and learning process. Table 1 describes how formative assessment probes and formative assessment classroom techniques (FACTs) link to each of the stages in the 5E Model.

The following is an illustrative example of how formative assessment probes and FACTs can be embedded into a sequence of 5E lessons targeting the grades 3–5 disciplinary core idea, *the amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish* (NGSS Lead States 2013).

FIGURE 1.

Lemonade probe.

Lemonade

A glass of unsweetened lemonade weighs 255 grams. A spoonful of sugar is weighed before stirring it into the lemonade. The sugar weighs 25 grams. Predict how much you think the sweetened lemonade will weigh after you stir in the sugar.

Please circle the best answer.

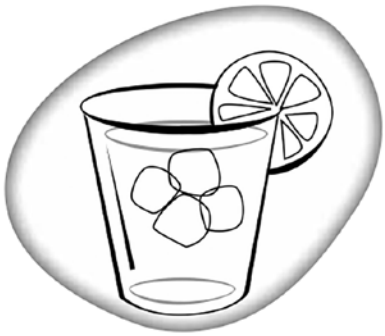
A It will weigh slightly less than 255 grams but more than 230 grams.

B It will weigh slightly more than 255 grams but less than 280 grams.

C It will weigh 230 grams.

D It will weigh 280 grams.

E It will weigh the same: 255 grams.



Describe your thinking. Provide an explanation for your answer.

Engage Phase: The "Lemonade" probe (Figure 1) elicits students' preexisting ideas about conservation of matter in a dissolving context (Keeley, Eberle, and Farrin 2005). Using the *Sticky Bars* FACT (Keeley 2008, 2016), students write their prediction on a sticky note and the teacher posts the notes as a bar graph, showing the range of predictions in the class. The graph indicates that most of the students selected answer choices A or B, revealing a commonly held misconception that the total weight will decrease because the sugar "disappears." The probe engages students in thinking about what happens to matter during a change in which it seems to disappear and stimulates their desire to find out. The teacher also uses the probe to connect to students' prior experiences with dissolving and organize their ideas and questions prior to the explore phase.

Explore Phase: The "Lemonade" probe is an example of a P-E-O probe in which students make a prediction (P), explain (E) the reason for their prediction, and launch into making observations (O) to test their initial prediction. The teacher provides the materials, similar to the ones in

TABLE 1.

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5E Stage of Instruction	Use Formative Assessment Probes or FACTs* to:
ENGAGE: Generate interest, stimulate curiosity, raise questions, uncover preconceptions and prior experiences	• Uncover preconceptions, prior experiences, or misconceptions resulting from prior instruction • Stimulate student interest in the concept or phenomenon • Activate student thinking and metacognitive processes • Have students generate initial questions about the concept or phenomenon Examples: probes, interest scale, directed K-W-L, annotated drawings, human scattergraph, sticky bars, everyday mystery stories, four corners
EXPLORE: Provide initial experiences to examine, investigate, and puzzle through ideas and phenomena and construct initial concepts and explanations	• Have students test predictions or hypotheses about an outcome • Engage in social construction of initial concepts, ideas, or practices • Provide opportunities to discuss and compare ideas • Quick checks of developing ideas or questions students have during the exploratory phase Examples: card sorts, P-E-O probes, a picture tells a thousand words, claim cards, group Frayer model, what are you doing and why? whiteboarding, extended sticky bars, muddiest point, 2 minute paper
EXPLAIN: Develop conceptual and procedural understanding; introduce formal concepts and vocabulary linked to students' experiences; engage in sense making and construction of scientific explanations	• Guide students in clarifying their thinking • Facilitate development of scientific explanations • Engage students in listening critically to each others' explanations • Formally introduce terminology, concepts, or principles • Revisit initial probes and revise based on new learning Examples: C-E-R, explanation analysis, RERUN, word use probes, word sort, VDR, RAQ, concept mapping, confidence level assessment, TAR; B-D-A drawings
ELABORATE: Apply concepts, ideas, and practices to new contexts; transfer of learning to new, related situations	• Use concepts, ideas, or practices within a new context or with different examples or phenomena • Encourage peer-to-peer checks for understanding Examples: Justified list probes; card sorts, refutations; missed conception; representation analysis; thought experiments; example, non-example; always, sometimes, never; ranking tasks
EVALUATE: Assess the extent to which students have achieved understandings and abilities; provide feedback as needed; engage students in self-reflection	• Assess the extent to which students have met a learning target • Provide peer-to-peer and teacher-to-student feedback • Encourage self-assessment and reflection on how ideas have changed Examples: new but related probes, 2/3 testing, collaborative cued corrections, I used to think...but now I know, look back, concept mapping cards, success indicators, turn probe into an open-ended question

* FACTs in these examples are described in *Science Formative Assessment: 75 Practical Strategies that Link Instruction, Assessment, and Learning* (Keeley 2008, 2016) and *Science Formative Assessment: 50 More Practical Strategies That Link Instruction, Assessment, and Learning* (Keeley 2015).

the probe. Students work in small groups to test their predictions and discuss their ideas as they investigate. Questions that arise during the engage phase are also explored, such as, "Does the amount of sugar make a difference? Does the temperature of the lemonade water make a difference?" At one point the teacher uses the FACT, *What Are You Doing and Why?* (Keeley 2008, 2016) to have students do a quick write explaining the purpose of what they are doing and the question it will help them answer. This provides formative feedback to the teacher to ensure that the lesson is meeting its learning goal. After students complete their investigations, the teacher uses the *Extended Sticky Bars* FACT (Keeley 2015) to provide an opportunity for students to change their initial prediction to the probe based on their observations. She provides a different-color sticky note in which students record their new answer choice, informed by their investigation. She posts the notes next to the initial bar graph so that students can see how their initial ideas have changed after the investigation. The second bar graph reveals that most of the students selected answer choice D. At the end of class the teacher uses the *2 Minute Paper* FACT (Keeley 2008, 2015) to have students do a quick write describing why they changed (or did not change) their answer and how the evidence from the investigation can be used to understand what happens to matter during dissolving.

Explain Phase: Prior to the next day's class, the teacher reads through the *2 Minute Papers* and determines that most students recognize that the weight of the sweetened lemonade is equal to the combined weight of the sugar and unsweetened lemonade. However, the students seem to have difficulty linking the evidence to their answer choice and using conservation reasoning to explain the combined weight of the lemonade. She plans the next day's lesson to introduce the formal concept of conservation of matter. She uses the FACT, *B-D-A Drawings* (Keeley 2015), to have students model in small groups what they think is happening to the sugar at the particle level when it dissolves in the lemonade. The B (before) drawing represents the model before the sugar is added. The D (during) drawing models what is happening as the sugar is added to the water, and the A (after) drawing models what happens after all the sugar dissolves. Each small group presents and explains its model. After the presentations, the teacher summarizes the models and points out which parts of their models represent what happens during dissolving. She introduces the concept of conservation of matter by explaining (while using one of the students' models) that matter always exists even though its form or location sometimes changes. She guides the class toward explaining that the combined weight of the sugar and unsweetened lemonade is evidence that the sugar is in the liquid in a form we cannot see using a basic particle model. After the class discussion and introduction of formal terminology, the teacher provides an opportunity for the students to revisit the probe and write a scientific explanation to support their new prediction.

Elaborate Phase: Dissolving is one context for understanding conservation of matter during a physical change. The teacher decides to use different contexts to determine whether students can transfer their learning about how matter is conserved during a physical change to a different situation. This time the teacher presents the class with a *card sort* FACT (Keeley 2008, 2016) that she created to determine whether students recognize that matter is conserved in different contexts. The examples she used to create the card sort were a piece of shredded paper, a container of water put into a freezer and frozen, melted butter, water boiling on a stove, a clay ball flattened, mixing sand and water, a popped balloon, mixing sugar and salt. The students sorted the cards into three groups: changes in which the total amount of matter stays the same; changes in which the total amount of matter changes; and changes we are not sure about. The teacher circulates throughout the class and notes whether the groups are able to generalize the concept of matter conservation to new examples. She engages the class in a discussion where groups present, evaluate, and defend their arguments about whether or not the amount of matter (weight) is conserved for each new example.

Evaluate Phase: At this stage, the teacher determines the students are ready to be formally evaluated on the extent to which they met the disciplinary core idea: *the amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish* (NGSS Lead States 2013). Before administering the formal assessment, she provides an opportunity for students to reflect back on their learning and think about how their ideas have changed. She has the students complete the FACT, *I Used to Think __ But Now I Know___* (Keeley 2008, 2016) in their note-

books, by filling in the blanks, and adding an additional piece to describe the experiences that led them to change their thinking.

The 5E Instructional Model is not only a research-based model that supports deep conceptual learning; it also helps teachers think strategically about formative assessment and how it is integral to effective instruction. As Rodger Bybee implies in his new NSTA Press Book title, the *BSCS 5E Instructional Model: Creating Teachable Moments*, purposefully embedding formative assessment probes and FACTs into 5E instruction is an effective way to create and support those teachable moments (Bybee 2015).■

Page Keeley (pagekeeley@gmail.com) is a science education consultant and the author of the Uncovering Student Ideas in Science series (http://uncoveringstudentideas.org).

References

Bybee, R. 2015. *BSCS 5E instructional model: Creating teachable moments*. Arlington, VA: NSTA Press.

Keeley, P. 2008. *Science formative assessment: 75 practical strategies for linking assessment, instruction, and learning*. Thousand Oaks, CA: Corwin Press.

Keeley, P. 2015. *Science formative assessment: 50 more practical strategies for linking assessment, instruction, and learning*. Thousand Oaks, CA: Corwin Press.

Keeley, P. 2016. *Science formative assessment: 75 practical strategies for linking assessment, instruction, and learning*, 2nd Edition. Thousand Oaks, CA: Corwin Press.

Keeley, P., F. Eberle, and L. Farrin. 2005. *Uncovering student ideas in science: 25 formative assessment probes*. Arlington, VA: NSTA Press.

NGSS Lead States. 2013. *Next generation science standards: for states, by states*. Washington, DC: National Academies Press.