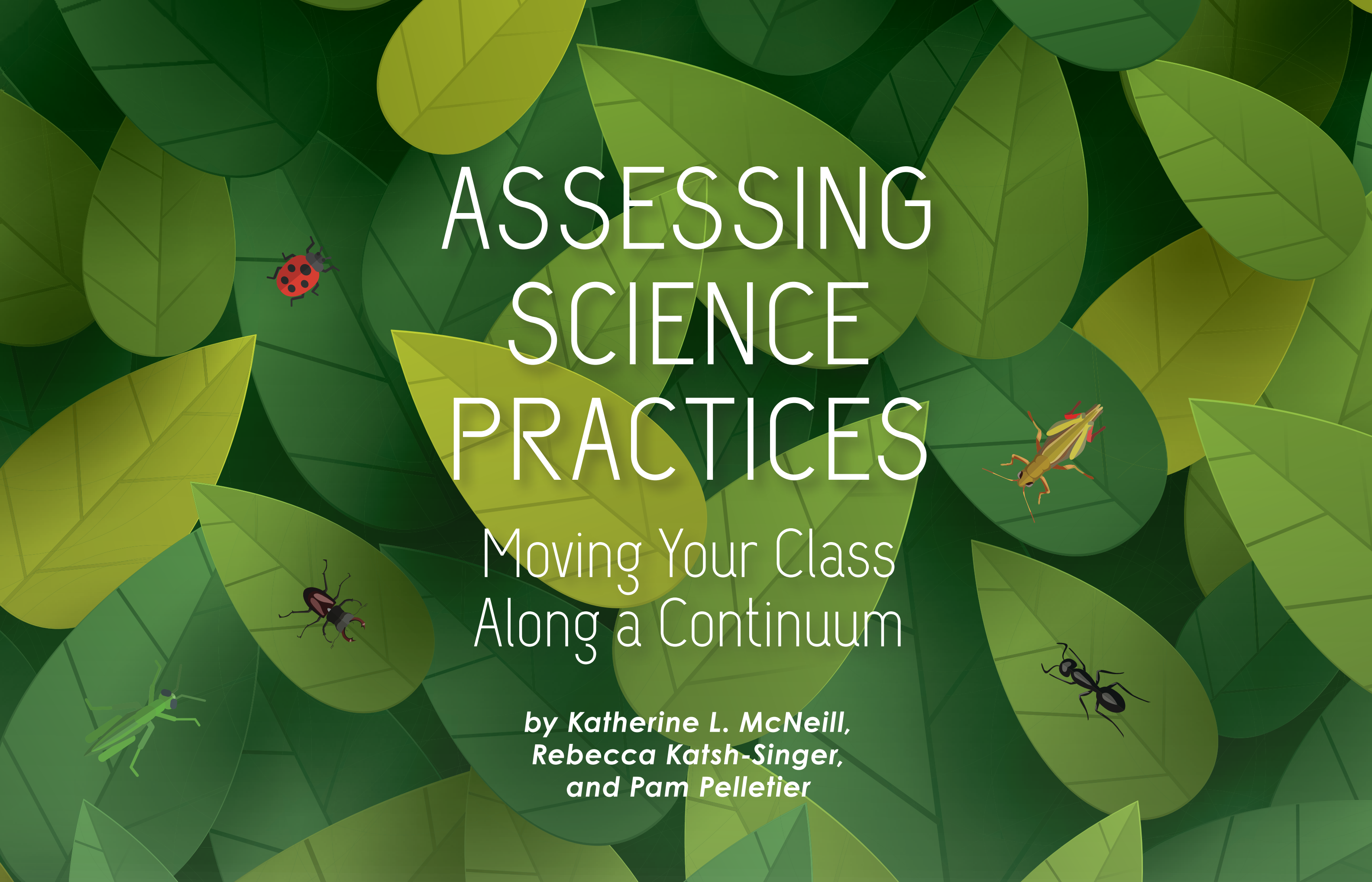

ASSESSING SCIENCE PRACTICES

Moving Your Class Along a Continuum

by Katherine L. McNeill, Rebecca Katsh-Singer, and Pam Pelletier

Ms. Richardson's sixth-grade students are at the end of a curriculum unit focused on plate tectonics (Regents of the University of California 2012). Specifically, her class is exploring a question: How will the Indian plate be different in 50 million years? She asked her class to participate in a science seminar which focused on whole-class argumentation. During the science seminar, she rearranged the chairs in her classroom to allow students to sit in two concentric circles (an inside circle and an outside circle). This arrangement encouraged students to talk directly to each other during the discussion. To prepare for the seminar, Ms. Richardson had students analyze data (including maps) and write their own arguments, based on their analysis. Ms. Richardson was interested in assessing the quality of her students' argumentation to help her design future science lessons that would better target this practice. Below is an excerpt from the beginning of the class discussion. Pablo volunteered to start the discussion and he read his argument to Ms. Richardson. This is how she responded:

Ms. Richardson: Pablo, I am going to ask that you say that one more time and a little bit slower and a little bit clearer. And make sure you address the people in the inside circle and not me. So, pretend I am not here. Okay. Go ahead.

Pablo: My claim is that the Indian plate will get smaller in 50 million years. My evidence is that on the collision zone—the Indian plate is located at a collision zone. And my reasoning is that at a collision zone, the plate folds and crumbles.

(A number of students raise their hands, including Ian.)

Ms. Richardson: Ian.

Ian: I disagree with Pablo. Because on the map it is surrounded by spreading zones. And my reasoning is that spreading zones will have it—that it will make new crust.

(A number of students raise their hands including Jose.)

Ms. Richardson: Jose.

Jose: My claim is that the Indian plate will get bigger and my evidence is that there are spreading zones around the boundaries of the Asian plates—at spreading zones plates move apart from each other.

Ms. Richardson: So, Jose, are you saying you agree with Pablo or you agree with Ian?

Jose: I agree with Pablo because he said it—oh, I agree with Ian that the Indian plate will get bigger.

Although the discussion includes argumentation (e.g., students use evidence to support claims), student difficulties in engaging in argumentation discussions also exist. Specifically, students are primarily reading their arguments to their teacher instead of listening to, building on, and questioning the ideas of their peers. What are key elements that teachers should look for to assess the quality of science practices such as, in this case, argumentation? How can a teacher's assessment of science practices be used to inform future instructional activities? What does it look like when a whole class's ability to engage in a particular science practice improves over time?

Assessing science practices

A Framework for K–12 Science Education (NRC 2012) and the *Next Generation Science Standards* (*NGSS*) (NGSS Lead States 2013) offer a transformative vision for science classrooms in which students actively engage in science practices as they apply disciplinary core ideas to make sense of the natural world. This includes a focus on eight science practices (see Figure 1), which may be the most significant challenge for teachers in terms of the successful implementation of the new standards (Bybee 2011). A classroom culture prioritizing science practices will require a shift away from science as a body of memorized facts to science as a way of thinking, talking, and acting that students need to engage in to make sense of the natural world.

With this shift to a classroom culture prioritizing science practices, teachers require effective assessment tools to identify the strengths and needs of their students for specific science practices to support continued improvement over time. While assessments often focus on individual student work, whole-class assessment tools can provide valuable information to move students along a continuum. Such assessments should include formative tasks that provide information about student achievement to guide instructional decision making (Wiliam 2011). Specifically, *NGSS* assessments should provide information about where students fall along a continuum, from novice entry points to exemplary proficiency, to inform the design of instruction (NRC 2014). As we move our instruction to the *NGSS*, students will be expected to engage in the three dimensions of the *NGSS* using science practices in the context of disciplinary core ideas and crosscutting concepts (known as three-dimensional instruction).

FIGURE 1 Eight science practices in the *NGSS*

1. Asking Questions (for science)
2. Developing and Using Models
3. Planning and Carrying Out Investigations
4. Analyzing and Interpreting Data
5. Using Mathematics and Computational Thinking
6. Constructing Explanations (for science)
7. Engaging in Argument from Evidence
8. Obtaining, Evaluating, and Communicating Information

However, it can be useful to focus on individual components, such as a science practice, to consider how to support students in building coherent understandings over time (NRC 2014).

In our work with teachers, we have found it challenging (and overwhelming for those new to the *NGSS*) to think about eight distinct practices. Consequently, we developed Figure 2 to group the practices using the ideas about them presented in the *Framework* about the science practices (NRC 2012). The figure is an oversimplification, but we find it productive for thinking about the eight science practices in relation to three categories: (1) Investigating Practices, (2) Sensemaking Practices, and (3) Critiquing Practices. The idea is that science is fundamentally about making sense of the natural world. Science is not a linear process and is not restricted to a single "scientific method" (NRC 2012). However, it is linked to nature; specifically, developing scientific knowledge about how the natural world works. The Investigating Practices focus on asking questions and investigating the natural world.

FIGURE 2 Understanding the natural world through investigating, sensemaking, and critiquing

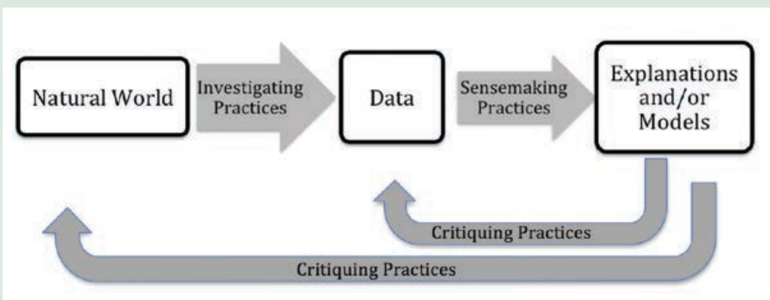

IMAGE COURTESY OF THE AUTHORS

FIGURE 3 Grouping the eight science practices into investigating, sensemaking, and critiquing

	Investigating practices	Sensemaking practices	Critiquing practices
Science practices	1. Asking Questions 3. Planning and Carrying Out Investigations 5. Using Mathematics and Computational Thinking	2. Developing and Using Models 4. Analyzing and Interpreting Data 6. Constructing Explanations	7. Engaging in Argument from Evidence 8. Obtaining, Evaluating, and Communicating Information

The products of these investigations are data. The Sensemaking Practices focus on analyzing that data by looking for patterns and relationships to develop explanations and models. Finally, the Critiquing Practices emphasize that students need to compare, contrast, and evaluate competing explanations and models as they make sense of the world around them. Critique is a hallmark of the practices of scientists, but it is frequently absent from classrooms (Osborne 2010).

Figure 3 includes one way to group the eight practices into these three categories; however, other groupings are possible. For example, an individual practice (such as modeling) can fit into different categories depending on how it is integrated into a science lesson. Our three groupings allow us to think about which science practices occur in classroom instruction. This is an important first step in assessing science practices—to consider what opportunities students have to engage in the science practices and use their findings to identify areas of need to target future growth.

In professional development work with teachers, we have found that many of the existing curricula and resources they use in their classrooms focus on the Investigating Practices, in that students conduct investigations and collect data about the natural world. Less common are curricular resources that support the Sensemaking Practices, such as constructing an explanation or developing a model. Even rarer are resources that support the Critiquing Practices, such as engaging in argument about competing explanations or models with different strengths and limitations. This focus on evaluation and critique is one element of the science practices that is new and differs from previous models of scientific inquiry, thereby providing rich opportunities for teachers to support student growth in these critical areas.

Science Practices Continuum Assessment Tool

When teaching the practices to students, we cannot overwhelm them with all of the practices at once. Identifying a practice (or subset of practices) to focus on can help students develop their understanding and abilities to engage in those practices within the context of three-dimensional instruction. After identifying the target science practice to use within a particular three-dimensional lesson (a lesson that emphasizes one or two practices, a specific disciplinary core idea, and a crosscutting concept), the next step is to assess a whole class's ability to engage in that practice. We developed the Science Practices Continuum as an assessment tool that includes simplified descriptions of each of the eight science practices (see Figure 4). The Continuum is based on Appendix F of the *NGSS*, particularly the 6–8 grade band, which provides significantly more detail for each practice. The greater detail and complexity in Appendix F should be integrated into future lessons as both students and teachers develop greater fluency with each practice.

The goal of the Continuum is to focus on one or two elements for each practice, which can be challenging for students and are productive levers for shifting classroom culture. These elements provide teachers with valuable information to inform instructional decisions that move students toward greater proficiency. At level 1 (Not Present), students are not engaged in the science practice. Moving to level 2 (Emergent), students participate in the science practice but exhibit one or two of the common student challenges identified in research literature. For example, in terms of developing and using models, students' models just describe or copy a phenomenon (rather than predicting or explaining the natural world) and students do not evaluate the merits and limitations of the model (Schwarz

FIGURE 4 Science Practices Continuum assessment tool

	Science practices	Level 1 (Not Present)	Level 2 (Emergent)	Level 3 (Proficient)	Level 4 (Exemplary)
Investigating science practices	1. Asking Questions	Students do not ask questions.	Students ask questions, but they are not typically scientific questions (i.e., not answerable through the gathering of evidence or about the natural world)	Students ask questions. Students' questions are both scientific and nonscientific questions.	Students ask questions. Students' questions are typically scientific (i.e., answerable through gathering evidence about the natural world).
	3. Planning and Carrying Out Investigations	Students do not design or conduct investigations.	Students conduct investigations, but these opportunities are typically teacher driven. Students do not make decisions about experimental variables or investigational methods (e.g., number of trials).	Students design or conduct investigations to gather data. Students make decisions about experimental variables, controls, or investigational methods (e.g., number of trials).	Students design and conduct investigations to gather data. Students make decisions about experimental variables, controls, and investigational methods (e.g., number of trials).
	5. Using Mathematics and Computational Thinking	Students do not use mathematical skills (i.e., measuring, estimating) or concepts (i.e., ratios).	Students use mathematical skills or concepts, but these are not connected to answering a scientific question.	Students use mathematical skills or concepts to answer a scientific question.	Students make decisions about what mathematical skills or concepts to use. Students use mathematical skills or concepts to answer a scientific question.
Sensemaking science practices	4. Analyzing and Interpreting Data	Students may record data but do not analyze data.	Students work with data to organize or group the data in a table or graph. However, students do not recognize patterns or relationships in the natural world.	Students work with data to organize or group the data in a table or graph. Students make sense of data by recognizing patterns or relationships in the natural world.	Students make decisions about how to analyze data (e.g., table or graph) and work with the data to create the representation. Students make sense of data by recognizing patterns or relationships in the natural world.

FIGURE 4 Science Practices Continuum assessment tool

	Science practices	Level 1 (Not Present)	Level 2 (Emergent)	Level 3 (Proficient)	Level 4 (Exemplary)
Sensemaking science practices (continued)	6. Constructing Explanations	Students do not create scientific explanations.	Students attempt to create scientific explanations, but students' explanations are descriptive instead of explaining how or why a phenomenon occurs. Students do not use appropriate evidence to support their explanations.	Students construct explanations that focus on explaining how or why a phenomenon occurs. Students do not use appropriate evidence to support their explanations.	Students construct explanations that focus on explaining how or why a phenomenon occurs and use appropriate evidence to support their explanations.
	2. Developing and Using Models	Students do not create models.	Students create models. Students' models focus on describing natural phenomena rather than predicting or explaining the natural world. Students do not evaluate the merits and limitations of the model.	Students create models focused on predicting or explaining the natural world. Students do not evaluate the merits and limitations of the model.	Students create models focused on predicting or explaining the natural world. Students do evaluate the merits and limitations of the model.
Critiquing Science Practices	7. Engaging in argument from evidence	Students do not engage in argumentation.	Students engage in argumentation where they support their claims with evidence or reasoning, but the discourse is primarily teacher-driven.	Students to engage in student-driven argumentation. The student discourse includes evidence and reasoning to support their claim. Students also agree and disagree, but rarely engage in critique.	Students engage in student-driven argumentation. The student discourse includes evidence, reasoning that links the evidence to their claim and critique of competing arguments during which students build on and question each other's ideas.
	8. Obtaining, evaluating, and communicating information	Students do not read text for scientific information.	Students read text to obtain scientific information, but do not evaluate this information. Students also do not compare or combine information from multiple texts considering the strengths of the information and sources.	Students read and evaluate text to obtain scientific information. Students do not compare or combine information from multiple texts considering the strengths of the information and sources.	Students read and evaluate text to obtain scientific information. Students compare and combine information from multiple texts considering the strengths of the information and sources.

et al. 2009). For engaging in argumentation, students have difficulty including both evidence and reasoning to support their claims and have difficulty engaging in student-to-student interactions in which they question and critique the ideas of their peers (Berland and McNeill 2010). At level 3 (Proficient), students engage in the practice effectively; however, they have some difficulties with common student challenges. Finally, level 4 (Exemplary) describes student expertise in engaging in the science practice.

Classroom example 1: Engaging in Argument from Evidence

If we return to the discussion in Ms. Richardson's classroom in relation to the Continuum for argumentation, we can assess the class as being predominately at level 2 (Emergent) based on the students who spoke during the 10-minute discussion. Students are using evidence and reasoning to support their claims that the Indian Plate will be either larger or smaller in 50 million years. This is a clear strength of the students in that they justify the claims put forth using the data they analyzed in maps. However, the conversation is not "student-driven," perhaps because this is a new form of discourse for students with new norms. For example, Pablo starts off by just reading his paper and Ms. Richardson has to prompt Jose about whether he agrees or disagrees with his classmates. This suggests that students need support talking directly to each other, rather than reading their written arguments to their teacher. In addition, students need to move beyond just agreeing or disagreeing to questioning and critiquing each other's arguments to better understand the strengths and weaknesses of these different claims.

It is challenging for a teacher to assess whole-class participation in science practices, such as argumentation, because of the complexities of classroom instruction. There are many different elements of student participation in instruction (such as student engagement) upon which a teacher can focus. However, the Continuum offers a quick tool to evaluate potential student challenges specific to the science practices and can be used multiple times across the year to assess growth. The teacher uses the Continuum by identifying a section of a lesson that focuses on a specific science practice, such as a 10-minute science seminar focused on argumentation. During the lesson, the teacher can take notes about the one or two elements that serve as levers for that practice. At the end of the lesson, the teacher then identifies which of the four levels in the Continuum best characterizes the majority of students' participation in the science practice. The teacher's assessment of student performance can come from either a full class discussion or from visiting different student groups, depending on the targeted science practice. Ideally, the teacher would listen and observe at least half of the students engaged in the practice at any one time, but particularly when students' performance is at level 1 (Not Present) and level 2 (Emergent), fewer students will be actively engaged.

In addition, we developed instructional activities for each science practice to help students move along the Continuum toward greater proficiency. We created one table for each science practice summarizing key instructional activities. The tables for each practice can be found on our website underneath the "Tools" tab (see Resources). For example, Figure 5 includes instructional activities for argumentation. Specifically, Ms. Richardson may want to use instructional strategies 5, 6, or 7, which focus on supporting argumentation with student-to-student interactions that allow students to question and critique each other's ideas. For example, in her next argumentation discussion, Ms. Richardson could implement strategy 5 and provide students with a poster that contains sentence starters and questions that students can use to critique different arguments. Additionally, she could use strategy 7 and remove herself from the discussion to encourage students to talk directly to each other, rather than reading their written arguments from their papers to the teacher.

Classroom example 2: Constructing Explanations

This second example is from a sixth-grade classroom studying adaptation and natural selection. The teacher, Ms. Flores, introduced a set of data about black and green bugs. In this lesson, the bugs lived in grassy areas and were hunted by birds. Over time, pollution from a nearby power plant altered the color of the grass in some areas of the habitat, changing it from green to black. Ms. Flores had students work in groups to look at data—a graph showing the bug population over time, a data table showing the pollution from the power plant, and pictures of the environment over time. She told students that their job was to use these data and work with their group to answer the question: Did the pollution affect the bugs? In answering this question, she stressed that students should construct an explanation that included why they think the pollution did or did not affect the bugs. Below is an excerpt from one small-group conversation:

Leslie: The graph here shows that for the past few years, there have been way more black bugs than green bugs.

Juan: Wow! Look at these pictures! The grass was green 10 years ago, but now it has some spots that are

FIGURE 5 Potential instructional activities for engaging in argument from evidence

1. Introduce students to the argumentation framework of claim, evidence, and reasoning (CER). A *claim* answers a question or problem, which could be an explanation or model. *Evidence* is data that support the claim, such as observations and measurements. *Reasoning* explains why the evidence supports the claim using scientific ideas or principles.
2. Provide students with scaffolds such as a graphic organizer, sentence starters, or questions that highlight the CER components to help them craft their arguments.
3. Revise argumentation questions in lessons or the curriculum to ensure that there is more than one possible claim that students could potentially support with evidence. When students have multiple competing claims, there is more opportunity for critique.
4. Facilitate a discussion about the norms for argumentation. Explain to students that they should be talking directly to each other and not through the teacher. In addition, they should be questioning and critiquing each other's ideas. However, it is also important for students to be willing to change their minds if new ideas or evidence is presented by their peers that convinces them of the strength of a competing claim.
5. Create a poster in the classroom that supports the CER structure, as well as students critiquing different ideas. It could include sentence starters such as, "My evidence is…" and "I disagree because…," as well as questions such as "What are some other possible claims? Do we have support for those claims?" and "Why did you decide to use that evidence to support your claim? Could the data be interpreted in a different way?"
6. Model for students what it looks like to question or critique another person's idea. For example, "I disagree with Maria's claim, because I interpreted the data in a different way. I think the data show that lung capacity is important for…"
7. Limit teacher talk during argumentation by physically removing yourself from the discussion (e.g., sit in the corner of the room) or telling students that you have a specific task during the discussion. For example, you can tell the class that your job is to record the different evidence that comes up during the conversation and that you will not be actively talking during the discussion.

turning black. Cool.

Leslie: I've never seen black grass before. I wonder why it turned black.

Sadie: Is that because of the pollution? So, the answer is that the pollution affects the bugs?

Juan: Sounds good to me.

In terms of the Continuum for explanation, this group of students is at a level 2 (Emergent), because they have only described that pollution affects the bugs and have not explained why the pollution is affecting the bugs. Based on this assessment, Ms. Flores could incorporate a variety of instructional strategies in her next lesson focused on explanations (see Figure 6). For example, she could use strategy 4 and project two examples of explanations—one that is solely descriptive and another that gets at the "why." The class could then discuss and critique the examples. In addition, she could use strategy 5 and provide her students with a graphic organizer that highlights the key components of an explanation to help scaffold their discussion.

Discussion

Developing a classroom culture that prioritizes science practices takes time. For teachers to better design instruction that meets the needs of their students, they need formative assessment tools that provide information that can be used to guide instruction and support student growth (William 2011). We find Figure 2 to be an effective tool to evaluate current instruction and identify opportunities for students to engage in the science practices. In addition, the Science Practices Continuum focuses on one or two key student challenges for each practice that can serve as an important lever to shift classroom culture. The Continuum is used to assess the class as a whole as students are engaged in a science lesson targeting at least one of the science practices. Assessing where the class is on the Continuum in conjunction with the potential instructional activities can provide valuable information to design more effective learning environments. In addition, using the Continuum three or four times over the school year for the same practice can help gauge student progress for a specific science practice. In this article, we present exam-

FIGURE 6 Potential instructional activities for constructing explanations

1. Discuss key features of explanations in science: explanatory account, science ideas, and evidence. An *explanatory account* describes how or why a phenomenon occurs. *Science ideas* are key concepts or principles that students apply to make sense of a specific phenomenon. *Evidence* is scientific data such as measurements and observations.
2. Create a poster with the key features for a scientific explanation, such as that it shows how or why something occurs.
3. Revise explanation questions in the curriculum or lessons to ensure that students need to answer with more than a simple "yes" or "no"; rather, they should require an explanatory account.
4. Provide examples of strong and weak examples (e.g., describes a phenomenon instead of explaining it). Critique the examples as a class.
5. Provide students with scaffolds such as sentence starters, questions, or graphic organizers that highlight key features. For example, a graphic organizer could include three sections labeled: (1) Your explanation—the how or why?; (2) Big science ideas that support your explanation and (3) Evidence that supports your explanation.
6. Ask students to highlight the key features of an explanation (explanatory account, science ideas, and evidence) in their own or a peer's writing.
7. Ask students to give feedback to each other about written explanations. Provide sentence starters to students to help them make specific statements about the explanations. Examples of sentences starters can include, "I have a question about your evidence…," "I am not sure that your writing explains why _____ occurs. Can you explain that to me?," or "How can we use our big science ideas to help explain _____?"

ples from two science practices. Additional case studies and instructional activities for the other six science practices are available on our website (see Resources). ■

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Resource

Instructional leadership for science practices—*www.sciencepracticesleadership.com*

Katherine L. McNeill (*kmcneill@bc.edu*) is a former middle school science teacher and an associate professor of science education in the Lynch School of Education at Boston College in Chestnut Hill, Massachusetts. ***Rebecca Katsh-Singer*** is a former middle school science teacher and a current PhD candidate in the Lynch School of Education at Boston College. ***Pam Pelletier*** is a former high school teacher and currently the director of science and technology/engineering in the Boston Public Schools.