Chapter 1

An Introduction to Formative Assessment Classroom Techniques (FACTs)

WHAT DOES A FORMATIVE ASSESSMENT-CENTERED CLASSROOM LOOK LIKE?

In a primary classroom, students are having a "science talk" to decide which organisms illustrated on a set of cards are "animals." After using a *Card Sort* strategy to group the cards as "animals" and "not animals," the teacher encourages the students to develop a rule that could be used to decide whether an organism is an animal. The students share their ideas, openly agreeing or disagreeing with their peers. The teacher records the ideas that are most common among students and notes the reasoning students use. She notices many students think animals must have fur or legs and that humans are not animals and makes note of this to address in the next lesson. She then gives students an opportunity to regroup their cards, using the rule they developed as a class. She listens carefully as students explain their reasoning based on the "animal rule" they developed. The teacher adds new cards to the *Card Sort.* Some students decide they need to revise the rule to fit the new cards. The teacher probes deeper to find out why some students revised their thinking.

In an intermediate classroom, students use a *P-E-O Probe* to predict and explain whether the mass of an ice cube in a sealed ziptop bag will increase, decrease, or stay the same after it melts. Using the *Human Scattergraph* technique, the teacher quickly sees that students differ in their predictions and confidence in their answer. She then provides them with an opportunity to discuss their prediction and the evidence that supports it in small groups. The teacher listens carefully and notes the preconceptions students use to support their prediction, particularly concepts they may have encountered previously, such as density, that seem to muddle their understanding of the conservation-of-matter phenomenon of what happens during a change in state. After students have had an opportunity to explain their thinking about what would happen to the mass of the ice cube after it melts, the teacher provides an opportunity for students to test their ideas by observing and recording the mass of an ice cube in a sealed ziptop bag before and after it melts. She notices how some students are starting to rethink their prediction and the evidence and reasoning they used to support it. The class then comes together to discuss and reconcile their findings with their initial predictions and ideas. They write a new explanation for the phenomenon. The students use *Scientists' Ideas Comparison* to compare how closely their new ideas match the scientific explanation.

In a middle school classroom, the teacher uses a *Familiar Phenomenon Probe* to uncover students' explanations for the phases of the moon. Using the *Sticky Bars* strategy to anonymously display students' initial ideas, the teacher and the class could instantly see that most students believed the phases of the moon were caused by the shadow of the Earth cast on the moon. Knowing that this would be a difficult idea to change, the teacher designs a lesson that involves the students in using one of the scientific and engineering practices described in the National Research Council's (2012) *A Framework for K–12 Science Education* and included as one of the three dimensions in the *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013) to make sense of and accurately explain this phenomenon. She engages the students in developing and using a model to visually see for themselves how the position of the moon in relation to the Earth and the sun results in the different moon phases. After students use their model to visualize and understand the phenomenon, they revisit their original explanations and have an opportunity to revise them, based on their model. The next day, students are given a task of researching lunar eclipses. They use the information from researching eclipses to work in small groups with *Whiteboards* to illustrate and explain the difference between a lunar eclipse and a new moon. Students share their *Whiteboard* ideas and get feedback from the class and teacher regarding the differences in representing the two sun-Earth-moon phenomena. At the end of the lesson, students use *I Used to Think . . . But Now I Know* to reflect on their initial explanation for the phases of the moon and describe how comparing the model of a lunar eclipse with the model of a moon phase helped them better understand both phenomena.

In a high school chemistry class, small groups of students are using *A&D Statements* to discuss and reconcile their different ideas about a claim made by several groups, "The mass of an iron object decreases as it rusts." One student who agrees with the claim is trying to persuade her classmates to consider her idea that rust is like a mold that eats and breaks down iron, causing it to lose mass. Another student who disagrees with the claim offers a rebuttal and argues that the oxygen in the air is combined with the iron to make rust, which would add additional mass. Each group is trying to come up with a consensus idea and explanation to share with the class along with a method to test its idea. The teacher circulates among groups, probing further and facilitating an argumentation session. Students write a *Two-Minute Paper* at the end of class to share their thinking with the teacher and describe what they need to do next to test their ideas. The teacher uses this information to prepare for student investigation the next day.

What do all these classroom snapshots have in common? Each of these examples combines formative assessment classroom techniques (FACTs) with instruction for a specific teaching and learning purpose. Often it is hard to tell whether a particular FACT serves an instructional, assessment, or learning purpose since they are so intertwined. Students are learning while at the same time the teacher is gathering valuable information about their thinking that will inform instruction and provide feedback to students on their learning.

Each of these snapshots gives a brief glimpse into the different techniques teachers use to promote student thinking, uncover students' ideas, and use information about their students' progress in moving toward a learning target to improve their instruction. The teaching strategies in these snapshots are just a few of the 75 FACTs described in Chapter 4, along with the underpinnings described in Chapters 1 through 3, that will help you understand and effectively use formative assessment. While you may be tempted to skip ahead and go directly to Chapter 4 to find FACTs you can use in your classroom, you are encouraged to first read Chapters 1 through 3. By having a firm knowledge base about the purposes and uses of formative assessment, as well as examining implementation considerations before you select a FACT, the image and use of formative assessment in your classroom will be sharper and more deliberately focused.

WHY USE FACTs?

Every day, science teachers are asking questions, listening carefully to students as they explain their ideas, observing students as they work in groups, examining student writing and drawings, and orchestrating classroom discourse that promotes the public sharing and evaluation of

> "Assessment for learning is any assessment for which the first priority in its design and practice is to serve the purpose of promoting pupils' learning. It thus differs from assessment designed primarily to serve the purposes of accountability, or of ranking, or of certifying competence" (Black & Harrison, 2004).

students' ideas. These purposeful, planned, and often spontaneous teacher-to-student, student-to-teacher, and student-to-student verbal and written interactions involve a variety of assessment techniques. These techniques are used to engage students in thinking deeply about their ideas in science, uncover the preexisting ideas students bring to their learning that can be used as starting points to build on during instruction, and help teachers and students throughout an instructional cycle determine how well individuals and the class are progressing toward developing scientific understanding.

The 75 science FACTs described in this book are inextricably linked to assessment, instruction, and learning. The interconnected nature of formative assessment clearly differentiates the types of assessments we call assessments *for* learning from assessments *of* learning—the summative assessments used to measure and document student achievement. The preposition makes a difference! Furthermore, a third preposition can be added: assessment *as* learning. As you will see once you begin using the techniques in this book, they may become learning activities as well as provide information about learning.

Although it is important to recognize that summative assessments can also be used formatively, they tend to be more formal in nature, tend to be given at an endpoint of instruction, and usually involve grading or other means of determining and documenting student achievement. Furthermore, if released items from large-scale tests are used formatively, be aware that they may not reveal commonly held misconceptions. Because common misconception answer choices are as likely to be selected by high-scoring students as low-scoring students, they do not discriminate and thus are rejected from most item pools when constructing standardized tests.

> "An assessment functions formatively to the extent that evidence about student learning is elicited, interpreted, and used by teachers, learners, or their peers to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have made in the absence of that evidence" (Wiliam, 2011, p. 43).

Figure 1.1 describes the different types and purposes of assessment in the science classroom. Note that diagnostic assessment becomes formative assessment when the information is used by the teacher to improve teaching and learning. For example, a teacher can collect data in response to a probing question to identify the commonly held ideas students have about a phenomenon. But if the data are not used to inform teaching and learning, then it is merely a diagnosis without action taken. In

Figure 1.1 Types and Purposes of Assessment

Diagnostic—To uncover what students understand and do not understand.

Formative—To inform instruction and provide feedback to students on their learning.

Summative—To measure and document the extent to which students have achieved a learning target.

NOTE: Diagnostic assessment becomes formative when the assessment data are used to inform instruction.

a medical context, this would be analogous to the sick patient who goes to the doctor and is diagnosed with a medical condition. To go beyond the diagnosis, the doctor would use the information collected diagnostically to formatively design the best course of treatment so that the patient's health would improve. At the same time, the patient self-monitors or receives feedback on the progress of his or her condition so that the patient can improve his or her health. Finally, the patient comes back for periodic physical exams, weeks, months, even years later. The doctor records the extent to which the treatment worked and the condition of the patient's overall health. This last check is analogous to summative assessment.

Each FACT described in Chapter 4 is a type of question, process, or activity that helps provide teachers and students with information about their factual, conceptual, and procedural understandings in science. Furthermore, the content of each FACT provides valuable information to inform the learning targets associated with core disciplinary ideas, scientific and engineering practices, or crosscutting concepts. These formative assessment techniques inform teaching by allowing the teacher to continuously gather information on student thinking and learning to make data-informed decisions to plan for or adjust instructional activities, monitor the pace of instruction, identify potential misconceptions that can be barriers as well as springboards for learning, and spend more time on ideas that students struggle with. Formative assessment is also used to provide feedback to students, engaging them in the evaluation of their own and their peers' thinking and learning as well as creating a feedback loop back to the teacher that informs instructional decisions. Figure 1.2 defines formative assessment in a nutshell.

In addition to informing instruction and providing feedback to students, many of the formative assessment techniques included in this book support the use of metacognitive skills and promote deeper student thinking and engagement.

The FACTs described in this book are designed to be easily embedded into classroom instruction. They are primarily used to assess *before and*

Figure 1.2 Definition in a Nutshell

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Formative assessment is a systematic process of collecting evidence about students' thinking and learning to inform instruction and provide feedback to the students while simultaneously promoting learning. It happens *during* the learning process.

It is assessment ***for*** learning rather than assessment ***of*** learning, and it can also be assessment ***as*** learning!

throughout the learning process rather than at an endpoint of instruction (except for reflection). Their main purpose is to improve student learning and opportunities to learn through carefully designed instruction. They are not used for the summative purpose of accountability—measuring and reporting student achievement. The versatility of the techniques described accommodates a range of learning styles and can be used to differentiate instruction and assessment for individuals and groups of students. FACTs can be used to spark students' interest, surface ideas, initiate an investigation, seek information from text and other resources, and encourage classroom discourse—these are assessment strategies that promote learning rather than measure and report learning. A rich repertoire of FACTs enables learners to interact with assessment in multiple ways—through writing, drawing, speaking, listening, physically moving, modeling, arguing, and designing and carrying out investigations. The following is a list of 20 purposes for using FACTs in the science classroom:

> "When data are used by teachers to make decisions about next steps for a student or group of students, to plan instruction, and to improve their own practice, they help *inform* as well as *form* practice; this is *formative assessment.* When data are collected at certain planned intervals, and are used to show what students have achieved to date, they provide a *summary* of progress and are *summative assessment*" (Carlson, Humphrey, & Reinhardt, 2003, p. 4).

1. Activate thinking and engage students in learning
2. Make students' ideas explicit to themselves and the teacher
3. Challenge students' existing ideas and encourage intellectual curiosity
4. Encourage continuous reflection on teaching and learning
5. Help students consider alternative viewpoints
6. Provide a stimulus for discussion and scientific argumentation

7. Help students recognize when they have learned or not learned something
8. Encourage students to ask better questions and provide thoughtful responses
9. Provide starting points for student investigations and idea exploration
10. Signal readiness to transition to formal concept development
11. Determine if students can apply scientific ideas and practices to new situations
12. Differentiate instruction for individuals or groups of students
13. Promote the use of academic language in science learning
14. Evaluate the effectiveness of a lesson
15. Help students develop self-assessment and peer assessment skills
16. Give and use feedback (student to student, teacher to student, and student to teacher)
17. Encourage social construction of ideas in science
18. Inform immediate or later adjustments to instruction
19. Encourage and include participation of all learners
20. Increase comfort in making one's own ideas public

Regardless of geographic area, type of school, diversity of student population, science discipline, and grade level science teachers teach, every teacher shares the same goal. That goal is to provide the highest quality instruction that will ensure that all students have opportunities to learn the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts that will help them become science-literate students and adults. Formative assessment provides ongoing opportunities for teachers to elicit students' prior knowledge; identify the scientific ideas and practices they struggle with, accommodate, or develop as they engage in the process of learning; and determine the extent to which students are moving toward or have reached scientific understanding at an appropriate developmental level. FACTs help teachers continuously examine how students' ideas form and change over time, how well they can use the scientific and engineering practices, and how students respond to particular teaching approaches. This information is constantly used to adjust instruction and refocus learning to support each student's intellectual growth in science.

HOW DOES RESEARCH SUPPORT THE USE OF FACTs?

The seminal report from the National Research Council, *How People Learn: Brain, Mind, Experience, and School* (Bransford, Brown, & Cocking, 1999), has significantly contributed to our understanding of how students learn science. This understanding has implications for what is taught in science, how science is taught, how science learning is assessed, and how to promote deeper understanding in science. Three core principles from this report strongly support the use of FACTs in the science classroom.

> **Principle 1:** If their [students'] initial understanding is not engaged, they may fail to grasp new concepts and information presented in the classroom, or they may learn them for purposes of a test but revert to their preconceptions (Bransford et al., 1999, p. 14).

This principle supports the use of FACTs as a way to elicit the prior ideas students bring to the classroom, making their thinking visible to themselves, their peers, and the teacher. Students do not begin science learning as blank slates waiting to be filled with knowledge. By knowing in advance the ideas students have already formed in their minds, teachers can design targeted instruction and create conditions for learning that take into account and build on students' preconceived ideas. Students' own ideas and the instructional opportunities that use them as springboards provide a foundation on which formal concepts and practices in science can be developed. As students engage in learning experiences designed to help them develop scientific understandings, teachers keep their fingers on the pulse of students' learning, determining when instruction is effective in helping students revise or refine their ideas or use of scientific and engineering practices and make midcourse corrections as needed.

> **Principle 2:** To develop competence in an area of inquiry, students must (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application (Bransford et al., 1999, p. 16).

This principle points out the importance of factual knowledge but cautions that knowledge of a large set of disconnected facts is not sufficient to support conceptual understanding. Several of the FACTs described in Chapter 4 not only provide strategies for teachers to assess students' knowledge of facts and understanding of concepts but also actually promote thinking that supports understanding. This thinking and the feedback students receive during the learning process help support the development of a conceptual framework of ideas. Teachers use the information on students' thinking to design opportunities that will help move students from novice learners to deeper, conceptual learners who can draw on and retrieve information from their framework. As concept development is monitored, reinforced, and solidified, formative assessment techniques are also used to determine how well students can transfer their new knowledge and skills from one context to another. This is particularly important as the NGSS, which several states are adopting or using to inform their revised standards, are more conceptually rigorous and require students to use a connected network of ideas.

> **Principle 3:** A "metacognitive" approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them (Bransford et al., 1999, p. 18).

John Flavel, a Stanford University psychologist, coined the term *metacognition* in the late 1970s to name the process of thinking about one's own thinking and learning. Since then, cognitive science has focused considerable attention on this process (Walsh & Sattes, 2005). Several FACTs described in this book promote the use of metacognitive strategies for self-regulation of learning. These strategies help students monitor their own learning by helping them predict outcomes, explain ideas to themselves, note areas where they have difficulty understanding scientific concepts, activate prior knowledge and background information, and recognize experiences that help or hinder their learning. White and Frederickson (1998) suggest that metacognitive strategies not be taught generically but rather be embedded into the subject matter that students are learning. The FACTs that support metacognition are designed to be seamlessly embedded into the science learning experiences that target students' ideas and thinking in science. They provide opportunities for students to have an internal dialogue that mentally verbalizes their thinking, which can then be shared with others.

Evidence from the research studies described in *How People Learn* (Bransford et al., 1999) indicates that when these three principles are incorporated into instruction, assessment, and learning, student achievement improves. This research is further supported by the metastudy described in *Assessment for Learning* (Black, Harrison, Lee, Marshall, & Wiliam, 2003), which makes a strong case, supported with quantitative evidence, for the use of formative assessment to improve learning, particularly to raise the achievement levels of students who have typically been described as low performers.

> "The teacher's job is not to transmit knowledge, nor to facilitate learning. It is to engineer effective learning environments for the students. The key features of effective learning environments are that they create student engagement, and allow teachers, learners, and their peers to ensure that the learning is proceeding in the intended direction. The only way we can do this is through assessment. That is why assessment is, indeed, the bridge between teaching and learning" (Wiliam, 2011, p. 81).

CLASSROOM ENVIRONMENTS THAT SUPPORT FORMATIVE ASSESSMENT

In addition to contributing to our understanding of how students learn science, *How People Learn* (Bransford et al., 1999) has changed our view of how classroom environments that support teaching and learning should be designed. These characteristics relate directly to classroom climates and cultures where the use of FACTs is an integral part of teaching and learning. These environments include the following:

Learner-Centered Environment. In a learner-centered environment, teachers pay careful attention to the knowledge, beliefs, attitudes, and skills students bring to the classroom (Bransford et al., 1999, p. 23). In a learner-centered classroom, teachers use FACTs before and throughout instruction, pay careful attention to the progress of each student, and know at all times where their students are in their thinking and learning. All ideas, whether they are right or wrong, are valued in a learner-centered environment. Learners come to value their ideas, knowing that their existing conceptions that surface through the use of FACTs provide the beginning of a pathway to new understandings.

Knowledge-Centered Environment. In a knowledge-centered environment, teachers know what the goals for learning are, the key concepts and ideas that make up the goals, the prerequisites on which prior and later understandings are built, the types of experiences that support conceptual learning, and the assessments that will provide information about student learning. In addition, these goals, key concepts and ideas, and prerequisite learnings can be made explicit to students as well so they can monitor their progress toward achieving understanding (Bransford et al., 1999, p. 24). The knowledge-centered environment uses FACTs to understand students' thinking to provide the necessary depth of experience students need to develop conceptual understanding. It looks beyond student engagement and how well students enjoy their science activities. There are important differences between science activities that are "fun" and those that encourage learning with understanding. FACTs support a knowledge-centered environment by promoting and monitoring learning with understanding.

Assessment-Centered Environment. Assessment-centered environments provide opportunities for students to surface, examine, and revise their thinking (Bransford et al., 1999, p. 24). The ongoing use of FACTs makes students' thinking visible to both teachers and students and provides students with opportunities to revise and improve their thinking and monitor their own learning progress. In a formative assessment-centered environment, teachers identify problem learning areas to focus on. They encourage students to examine how their ideas have changed over the course of a unit of study. Having an opportunity to examine their own ideas and share how and why they have changed is a powerful way to connect the student to the teaching and learning process.

> "An important feature of the assessment-centered classroom is assessment that supports learning by providing students with opportunities to revise and improve their thinking" (Donovan & Bransford, 2005, p. 16).

Community-Centered Environment. A community-centered environment is a place where students learn from each other and continually strive to improve their learning. It is a place where social norms are valued in the search for understanding and both teachers and students believe that everyone can learn (Bransford et al., 1999, p. 25). Within this environment, FACTs are used to promote intellectual camaraderie around discussing and learning ideas in science. A science community-centered environment that uses FACTs encourages the following:

- Public sharing of all ideas, not just the "right answers"
- Safety in academic risk taking
- Shared revision of ideas and reflection
- Questioning and clarification of explanations
- Productive discussions with peers
- Use of norms for respectful scientific argumentation
- Group and individual feedback on teaching and learning

A classroom "ecosystem" with these four overlapping environments is a place where students and teachers both feel part of an intellectual learning community that is continuously improving opportunities to teach and learn. It is a place where students and teachers thrive. It is a place where the connections between assessment, teaching, and learning are inseparable.

CONNECTING TEACHING AND LEARNING

Imagine the following scenario from a popular cartoon. Two friends are talking about their pets. One friend says that he taught his dog how to whistle.

> "Learning can and often does take place without the benefit of teaching—and sometimes even in spite of it—but there is no such thing as effective teaching in the absence of learning" (Angelo & Cross, 1993, p. 3).

The other friend looks at the dog and waits for him to whistle. After encouraging the dog to whistle with no luck, his friend repeats that he said he taught his dog how to whistle, but he didn't say his dog learned how to whistle. Without the effective use of formative assessment, teaching science to children can be like teaching your dog to whistle.

Teaching without learning can and does happen in science classrooms. The unfortunate truth is, even with what one perceives as his or her most engaging activity or best teaching moments, instruction can result in little or no gain in conceptual understanding if the time is not taken to find out students' initial preconceptions, ascertain their readiness to learn, provide opportunities for them to grapple with alternative ideas, monitor their learning to uncover any conceptual difficulties that can be addressed during instruction, and provide opportunities for feedback and reflection.

Students are very good at playing the "game of school." They know how to give teachers the answer the teacher wants but might not be what the student actually believes or thinks. Even our brightest students can "learn" science for the purpose of passing a test but then quickly revert back to their misconceptions. Gaps often exist between what was taught and what students actually learned, particularly if a student interprets a concept in a way that was not intended by the teacher's instruction. Frequently, these gaps do not show up until after students have been summatively assessed through end-of-unit, district, or state assessments, and sometimes they do not show up at all. When this happens, these misconceptions can follow students from grade to grade, right into adulthood. After giving a summative assessment, it is often too late to go back and modify the lessons, particularly when assessments given months and even years later point out the gaps in student learning.

To stop this inefficient cycle of backfilling the gaps, teachers need better ways of determining where their students are in their thinking and understanding prior to and throughout the instructional process. They need techniques that can be used on the fly at a moment's notice as well as techniques that can be planned for in advance. Students also need to be actively involved in the assessment process so that they are learning through assessment as well as providing useful feedback to the teacher and other students. Good formative assessment practices raise the quality of classroom instruction and promote deeper conceptual learning. Formative assessment ultimately empowers both the teacher and the student to make the best possible decisions regarding teaching and learning.

Linking assessment, instruction, and learning does not merely involve adding some new techniques to teachers' repertoire of strategies. The purposeful use of FACTs, on a continuous basis, provides much more—it

> "Formative assessment isn't just about strategies to ascertain current knowledge—formative assessment happens after the finding out has taken place. It's about furthering student learning during the learning process" (Clarke, 2005, p. 1).

organizes the entire classroom around learning and informs ways teachers can provide more effective learning experiences based on how their own students think and learn. Formative assessment can be used formally or informally, but it is always purposeful. The FACTs teachers use and the actions they take based on the information they have gathered and analyzed can be immediate, the next day, over the course of a unit, or even shared with and used by teachers who will have the same students the next year. If information about student learning is collected but not used as feedback for the teacher or student to take action that will improve teaching or learning, then it is not formative. It becomes information for information's sake. For example, using a FACT to find out if students have misconceptions similar to the commonly held ideas noted in the research literature is interesting and important in and of itself. However, just knowing students have these ideas does not make this a formative assessment activity. It is the collecting of this information and the decisions made as a result of carefully examining the data that gives it the distinction of formative assessment and connects teaching to learning.

UNDERSTANDING MISCONCEPTIONS IN SCIENCE: MISCONCEPTIONS ABOUT MISCONCEPTIONS

Researchers tend to use words such as alternative conceptions, partial ideas, preconceptions, naïve conceptions, facets of understanding, schema, phenomenological primitives, and more to describe the ideas students have that are not entirely consistent with the scientific understanding of a concept or idea. Since misconception is the term familiar to practitioners, it is the word that is used throughout this book. However, familiarity can lead to complacency when practitioners are not clear about what a misconception is and how to best address it. Recognizing that the word misconception is a general way of referring to views students hold about the natural world that differ from conventional scientific explanations is the first step in dispelling some of the "misconceptions" practitioners have about misconceptions. It is important to take the time to understand what type of misconception a student has and how it may have developed. Resist the urge to immediately correct a misconception; instead, use students' ideas as springboards to guide them through a process of conceptual change. Understanding is a continuous process that happens throughout students' K–12 education as well as throughout teachers' professional learning. Understanding what underlies the word *misconception* will ultimately improve student learning and strengthen teaching that incorporates continuous formative assessment (Keeley, 2012). The following are some of the common misconceptions science teachers and other practitioners may have about misconceptions in science:

All science misconceptions are the same. The word *misconception* is used to identify a range of ideas students have that are not entirely scientifically correct. Some of these ideas are not completely "wrong" in a students' common-sense world. Inaccurate ideas in science and mathematics have been categorized in a variety of ways, including *preconceptions, conceptual misunderstandings, intuitive rules, vernacular misconceptions*, *pseudoscientific ideas, overgeneralizations, common errors,* and *factual misconceptions* (NRC, 1997). It is important to understand that the word *misconception* is a general way of lumping together students' scientifically inaccurate or partially accurate ideas. Once a misconception is identified, teachers should delve further to understand the type of misconception the student holds. Identifying a specific type of misconception can help teachers make better decisions for addressing students' ideas. For example, vernacular misconceptions arise from the way we use words in our everyday language. In our everyday language, *acceleration* means going faster, but in physics it can mean going faster, slowing down, or changing direction. Knowing that a misconception originated from students' everyday encounter with a word or phrase can help teachers identify strategies for helping students be more aware of the impact word use has on their scientific thinking.

All science misconceptions are major barriers to learning. Just as some learning standards have more weight in promoting conceptual learning than others, the same is true of misconceptions regarding impeding science learning. For example, the idea that when once-living material decays, it simply disappears and no longer exists, presents a significant conceptual barrier to understanding what happens to the flow of matter in ecosystems. In contrast, students who think the blood in our veins is blue also have a misconception. While scientifically incorrect, this blue blood idea does not significantly affect students' conceptual understanding of blood flow and the circulatory system. The first example is a conceptual misconception. The second is a trivial, factual misconception. A conceptual misconception warrants greater attention than a trivial factual misconception. When using FACTs that probe for students' misconceptions, it is important to focus on key conceptual ideas rather than minor facts.

Only "those" students have misconceptions. Some teachers believe that younger students, low-performing students, students in the general classes, special education students, or students from lower socioeconomic classes are the ones who primarily have misconceptions about fundamental concepts in science. Wrong! Everyone harbors misconceptions, regardless of age, socioeconomic background, or academic achievement. Even science teachers hold some deeply rooted misconceptions that went unchallenged and unresolved throughout their K–16 education. Scientists have them, too. Some scientists are so specialized in one field of science that they have misconceptions in other disciplinary areas of science. The assumption that misconceptions are more apt to surface among certain types of students is generally false. As the Private Universe series has shown us, even the brightest students who take advanced classes and graduate from prestigious universities, like Harvard and MIT, harbor science misconceptions about basic, fundamental ideas (Private Universe Project, 1995). Using formative assessment to uncover and act on basic misconceptions is important for *all* students.

Misconceptions must be fixed right away. Teachers often feel compelled to correct a misconception on the spot. This tendency to fix misconceptions is common. This may be appropriate for factual, trivial misconceptions, which can be corrected on the spot, but it is not the case with conceptual misconceptions about big ideas in science. Conceptual misconceptions can be useful as starting points. Rather than trying to fix students by correcting their misconceptions on the spot, it is important to provide instructional experiences that will confront students with their thinking and guide them through a process of conceptual change that allows them to willingly give up the misconception, resulting in deeper understanding. However, there comes a point when you cannot let a misconception linger indefinitely and you must address it.

Misconceptions are a bad thing. The very word *misconception* seems to have a pejorative connotation to most practitioners. Students do not come to the classroom as blank slates. In fact, they come with many preconceived ideas about how the world works that make sense to them. According to constructivist theory, when new ideas are encountered, they are either accepted, rejected, or modified to fit existing conceptions. It is the cognitive dissonance students experience when they realize an existing conceptual framework no longer works for them that makes students willing to give up a preexisting idea in favor of a scientific one. Having ideas to work from, even if they are not completely accurate, leads to deeper understanding when students engage in a conceptual-change process. Starting with students' existing conceptions is like building a bridge from where they currently are to where you want them to be conceptually. Harvard researcher Philip Sadler (1998) describes misconceptions as "steppingstones" that are absolutely essential for helping our students gradually change their conceptual frameworks, so they can understand the modern scientific view of our natural world and the universe around us.

Misconceptions come mostly from experiences outside the classroom. Many preconceptions students bring to their learning come from their everyday encounters with the natural world or things they have read in books or seen and/or heard in the media. This is particularly common in science. However, it is harder for teachers to accept that misconceptions can also arise from students' experiences inside their classroom, whether taught intentionally or unintentionally. For example, a surprising number of high school students, even after taking chemistry, think that a chemical bond is a structural part of an atom that links it to other atoms. While a teacher most likely did not teach this, the use of ball-and-stick models or structural diagrams inadvertently led to this misconception. It is important to know that students make their own meaning out of activities they experience in the classroom, representations and models they use, and words they hear during instruction. Formative assessment can help teachers uncover the misconceptions that might arise during instruction.

Identifying misconceptions is formative assessment. Many teachers are enthused to use the probes in the *Uncovering Student Ideas in Science* series (see the Appendix) and the FACTs in this book. Some teachers erroneously think that formative assessment in science is mostly about uncovering students' misconceptions. Using FACTs to identify students' misconceptions is a form of diagnostic assessment. Diagnostic assessment does not become formative assessment until you use the information you have gathered about students' misconceptions to change or modify your instruction and provide feedback to students as they are learning to help students achieve conceptual understanding. That is the essence of formative assessment, with the focus placed on instruction for conceptual understanding, not just the act of identifying misconceptions. If you use FACTs to uncover misconceptions but continue doing what you have always done, without modifying your instruction to address students' ideas, then you are not practicing formative assessment.

There is tremendous interest in the science education community in identifying misconceptions. You can learn a lot about students by understanding their misconceptions and using them to build a conceptual bridge from where they are to where they need to be. However, first be clear about what misconceptions are as well as what they are not.

MAKING THE SHIFT TO A FORMATIVE ASSESSMENT-CENTERED CLASSROOM

Formative assessment requires a fundamental shift in our beliefs about the role of a teacher. In a formative assessment-centered classroom, teachers interact more frequently and effectively with students on a day-to-day basis, promoting their learning (Black & Harrison, 2004). This interaction requires the teacher to step back from the traditional role of information provider and corrector of misconceptions to listen to and encourage a range of ideas among students. The teacher takes all ideas seriously, whether they are right or wrong, while helping students think and talk through their ideas and consider evidence that supports or challenges their claims. During such interactions, teachers are continuously thinking about how to shape instruction to meet the learning needs of their students and build a bridge between their initial ideas and the scientific understandings that make up the learning targets.

> "Even when college teachers routinely gather assessment information on student learning through questions, quizzes, homework, and exams, it is often collected too late—at least from the students' perspective—to affect their learning. In practice, it is very difficult to 'de-program' students who are used to thinking of anything they have been tested and graded on as being 'over and done with'" (Angelo & Cross, 1993, p. 7).

The teacher also plays a pivotal role in connecting assessment to students' opportunities to understand how science is conducted in the real world. Providing opportunities for students to make discoveries through their own investigations and authentic testing of ideas often surfaces new ideas and scientific ways of thinking. The provision of opportunities to speak, write about, and draw to organize thinking about such discoveries helps give rise to the students' view of science as an enterprise that values curiosity and personally meaningful insight (Shapiro, 1994). Furthermore, several of the FACTs incorporate the use of the scientific and engineering practices described in *A Framework for K–12 Science Education* (NRC, 2012) and the NGSS (NGSS Lead States, 2013), particularly the development and use of models, constructing explanations and solutions, engaging in argument from evidence, and evaluating and communicating information. The chart on page 49 shows how the FACTs support the scientific practices.

Traditionally, science teachers were considered the providers of content that students then learned—teachers teach content and, as a result, students learn. This factory assembly line model of learning assumed students came to class with empty heads and the role of the teacher was to fill those heads with facts and information. The role of the teacher in a formative assessment-centered classroom is more of a facilitator and monitor of student learning. The teacher's role expands to helping students use strategies to understand how well they are learning. The teacher recognizes that all students come to their learning with ideas in their heads. Regardless of whether their ideas are right or wrong initially, everyone's ideas matter. The teacher designs the bridge that will take students from where they are to where they need to be. But the learning cannot be done to students by the teacher. It must come from the students. As a result, students must become more conscious of the learning process itself and take greater responsibility for their own learning.

In a formative assessment-centered classroom, students learn to play an active role in the process of learning. They learn that their role is not

> "The role of the learner is not to passively receive information, but to actively participate in the construction of new meaning" (Shapiro, 1994, p. 8).

only to engage in their own learning but to support the learning of others as well. They come to realize that learning has to be done *by* them—it cannot be done *for* them. They learn to use various FACTs that help them take charge of their own learning and assess where they stand in relation to identified learning goals. When they know what the learning target is, they use metacognitive skills along with peer and self-assessment strategies that enable them to steer their own learning in the right direction so they can take responsibility for it (Black & Harrison, 2004).

Standards and learning goals have a significant impact on what teachers teach and students learn. Developing content knowledge that includes important scientific facts, conceptual ideas, scientific and engineering practices, and habits of mind is at the center of science teaching and learning. As a result, teaching, assessing, and learning must take place with a clear target in mind. Standards should not become a checklist of content, skills, and practices to be taught and assessed. Rather, they inform three-dimensional thinking about disciplinary core ideas, scientific and engineering practices, and crosscutting concepts as an interconnected cluster of learning goals that develop over time. By clarifying the specific ideas and skills described in standards and articulated as learning goals, teachers are in a better position to uncover the gap between students' existing knowledge or skills and the knowledge or skills described in the learning goal. As a result, they are better able to monitor that gap as it closes (Black et al., 2003). While a particular FACT may determine the approach that teachers take to uncover students' ideas and modify instruction accordingly, the fundamental ideas, skills, and practices students need to learn and be able to use remain the same. The focus of teaching and learning is on meeting goal-oriented learning needs rather than delivering the "M&M curriculum" (mention & move on) at an established pace or teaching a favorite activity that does little to promote conceptual understanding.

Identifying and targeting learning goals is not the sole purview of the teacher. In a formative assessment-centered classroom, teachers share learning goals with students. This may involve breaking them down into the key ideas and practices students will learn and indicators of success that reveal the extent to which students have learned and can use key ideas and practices. Awareness of the goals for learning and what success looks like in achieving them helps students see the bigger picture of learning and make connections to what they already know about science concepts.

Another major shift that happens in a formative assessment-centered classroom is the recognition of the importance of students' ideas. Traditional instruction involved the passing on of information from the teacher or the instructional materials, with little thought given to building on students' initial conceptions. Students form many of their ideas in science before they ever formally encounter them in the classroom. These ideas come from previous school and life experiences and often conflict with the scientific understandings teachers are trying to develop. These preformed ideas are referred to in a variety of ways, including naïve ideas, misconceptions, facets of understanding, phenomenological primitives, partial understandings, commonly held ideas, or alternative conceptions. In this book, they are referred to generically as *misconceptions*, although the term is not meant to be construed negatively and does not necessarily imply that the student's idea is completely incorrect. In some cases, misconceptions include partially formed correct ideas, but they are not yet put together in a way that is scientifically correct and coherent. It is important to recognize that these misconceptions have the following general characteristics:

> Putting one's ideas forward allows an opportunity for students to experience uncertainty and cognitive dissonance—the first step in building a bridge between students' ideas and scientific knowledge.

They form early, often before school begins, and continue lifelong.

They are subtle and can easily be missed by teachers who are unaware of them.

They are separable. Students retain their personal ideas even though they might give "school answers."

They are persistent, even after being disproved.

They are highly personal—each student sees experiences or draws conclusions from his or her point of view and constructs a personal meaning.

They appear to be incoherent to the teacher but make a lot of sense to the student. (Connor, 1990)

A constructivist approach to teaching and learning posits that students' existing ideas make a difference to their future learning, so effective teaching needs to take these existing ideas into account. Research indicates that misconceptions held by students persist into adulthood if they are left unconfronted and unchallenged (Carre, 1993). However, this does not simply imply that misconceptions are a bad thing and must be confronted on the spot as "wrong ideas." Rather than immediately correcting misconceptions when they surface, teachers should gather information that may reveal how misconceptions can be used as starting points for instruction. Starting with students' ideas and monitoring their progress as they are guided through activities that help them recognize when their ideas no longer work for them and need to be modified or changed is the essence of an idea-focused, formative assessment classroom that supports conceptual change. Experiencing cognitive dissonance when one realizes their initial ideas no longer make sense is a powerful way to learn and develop enduring understandings in science. To learn more about teaching for conceptual understanding and understanding the nature of students' ideas, see the Appendix for a description of the resource *Teaching for Conceptual Understanding in Science* (Konicek-Moran & Keeley, 2015).

CONNECTIONS TO CURRENT STATE STANDARDS, *A FRAMEWORK FOR K–12 SCIENCE EDUCATION*, NEXT GENERATION SCIENCE STANDARDS, AND LITERACY CAPACITIES

The FACTs in this book can be used with any science and language literacy standards. For states that have adopted the NGSS, FACTs provide opportunities to elicit, monitor students' progress in understanding and using, and reflect on the disciplinary core ideas, scientific and engineering practices, and crosscutting concepts in the NGSS. For states that have adopted the ELA Common Core, FACTs utilize the literacy capacities of reading, writing, speaking, and listening. The FACTs become assessment activities that mirror the content, skills, and practices in existing science and English language arts state standards as well as the NGSS and ELA Common Core. Furthermore, many of the FACTs combine more than one dimension of standards. For example, *Justified Lists* can be used to formatively assess whether students can transfer their understanding of a disciplinary core idea or concept to examples other than the ones they encountered in their classroom investigations while simultaneously assessing and providing feedback on the scientific explanations or arguments students used to justify their claims.

> "Because NGSS-aligned instruction will naturally involve a range of activities, classroom assessment that is integral to instruction will need to involve a corresponding variation in the types of evidence it provides about student learning. Indeed, the distinction between instructional activities and assessment activities may be blurred, particularly when the assessment purpose is formative. A classroom assessment may be based on a classroom discussion or a group activity in which students explore and respond to each other's ideas and learn as they go through this process" (NRC, 2014, p. 87).

Learning is an ongoing process for both students and for scientists (NRC, 2014). It is important for teachers to recognize that students are not yet scientists, but rather emerging practitioners of science, and their ways of talking, writing, investigating, modeling, thinking, and reasoning may differ from professional scientists in developmental ways. Both *A Framework for K–12 Science Education* (NRC, 2012) and the NGSS emphasize that learning should be seen as a progression of learning in which students progress in their understanding throughout the course of a unit, the entire school year, and even across a K–12 span of learning. For this reason, it is important to formatively assess where students *are* regarding a learning goal in the standards and use that data to inform instruction that will help build a bridge between where students are and where they *need to be* regarding a learning goal, even if that bridge starts with ideas that should have been conceptually developed and understood at prior grade levels.

> "The framework and the NGSS address the process of learning science. They make clear that students should be encouraged to take an investigative stance toward their own and others' ideas, to be open about what they are struggling to understand, and to recognize that struggle as part of the way science is done, as well as part of their own learning process. Thus, revealing students' emerging capabilities with science practices and their partially correct or incomplete understandings of core ideas is an important function of classroom assessment" (NRC, 2014, p. 90).

A key goal of standards-based, aligned classroom assessments is to help teachers and students understand what has been learned and what areas will require further attention. Formative assessments will also need to identify likely misunderstandings, productive ideas of students that can be built on, and interim goals for learning (NRC, 2014). The FACTs in this book can help teachers uncover the ideas students bring to their learning, understand where student ideas fall on a trajectory of learning, and inform instructional decisions designed to build a conceptual bridge that will link the gap between students' existing ideas and the grade level expectation for the disciplinary core idea, scientific or engineering practice, or crosscutting concept.

The FACTs in this book also support literacy goals in state standards as well as the literacy capacities in the ELA Common Core. For example, consider the following list of skills and practices:

- Construct effective arguments
- Request clarification
- Ask relevant questions
- Build on others' ideas
- Question assumptions and premises
- Assess the veracity of claims
- Assess the soundness of reasoning
- Cite specific evidence
- Make their reasoning clear
- Constructively evaluate others' use of evidence

- Evaluate others' points of view critically and constructively
- Express and listen carefully to ideas
- Cite specific textual evidence to support conclusions
- Participate effectively in a range of conversations and collaborations with diverse partners
- Build on others' ideas and express their own clearly and persuasively

At first glance these appear to be skills and practices used in science that might be described in a state's science standards or framework, particularly the skills and practices that support productive science discussions. However, these did not come from a set of science standards. In fact, these phrases were taken from a literacy publication: the English Language Arts Standards from the Common Core State Standards Initiative (NGAC and CCSSO, 2010). This list of speaking and listening literacy capacities clearly illustrates the reciprocal nature of science and literacy.

The FACTs in this book utilize many of these language intensive practices. Through speaking and listening, students reveal their ideas, examine others' reasoning, and communicate their understandings at various stages of an instructional cycle. The information gathered by the teacher is used to plan for subsequent instruction in developing conceptual understanding of scientific ideas and use of scientific and engineering practices. FACTs that involve use of the literacy capacities listed above can also be used to elicit evidence of how students apply ELA skills and processes within a science context. This formative assessment information feeds back not only to the science teacher, but to the ELA teacher as well, thus promoting formative assessment that integrates across standards.

> "Science and engineering practices are language intensive, and engagement in these practices requires science classroom discourse. Students speak and listen as they present their ideas or engage in reasoned argumentation with others to refine their ideas and reach shared conclusions. They read, write, view, and visually represent as they develop their models and explanations. These practices offer rich opportunities and demands for language learning at the same time as they promote science learning" (Lee, 2012, p. 2).

Two tables are included in Chapter 3 of this revised second edition of *Science Formative Assessment: 75 Practical Strategies for Linking Assessment, Instruction, and Learning* to help the user see the connection between the FACTs and the current vision K–12 science education is moving toward in several states. This vision and articulation of content and practices comes from the NRC's *A Framework for K–12 Science Education*. The *Framework* was used to develop the NGSS. Many states that are not adopting the NGSS are using the *Framework* to inform revisions to their standards. Most new curricula and teacher preparation courses are also being informed by the *Framework*. Even if your state has not revised its standards using the *Framework,* most of the FACTs in this book and the examples provided will relate to or align with your state's inquiry and content standards in science as well as literacy standards used in science.

One of the features that makes this formative assessment book different from other books on formative assessment is that it is specific to science. Each FACT description in Chapter 4 includes an example of what the FACT looks like when it is used in science. Furthermore, Table 3.1 on page 45 shows how FACTs are used across the life, physical, Earth, and space disciplines of science. It includes all the FACTs in Chapter 4 and lists the grade level of the example provided, the concept addressed by the example, and the connection to a disciplinary core idea in *A Framework for K–12 Science Education.* These are just illustrative examples, and the chart is not intended to show that each FACT corresponds to a specific grade level, concept, or disciplinary core idea. The FACTs can be used across K–12, and even K–16 and with teachers in professional development settings, and with a variety of disciplinary content. It is only intended to show the range of examples included for the user of this book.

Users of this book can also see how use of a FACT supports the use of a scientific practice. Table 3.2 on page 49 shows the connection between FACTs and the scientific practices. For example, several FACTs involve the construction of explanations, developing models, or engaging in argument. Although the practices in the *Framework* are described as the scientific and engineering practices, for the purposes of this book, only the scientific practices are emphasized. However, the user of this book can clearly make the link to the engineering practices as well.

As you gain a deeper understanding of the purposes and uses of formative assessment, you may find yourself reshaping FACTs or developing new ones. You might find that some FACTs work better than others depending on the scientific idea being assessed or the nature of the learners in your classroom. Many of the FACTs described in Chapter 4 may be new to you; others may be ones you use routinely. Regardless of how you use the FACTs or your familiarity with them, one important implication for the science classroom stands out—formative assessment provides an effective way for teachers to create classrooms that reflect current research on teaching and learning and provide greater opportunities for all students to achieve deeper levels of learning consistent with the vision of K–12 science education described by the NRC in *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012).