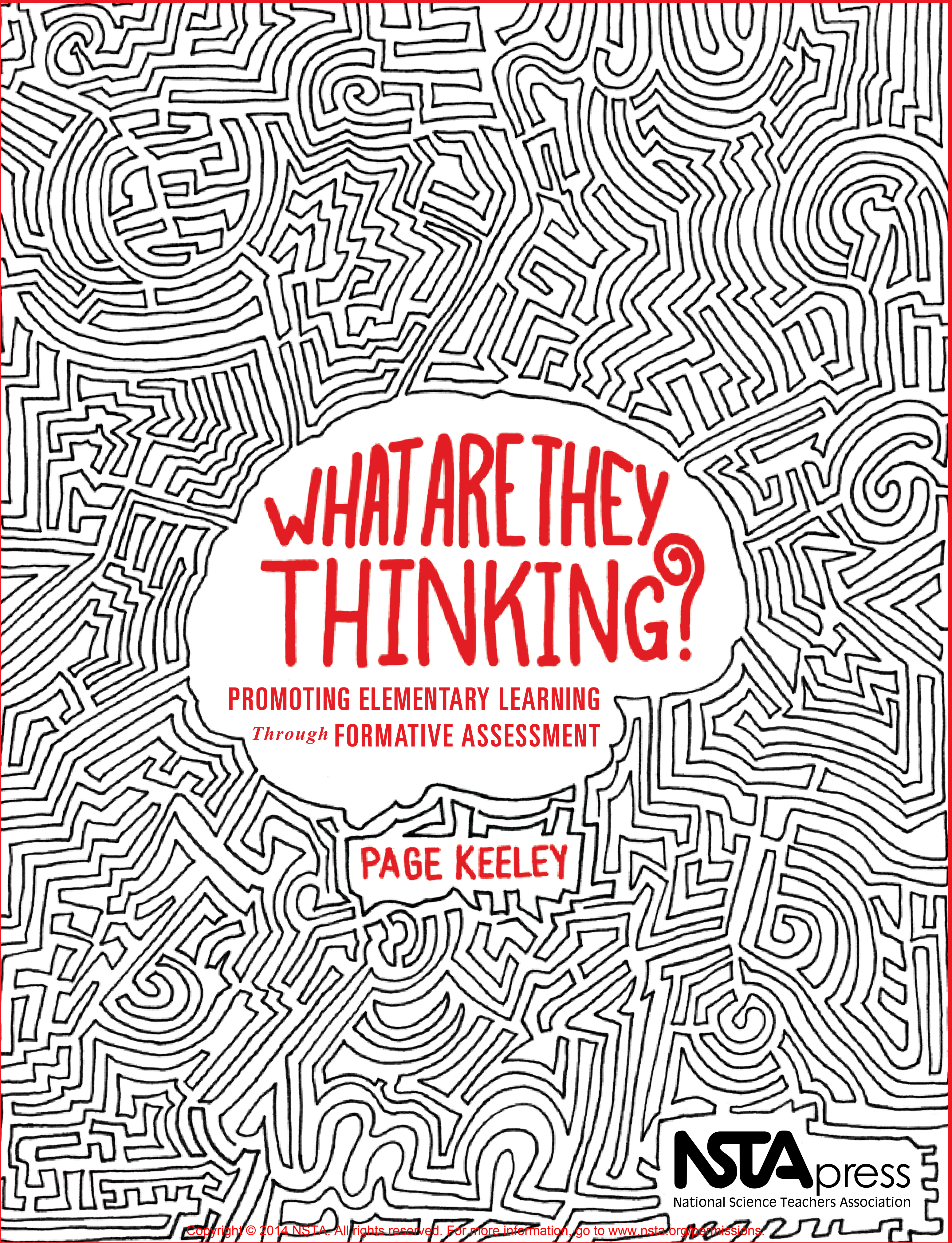

WHAT ARE THEY THINKING?

PROMOTING ELEMENTARY LEARNING *Through* FORMATIVE ASSESSMENT

PAGE KEELEY

NSTA press
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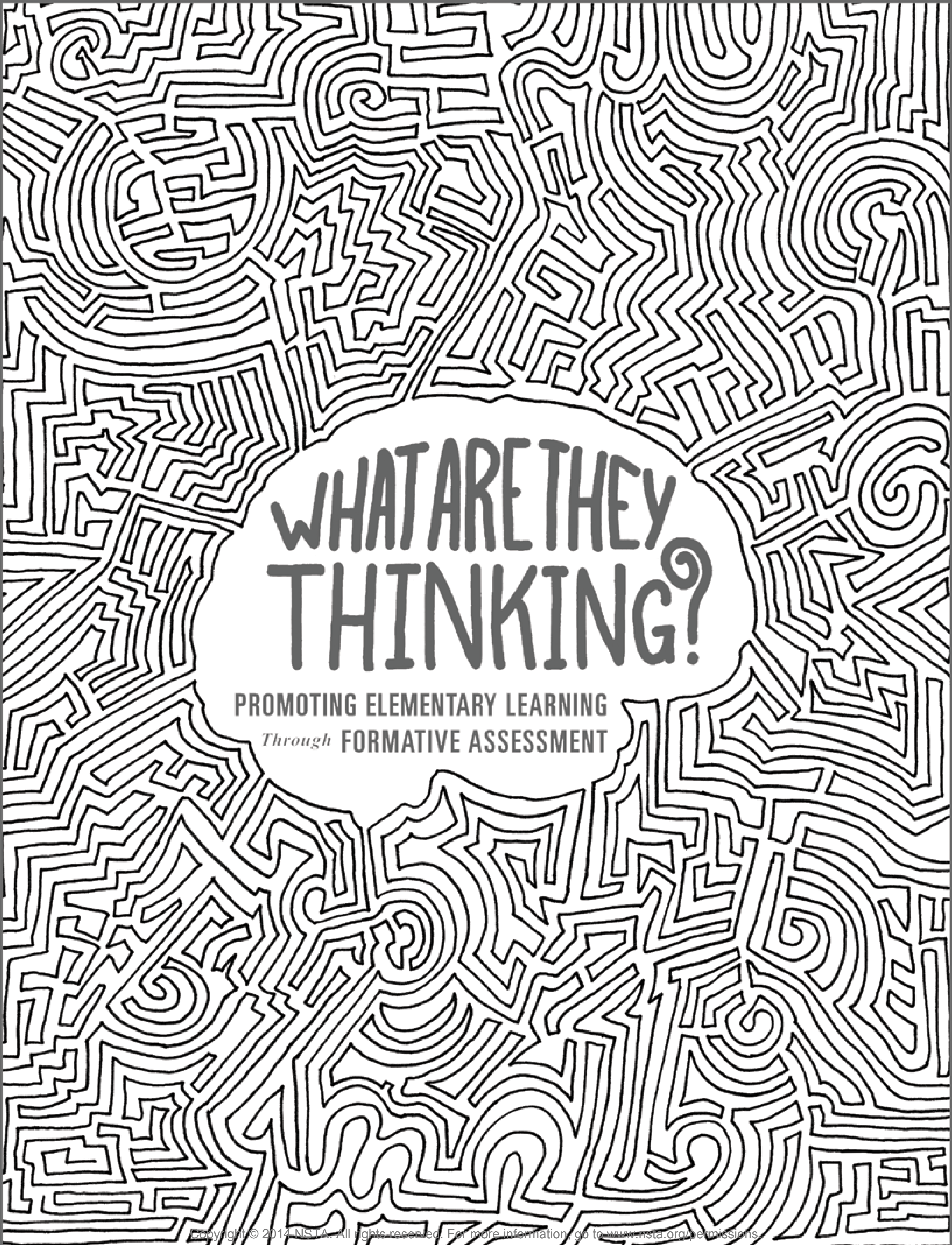

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About the Author

PAGE KEELEY recently retired from the Maine Mathematics and Science Alliance (MMSA) where she was the senior science program director for 16 years, directing projects and developing resources in the areas of leadership, professional development, linking standards and research on learning, formative assessment, and mentoring and coaching. She has been the principal investigator and project director of three National Science Foundation grants: the Northern New England Co-Mentoring Network, PRISMS: Phenomena and Representations for Instruction of Science in Middle School; and Curriculum Topic Study: A Systematic Approach to Utilizing National Standards and Cognitive Research. She has also directed state Math-Science Partnership projects including TIES K–12: Teachers Integrating Engineering into Science K–12 and a National Semi-Conductor Foundation grant, Linking Science, Inquiry, and Language Literacy (L-SILL). She also founded and directed the Maine Governor's Academy for Science and Mathematics Education Leadership, a replication of the National Academy for Science and Mathematics Education Leadership of which she is a Cohort 1 Fellow.

Page is the author of 16 national bestselling books, including four books in the *Curriculum Topic Study* Series, nine volumes in the *Uncovering Student Ideas in Science* series, and three books in the *Science Formative Assessment: 75 Practical Strategies for Linking Assessment, Instruction, and Learning* series. Currently she provides consulting services to school districts and organizations throughout the United States on building teachers' and school districts' capacity to use diagnostic and formative assessment. She is a frequent invited speaker on formative assessment and teaching for conceptual change.

Page taught middle and high school science for 15 years before leaving the classroom in 1996. At that time she was an active teacher leader at the state and national level. She served two terms as president of the Maine Science Teachers Association and was a District II NSTA Director. She received the Presidential Award for Excellence in Secondary

Science Teaching in 1992, the Milken National Distinguished Educator Award in 1993, the AT&T Maine Governor's Fellow in 1994, the National Staff Development Council's (now Learning Forward) Susan Loucks-Horsley Award for Leadership in Science and Mathematics Professional Development in 2009, and the National Science Education Leadership Association's Outstanding Leadership in Science Education Award in 2013. She has served as an adjunct instructor at the University of Maine, was a science literacy leader for the AAAS/Project 2061 Professional Development Program, and serves on several national advisory boards. She is a science education delegation leader for the People to People Citizen Ambassador Professional Programs, leading the South Africa trip in 2009, China in 2010, and India in 2011.

Prior to teaching, she was a research assistant in immunology at the Jackson Laboratory of Mammalian Genetics in Bar Harbor, Maine. She received her BS in life sciences from the University of New Hampshire and her MEd in secondary science education from the University of Maine. In 2008 Page was elected the 63rd president of the National Science Teachers Association (NSTA).

Foreword

Page Keeley's popular book series "Uncovering Student Ideas…" led to the creation of a column in *Science and Children* offering probes and strategies for use by elementary teachers. This column has been popular since its inception with readers eager to use each probe in their classrooms. The popularity is due to several characteristics of Page's probes—they are based on research, aligned with grade band expectations, easily implemented, and effective.

Probes uncover students' ideas. Every child brings prior understanding to each learning experience, whether incomplete, incorrect, or fully developed. It is critical to understand what children bring to the learning environment both before proceeding with instruction and during lessons to provide scaffolding and regulate rigor. Every step of the way, throughout the development of conceptual understanding, we must have a clear picture of what students have learned and the understanding they are developing. This is the vital role of Page's assessment probes.

Never has formative assessment been more important than now. With the release of the *Next Generation Science Standards* and shifts in state standards there is new emphasis on progressions of learning and conceptual understanding. *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* is specific: "To support students' meaningful learning in science and engineering, all three dimensions need to be integrated into standards, curriculum, instruction, and assessment" (NRC 2012, p. 2). It goes on to mention the role of formative assessment explicitly and points out the need for this component in teacher professional development to enhance the capacity of schools to implement effective science curriculum.

Once you have read and used the suggestions provided in any of the chapters in this collection, you will find many applications that support your understanding of student knowledge while also providing new learning opportunities. The variety of formats; the manner in which they are embedded in instructional models; and the strategies they provide to create opportunities for science talk, initiating investigations, eliciting questions, self assessment, and reflection on learning are all applicable to many settings.

Page has selected a variety of probes to share with you that provide a wide perspective. Beginning with how to use the book she goes on to provide ways in which professional learning, by both individuals and communities, can effectively be created. Once you have studied and used some of Page's suggestions, I know you will join me in thanking her for sharing this wonderful collection of strategies and materials. *What Are*

They Thinking? is specifically designed to support elementary teachers as they assess student understanding and Page has provided the insight and knowledge to assure you of success in supporting your students moving toward conceptual understanding.

Linda Froschauer
Editor, *Science and Children*
NSTA President, 2006–2007

REFERENCE

National Research Council (NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

Introduction

The Role of Formative Assessment in Elementary Science: An Overview

Formative assessment in science is a process that informs instruction and supports learning through a variety of tools and techniques aimed at uncovering and examining students' thinking, then using that information to drive instruction that supports students moving toward conceptual understanding of the learning target. Formative assessment in science is inextricably linked to learning. As teachers are collecting information about students' thinking related to core concepts and phenomena, students are simultaneously constructing new understandings, revising prior beliefs, and strengthening their ability to engage in the practices of science and engineering. Formative assessment is frequently referred to as assessment *for* learning rather than assessment *of* learning. One can even add a third preposition—assessment *as* learning. As you will see in each of these chapters, the formative assessment tool or technique highlighted is in essence a learning activity for students, as well as a way for the teacher to gather information about students' ideas and ways of thinking in order to determine next steps in moving their learning forward.

Elementary science teachers face an added challenge using formative assessment to move students' learning forward. Because science is a way of understanding our natural world, students arrive with ideas that have already been formulated based on their everyday experiences outside the classroom. These experiences begin in infancy, long before students enter the formal classroom. Daily experiences and interactions with "felt weight," moving objects, shapes, light and shadows, observations of living things, dropping objects, "disappearing" materials, visible changes, and other phenomena are already shaping children's ideas at an early age. Therefore, one important use of formative assessment in science is uncovering the preconceptions students bring with them to their learning, as these preconceptions will often affect the way students think about new information. Children make sense of the content they encounter in the science classroom in their own way, based on their interactions with the natural world, the words they encounter in their daily conversations and in various media, the materials they use, and the contexts in which they learn.

By taking the time to understand students' thinking at any point during an instructional cycle, instruction becomes more focused and deliberate in moving students toward an intended learning target. It begins by helping students think about—and then verbalize or write about—their existing ideas, giving them and the teacher a springboard from which to launch into instructional experiences that will build a bridge between where students are and where they need to be. Targeted instruction then confronts students' existing ideas, providing opportunities for them to test their ideas through investigation and engage in productive science talk that incorporates scientific reasoning, construction of scientific explanations, and argumentation supported by evidence. As the teacher uses formative assessment to monitor changes in students' ideas and ways of thinking, students often resolve the conflict between their initial ideas and new ways of thinking. This process is called *conceptual change* and is strongly supported by the use of formative assessment throughout a full cycle of instruction. It begins with the elicitation of students' initial ideas and ends with reflection on new knowledge and changes in thinking.

However, to use formative assessment to promote learning in the elementary classroom, the teacher must have access to a repertoire of formative assessment classroom techniques (FACTs) and specially designed questions that link research on learning to core concepts in science (probes). But having access to these tools at your fingertips is not enough. Teachers also need to understand *how* these tools are appropriately used for formative assessment and what formative assessment looks like in the elementary classroom. That is the purpose of this book—to build and support elementary teachers' capacity to use formative assessment tools to link assessment, instruction, and learning in the science classroom.

This book will help elementary teachers deepen their understanding of their students' thinking in order to promote conceptual learning in the K–6 classroom. It moves instruction away from the pervasive practice of selecting an activity first to instead starting with an understanding of students' ideas and then selecting an appropriate activity to begin instruction. It helps teachers make adjustments to their instructional materials throughout the cycle of instruction. This is very different from following "the script" without understanding if the "script" is the right match to where students are in their thinking. The focus is on what the student is thinking and learning, not the materials or activities. This is the difference between teaching science as a series of "hands-on" activities and teaching science for conceptual understanding.

Elementary teachers are the first line of offense in addressing common misconceptions that follow students from elementary grades into middle school, into high school, and even into adulthood. This is why it is so important to build elementary teachers' capacity to continuously and seamlessly use formative assessment in science. If elementary students are provided with opportunities to resolve the inconsistencies between their way of thinking and the scientific way of thinking, many of the difficulties that students encounter in later grades as they progress through increasingly complex ideas and ways of thinking can be eliminated. Clearly, this is why elementary teachers are important to developing science-literate high school graduates, well prepared and interested in entering STEM fields in college or in the workplace. Elementary science teachers are critical links in a K–12 system of science learning. This book is intended to support you in that critical role!

Organization of This Book

This book is organized into 30 chapters. Each chapter features an article written for the NSTA *Science and Children* journal's monthly column, "Formative Assessment Probes: Promoting Learning Through Assessment." Each article features a formative assessment probe from one of the eight books in the NSTA Press series *Uncovering Student Ideas in Science.*

A probe is a two-tiered assessment specifically designed to reveal common misconceptions. It begins with an engaging prompt situated in a familiar context, followed by a set of selected responses. Many of the distracters in the selected responses mirror the research on children's alternative conceptions. The number of distracters used depends on the number of research-identified misconceptions. The probes avoid the use of technical terminology in order to uncover students' conceptual understanding and not their memorization of definitions. The selected response is then followed by a section in which students explain their thinking by constructing an explanation. It is this part of the probe that reveals the reasoning students use to make sense of a concept or phenomenon. It also provides insight into how a student's misconception may have developed: from their experiences in and out of the classroom, the words they encounter, their intuition, the context in which previous learning took place, or from their misinterpretation during the teaching and learning process.

Probes are often combined with a FACT (formative assessment classroom technique). FACTs are used in a variety of formats, ranging from individual formative assessment to uncovering student ideas within a small group or during a whole-class discussion. FACTs and probes are embedded throughout an instructional cycle of engagement and elicitation, exploration of ideas, formal concept development, application, and reflection. They fit easily within a 5E model of instruction or any variety of instructional models that use a learning cycle approach. FACTs serve a variety of teaching and learning purposes, including engaging and motivating students, eliciting preconceptions, activating thinking and metacognition, providing stimuli for productive science talk, initiating investigations, determining learning transfer, improving the quality of questions and responses, providing feedback, peer and self-assessment, and post-assessment or reflection on learning.

The articles in each chapter were specifically written to illustrate how a formative assessment probe, often combined with a FACT, is used in a K–6 classroom. While each of the books in the *Uncovering Student Ideas in Science* series provides K–12 teacher notes that accompany each probe, the teacher notes in the book series do not provide extensive descriptions of how the probe is used in an elementary classroom, actual examples of student work or transcripts of students talking about their ideas, or illustrative examples of instructional decisions made by elementary teachers. The article included in each chapter provides this information specifically for elementary teachers, giving deeper insight into the formative assessment process and complementing the teacher notes. In addition, a link is provided at the end of the chapter that will take the reader to a website where they can download a copy of the probe to use with their students (Note: Only the probe is provided in each of the links in the chapters. The teacher notes for each probe are found in the referenced book in which the probe was originally published).

Each chapter also includes a Reflection and Study Guide. These guides include a set of questions designed to help the reader reflect on what they learned after reading the chapter. The questions can also be used for pre-reading. This is followed by a section on "Putting Formative Assessment Into Practice" that can be used after teachers try out the probe with their students. This section guides teachers in examining their own students' thinking and reflecting on their use of the formative assessment probe or FACT. A final set of questions in the "Going Further" section can be used to extend professional learning by suggesting other resources for individual or collaborative group learning. Many of these suggestions include links to *A Framework for K–12 Science Education* or the *Next Generation Science Standards*. Even if your state has not adopted the *NGSS*, the links provided will help you clarify the content in your own standards and provide you with a lens to focus on what effective teaching and learning in science involves when using the formative assessment probes.

Suggestions for Using This Book

The primary purpose of this book is to improve and support the teaching and learning of elementary science by embedding formative assessment into daily instruction. This purpose can be met through an individual teacher's use of this book or through collaborative structures for teacher learning. The following are suggestions for ways to use this book as a teacher, teacher leader, mentor, science specialist, professional development provider, or preservice instructor.

Overall Use of This Book

- Use Table 1 (pp. xvi–xvii) to match your own instructional or professional learning objective to the focus of the chapter and the probe that is highlighted. Read the chapter and use the Reflection and Study Guide questions to deepen your learning and inform your instruction before you teach a curricular unit.
- If you have not used the probe before, answer the probe yourself before reading the chapter. By experiencing the process of thinking through your own ideas, you may better understand what your students experience as they think through their ideas.
- If you have access to the *Uncovering Student Ideas in Science* books, read the teacher notes after completing the chapter. The teacher notes provide additional details on curricular considerations, related research, connections to national standards, and instructional suggestions that complement the chapter.
- After reading a chapter and using the guiding questions, note what you will do differently in your classroom as a result. Also note any information or suggestions to share with colleagues at the school or district level.
- If you are a classroom teacher or have access to students, try out the probe or FACT with children and compare what you experienced and learned through your own students with the chapter description or classroom vignette.
- Use the "Going Further" suggestions to extend your learning after reading the chapter. Search the internet or the NSTA Learning Center (*http://learningcenter.nsta.org*) for additional resources to continue your learning related to the chapter.

Structures for Professional Learning

- Chapters can be used within a workshop format to address content or a teaching strategy. Select chapters that match the professional learning goal of a workshop.
- Professional Learning Communities (PLCs) can select chapters for reading, discussion, and application to their professional goals as a PLC.
- Form study groups to learn about, try out, examine, and improve upon techniques for formative assessment. Choose a chapter to read, discuss, try out, and report back on its use.
- Create a classroom video of your use of a probe or FACT discussed in one of the chapters. Share and discuss the chapter with peers. Use the video to discuss and provide constructive feedback on the use of the probe or FACT.

TABLE 1. FEATURED PROBES AND TOPICS

Chapter	Probe	Topic
1	Doing Science	Scientific investigation; examine how misuse of the "scientific method" impacts students' ideas about the nature of science
2	Floating Logs	Floating and Sinking; use of intuitive rules to reason about floating and sinking
3	Does It Have a Life Cycle?	Life cycles; addressing the limitations of context in the curriculum
4	What Is a Hypothesis?	Hypotheses; revealing misconceptions teachers have about the nature of science that can be passed on to students
5	How Far Did It Go?	Linear measurement; difficulties students have with measurement, particularly with a non-zero starting point
6	Needs of Seeds	Seed germination and needs of living things; engaging in evidence-based argumentation
7	The Mitten Problem	Energy transfer, heat, insulators; teaching for conceptual change and how children's everyday experience affects their thinking
8	Is It Living?	Characteristics of living things; examine ways to uncover "hidden meanings" students have for some words and concepts in science
9	Various probes	A variety of probes and FACTs are used to show purposeful links to various stages in an assessment, instruction, and learning cycle
10	Emmy's Moon and Stars	Solar system, relative distances; importance of examining students' explanations even when they choose the right answer; impact representations have on children's thinking
11	Talking About Forces	Forces; examining common preconceptions and use of language to describe forces and motion
12	Is It an Animal?	Biological conception of an animal; explore how formative assessment probes can be used to engage in teacher action research
13	Pond Life	Single-celled organisms; use of representations to examine students' ideas
14	Objects in the Sky	Seeing the Moon in daytime; Challenges the adage "seeing is believing" with "believing is seeing"—examines reasons why children hold on to their strongly held beliefs
15	Can It Reflect Light?	Light reflection; addressing students' preconceptions with firsthand experiences that support conceptual change

Chapter	Probe	Topic
16	Is It Food for Plants?	Food, photosynthesis, needs of plants; using bridging concepts to address gaps in learning goals, understanding students' common sense ideas
17	Where Did the Water Come From?	Condensation; Using the water cycle to show how a probe can be used to link a core content idea, scientific practice, and a cross-cutting concept.
18	Catching a Cold	Infectious disease, personal health; Using a probe to uncover common myths and folklore related to the common cold
19	Me and My Shadow	Sun-Earth System; using a formative assessment probe to engage students in productive science talk
20	Birthday Candles	Light transmission, connection between light and vision; using drawings to support explanations
21	Mountain Age	Weathering and erosion; organizing student data using a classroom profile for instructional decisions and professional development
22	Solids and Holes	Floating and sinking; density; using the P-E-O technique to launch into investigations
23	Chrysalis	Life cycle; over-emphasis on labeling diagrams with correct terminology may mask conceptual misunderstandings related to the life cycle of a butterfly.
24	Batteries, Bulbs, and Wires	Electrical circuits; lighting a bulb with a battery and a wire; how science kit materials may make it difficult for students to examine the way a complete circuit works
25	Is It a Rock?	Rocks; human-made materials; how continuous assessment is used throughout an instructional unit.
26	Is It a Solid?	Solids and liquids; using the claim card strategy to uncover ideas and support students' construction of explanations using claims and evidence.
27	When Is the Next Full Moon?	Moon cycle, using the concept cartoon format to uncover ideas before making observations
28	Swinging Pendulum	Motion patterns; using formative assessment of a scientific idea to assess readiness for an engineering problem
29	Is It Melting?	Melting and dissolving; illustrating use of a probe in professional development to uncover misconceptions and make formative decisions for teacher learning
30	Is It Made of Parts?	Structure of organisms; scaffolding formative assessment of a learning target by identifying and assessing sub-ideas

- Combine a chapter with the use of a protocol for looking at student work (LASW). The chapter can provide the groundwork or information for next steps after teachers discuss student work.
- Create a seminar series that features a chapter for each session. Use Socratic dialogue to discuss the chapter.
- Teachers who mentor new teachers can read and discuss chapters together. The new teacher can try out the probe or FACT and reflect on his or her learning with the mentor teacher. The mentor teacher can provide useful feedback as a link between the chapter and the novice teachers' practice.
- Lesson study groups can use the chapters to inform the design of the lesson they will use. Discussions during the debriefing of the lesson can be linked back to the chapter.
- Form a book study group, face-to-face or electronically. Select chapters for the book study. Use the Reflection and Study Guide for in-person or online discussions.
- Share and discuss a chapter during a grade-level team or faculty meeting. Discuss how the example of formative assessment could be applied to other disciplines.
- Curriculum planning committees can use the chapters to consider ways to embed formative assessment into the elementary curriculum. Use the chapter to provide implementation support for the curriculum.
- Conduct collaborative action research with a colleague. Choose a chapter and design a classroom research project related to the chapter. Use the example and suggestions in Chapter 12 (Teachers as Classroom Researchers) to engage in teacher research using the probes.
- Use a formative assessment probe for teacher learning in workshops or other settings. After teachers respond to the probe, use ideas from the chapter to make formative decisions or engage teachers in practices such as argumentation.
- Select chapters that can support teachers in implementing the *NGSS* or their state standards. Use the chapter for discussions about formative assessment and learning targets.
- Consider writing your own article about the use of a formative assessment probe or FACT. Use the examples in this book to help you. Consider sharing your article with your school colleagues or submitting for publication in NSTA's *Science and Children.*
- Use the book as a whole-group jigsaw book study during teacher institutes. Assign chapters to pairs or small groups as reading assignments. Each group can prepare a short presentation to teach what they learned to others.

- Preservice instructors can use this book as a required text in their courses or select specific chapters to integrate into their courses.
- Science curriculum coordinators can use chapters to support teachers working toward improving their practice.
- The *Science Formative Assessment* book series (Keeley 2008, 2014) has been frequently used in a variety of professional learning formats. Select chapters that highlight use of a FACT and combine with the reading from *Science Formative Assessment.*
- Select a probe that can be used across grade levels. Administer the probe, collect data on students' thinking, and engage colleagues in cross-grade-level data-driven discussion. Use the chapter to ground the group's discussion about the probe and students' ideas.
- Come up with your own idea for ways to use these chapters for professional learning that builds teachers' understanding of how to use formative assessment effectively.

Teacher Learning Outcomes

Whichever chapters you decide to use in this book or the variety of ways you decide to use them, consider the following outcomes:

1. You may learn new content about the science you teach. Everyone has misconceptions, including teachers (*all* teachers, not just elementary teachers). These chapters might surface long-held misconceptions you were not aware that you had. Working through and resolving these misconceptions is a significant part of your professional learning.
2. You will learn a lot about your own students. Although the chapters describe scenarios of students in other classrooms, it is quite likely your students will think and respond in a similar way. Furthermore, trying out the probes with your own students will give you insight into your own students' thinking and how similar their ideas are to what has been learned from research about children's ideas in science.
3. You will learn new instructional strategies that link assessment and instruction, which will help you build a rich repertoire of effective teaching practices.
4. You will increase your capacity to implement the disciplinary core ideas, the scientific and engineering practices, and the crosscutting concepts in the *NGSS*. Even if your state has not adopted the *NGSS*, your teaching and your students' learning connected to your state's standards will be enhanced through your knowledge of formative assessment practices connected to the *NGSS*.

5. You will bring new vitality and food for thought to collaborative teacher learning by sharing and discussing these chapters and the use of the probes with your colleagues in a variety of professional learning formats. The value in sharing the probes, your student data, your inquiries into practice, and your new learning with other teachers cannot be overstated. It is transformative and will lead to significant changes in practice among teachers at all levels of experience, within and across classrooms.

Continuing Your Learning

When you finish the book, your learning about using formative assessment probes in the elementary classroom does not end with the final chapter. Continue to check out Page Keeley's formative assessment probe column each month in *Science and Children*, as well as articles written by other authors that feature the use of a formative assessment probe or formative assessment strategies. Visit the *Uncovering Student Ideas in Science* website at *www.uncoveringstudentideas.org* for additional ideas. Go to the NSTA Learning Center (*http://learningcenter.nsta.org*) and participate in discussions with other teachers who are using the probes and formative assessment strategies. Attend an NSTA area or national conference and look for sessions on formative assessment, including sessions presented by the author of this book and her colleagues. And finally, share the ways you have used this book by contacting the author, Page Keeley, at *pagekeeley@gmail.com*. By sharing your ideas, together we can build a collaborative community to promote elementary science learning through formative assessment.

Chapter 11

Pushes and Pulls

Students have early childhood experiences with basic force concepts well before they encounter the word *force* in the science classroom. For example, it doesn't take long for a child to figure out that pushing or pulling on a toy will cause it to move in the direction of the push or pull. From a very early age, children push and pull on the objects they play with. The forces that young children are most familiar with are ones exerted by their own or someone else's bodies. Their observations of forces usually involve human actions or actions by other living things such as a puppy pushing a ball away with its nose. As a result, many children develop an idea of forces being equated with living things and movement long before they learn about forces in the elementary science classroom. The way the word *force* is used in everyday language affects students' understanding of force in a science context. For example, young children often associate the word *force* with coercion, physical activity, and muscular strength (Driver et al. 1994). This transfers to their notion of a push or pull as well.

When the concept of force is first taught in the elementary curriculum, it is usually introduced as a push or a pull. *A Framework for K–12 Science Education* describes grade-band endpoints for the Core Idea: Motion and Stability: Forces and Interactions (NRC 2012). It states that by the end of grade 2 students should know that objects pull or push each other when they collide or are connected.

What do we know about students' ideas related to pushes and pulls? Early research studies have shown that some students have difficulty associating manifestations of force with pushes or pulls. For example, some primary-age children do not associate a kick or a throw with a push. Furthermore, some students believe there is a force that just holds things in place without pushing or pulling, such as a book on a table (Driver et al. 1994; Minstrell 1982).

Students' preconceptions about pushes or a pulls may affect their learning about types of forces and the interactions involved. The friendly talk probe "Talking About Forces"

FIGURE 11.1.
The Talking About Forces Probe

Talking About Forces

Five friends were talking about forces. This is what they said:

Rae: "I think a push is a force and a pull is something else."

Scott: "I think a pull is a force and a push is something else."

Yolanda: "I think a force is either a push or a pull."

Miles: "I think forces are neither pushes nor pulls. I think they are something else."

Violet: "I think pushes and pulls are forces, but there is also another type of force that just holds things in place."

Which friend do you agree with the most? ___________________

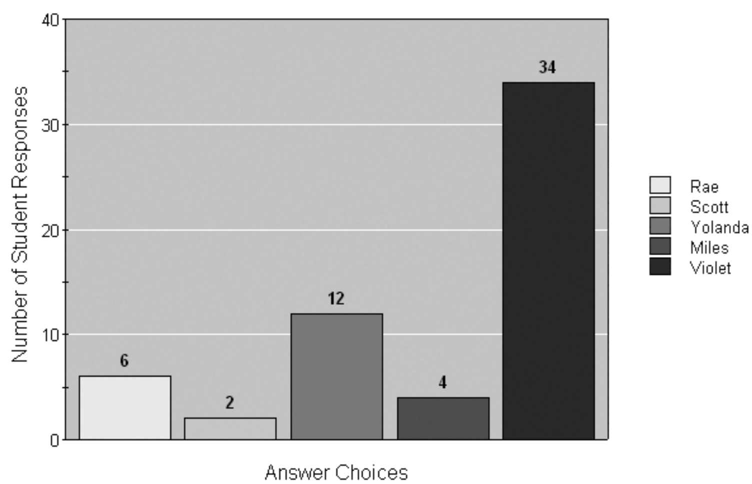
Explain your thinking. Describe what you think a force is.

(Figure 11.1) can be used to uncover students' preconceptions of the familiar words *push* and *pull* and what they mean in the context of forces (Keeley and Harrington 2010). A friendly talk assessment probe is a type of selected response assessment probe in which students select the character they agree with the most (Keeley 2008). With younger students (K–2) it is best to adapt the probe using only the first three answer choices: Rae, Scott, and Yolanda. The information gathered by the teacher can be used to inform learning opportunities in which primary age students can explore and identify a variety of pushes and pulls.

For example, if some students identify force with a push but not a pull, that is an indication to the teacher that students need opportunities to experience both pushes and pulls as forces. A teacher might take students on a "Push and Pull Walk" to identify examples of things they observe being pushed or pulled. Or, a teacher can use a card sort activity in which students are given a set of pictures or descriptions of an action printed on cards that they then sort into examples of forces that are pushes, forces that are pulls, and ones they are not sure about. Listening to the students share their reasons why something is an example of a push or a pull provides insights into students' thinking about forces and interactions between objects.

FIGURE 11.2.

Grade 4 Responses to Talking About Forces



Years later, after students have been taught basic ideas about forces as pushes and pulls, students may still hold on to their own interpretations of pushes and pulls. For this reason, it is helpful to use formative assessment probes to uncover students' ideas about important prerequisite concepts "learned" in prior grades, before building toward progressively more complex concepts. Figure 11.2 shows results from 58 fourth graders who responded to this probe prior to beginning a unit on force and motion. The students had previously encountered the basic concept of force as a push or pull in second grade.

As you can see from the graph, most of the students selected Violet, which matches the research finding that a "holding force" is a commonly held idea. The idea of a holding force may originate well before students reveal this common misconception in middle school or the physics classroom. Most of the students who agreed with Violet generally explained that pushes and pulls are forces because they make things move, but there is another type of force that keeps things from moving. Several students used the example of a refrigerator magnet "having a force that stuck the magnet to the refrigerator." Students who selected Yolanda typically explained that both pushes and pulls cause movement so they are examples of forces. These students equate force with movement.

Overall, the assessment probe reveals that students need opportunities to analyze forces where motion is obvious, less obvious, as well as forces acting on objects at rest. *A Framework for K–12 Science Education* states that by the end of fifth grade, students should know that "An object at rest typically has multiple forces acting on it, but they counterbalance one another."

Although there is more research to be done on diverse students' ideas related to force and motion, particularly with younger children's notion of a push or pull, teachers can gather and analyze their own assessment data to understand their students' ideas and make informed decisions about appropriate learning pathways. The new *Framework for K–12 Science Education* has provided us with updated descriptions of the content and sequence of learning expected of all students. Using formative assessment probes, such as the example provided, can help teachers understand where their own students' ideas are in relation to the Core Ideas described in the *Framework*. Furthermore, the probes can reveal conceptual difficulties your own students may face as they build toward progressively more detailed and sophisticated understandings.

Connecting formative assessment probes to the Core Ideas described in *A Framework* will help you move toward the vision of science teaching and learning that both the *Framework* and the *Uncovering Student Ideas in Science* series embodies. Now that the *Framework* has been released, let's continue to explore this powerful connection between formative assessment and the core ideas. And remember, the probes are not formative unless you use the results to inform your teaching and promote learning!

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INTERNET RESOURCE

Uncovering Student Ideas in Science series
www.nsta.org/publications/press/uncovering.aspx

NSTA CONNECTION

Download a full-size "Talking About Forces" probe at *www.nsta.org/SC1110*.

Pushes and Pulls
Reflection and Study Guide

QUESTIONS TO THINK ABOUT AFTER YOU READ THIS CHAPTER

1. Children have experiences with forces before they start school. They also encounter the word *force* in their everyday language. How do their everyday experiences outside of school and language affect they way they think about forces in science class?
2. Students initially learn about forces through pushes and pulls. How do students' preconceptions about pushes and pulls affect their thinking about forces?
3. "Talking About Forces" is an example of a probe format frequently used in the *Uncovering Student Ideas in Science* series, called a friendly talk probe. How is this format different from a typical multiple-choice question? What do you like about this format?
4. Notice how the picture in this probe and the names used for the answer choices portray diversity. Why is it important for students in the science classroom to see examples of people representing diverse groups talking about their ideas?
5. Examine each of the answer choices to the probe. What kinds of instructional experiences would you provide to address each of these answer choices?
6. How do you think student responses in grades K–2 may differ from students in grades 3–5? How do you think students' responses in grades 3–5 may differ from students in grades 6–8? What do you think may account for these differences?

Are there some ideas about pushes and pulls that may be resistant to change across grade spans?

7. If pushes and pulls are taught in the K–2 curriculum, why would a teacher in grades 3–5 use this probe? Are formative assessment probes limited to the grade level in which a specific idea is taught?
8. Examine the data from Figure 11.2. Grade 4 Responses to Talking About Forces. What do the data tell you? What factual statements can you make from the data? What inferences might you draw from the data?
9. How is it useful for teachers to collaboratively examine student thinking by pooling their data and having data-driven discussions about student thinking? How can you use collaborative inquiry into examining student thinking in your school or other setting?
10. How is it useful to examine and reference readings from *A Framework for K–12 Science Education* (NRC 2012), the *Benchmarks for Science Literacy* (AAAS 2009), or the *Atlas of Science Literacy* (AAAS 2001, 2007) when analyzing student data from a formative assessment probe?

PUTTING FORMATIVE ASSESSMENT INTO PRACTICE

1. What did you learn about your students' understanding of forces as pushes and pulls? Were you surprised by any of their answer choices and explanations?
2. What ideas did your students use to support their answer choices? Do their responses reveal evidence of the source of their misconception or their understanding?
3. What modifications will you make to your curriculum, instruction or instructional materials based on students' responses to this probe?
4. Did you engage in collaborative discussions about the student work from this probe with other teachers who used the same probe? What protocol or process did your group use to examine and discuss the data? What kinds of decisions did your group come up with based on the discussion?
5. Based on what you learned about your students' ideas about pushes and pulls, what advice or suggestions do you have for your colleagues and future teachers?

GOING FURTHER

1. Read and discuss the Teacher Notes for the "Talking About Forces" probe (Keeley and Harrington 2010, pp. 72–74). Pay particular attention to the Related Research and Suggestions for Instruction and Assessment sections.

2. Read and discuss the section on Core Idea PS2 Motion and Stability: Forces and Interactions on pages 113–120 in *A Framework for K–12 Science Education* (NRC 2012) or online at *www.nap.edu/openbook.php?record_id=13165&page=113*
3. Examine the NSDL Science Literacy Strand Map on Laws of Motion at: *http://strandmaps.nsdl.org/?id=SMS-MAP-1357*. Follow the strand "forces and motion" and discuss how the idea of pushes and pulls begins in K–2 and build progressively.
4. Examine and discuss the *Benchmarks for Science Literacy* (AAAS 2009) research summary on forces. Scroll down to 4F Motion: The Concept of Force. *www.project2061.org/publications/bsl/online/index.php?chapter=15&section=C&band=4#4.*
5. Watch and discuss the NSTA archived web seminar on the *NGSS* core idea of Motion and Stability: Forces and Interactions at *http://learningcenter.nsta.org/products/symposia_seminars/NGSS/webseminar28.aspx.*

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WHAT ARE THEY THINKING?

Promoting Elementary Learning Through Formative Assessment

"Children are continually developing ideas and explanations about their natural world. … Some of these ideas are consistent with the science children are taught; others differ significantly from scientific explanations. Many of these ideas will follow students into adulthood if they remain hidden from the teacher and unresolved. The challenge for teachers is to find ways to elicit these ideas and then use appropriate strategies to move students' learning forward."

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GRADES K–5

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