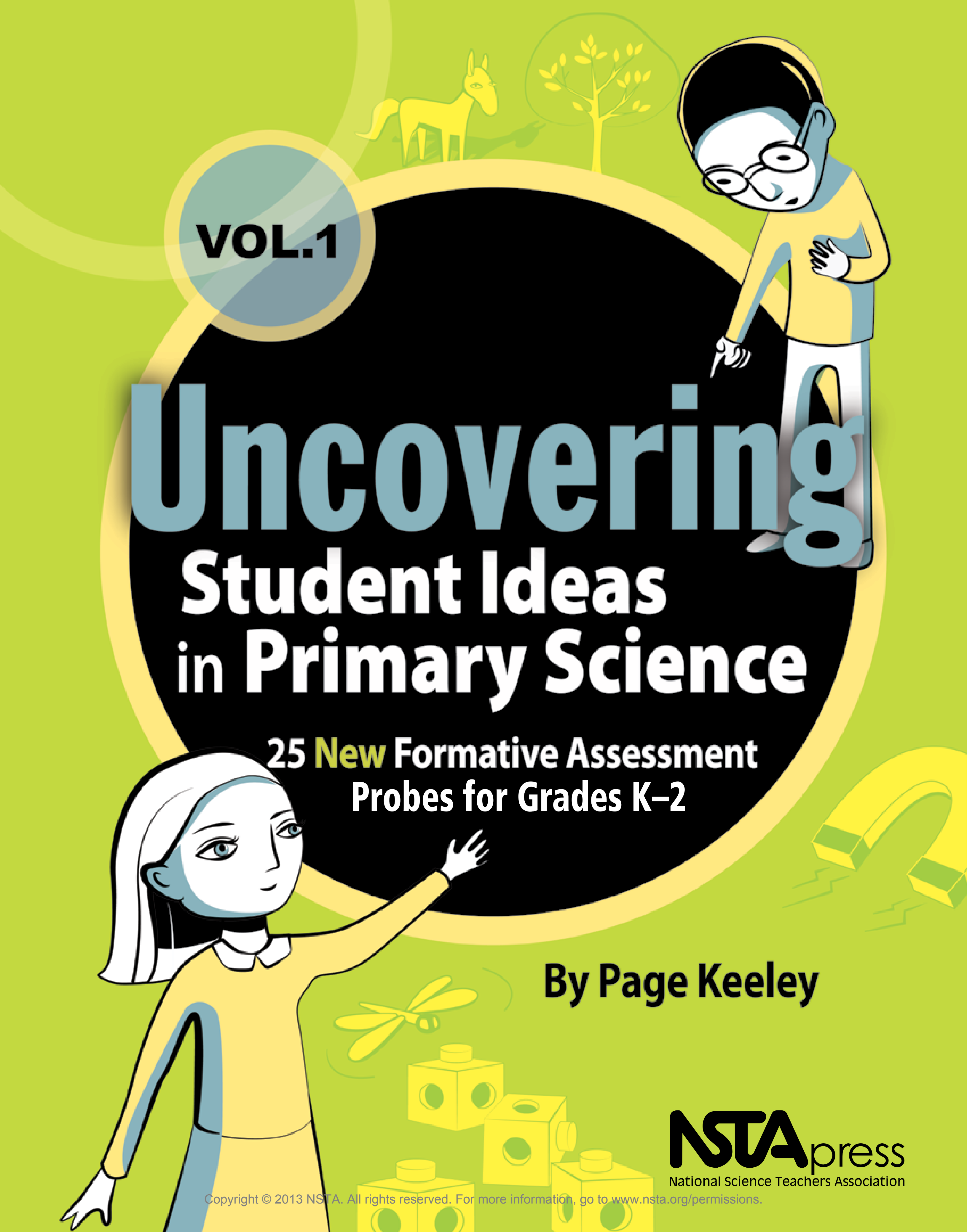
VOL.1

Uncovering Student Ideas in Primary Science

25 New Formative Assessment Probes for Grades K–2



By Page Keeley

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Contents

Preface ... ix

Acknowledgments ... xix

About the Author ... xxi

Introduction ... xxiii

Section 1. Life Science

Concept Matrix ... 2

1 Is It Living? ... 3

2 Is It an Animal? ... 9

3 Is It a Plant? ... 15

4 Is It Made of Parts? ... 21

5 Seeds in a Bag ... 25

6 Do They Need Air? ... 31

7 Senses ... 35

8 Big and Small Seeds ... 39

Section 2. Physical Science

Concept Matrix ... 44

9 Sink or Float? ... 45

10 Watermelon and Grape ... 49

11 Is It Matter? ... 53

12 Snap Blocks ... 59

13 Back and Forth ... 63

14 When Is There Friction? ... 67

15 Marble Roll ... 71

16 Do the Waves Move the Boat? ... 75

17 Shadow Size ... 79

18 Rubber Band Box ... 83

19 Big and Small Magnets ... 87

Section 3. Earth and Space Science

Concept Matrix 92
20 What Makes up a Mountain? 93
21 Describing Soil 97
22 Is a Brick a Rock? 101
23 When Is My Shadow the Longest? 105
24 What Lights up the Moon? 109
25 When Is the Next Full Moon? 113

Index 117

Dedication

This book is dedicated to Emma Elizabeth Keeley, Lincoln Wright DeKoster, Court Wilson Brown, Jack Anthony Morgan, Cadence Jane Friend-Gray, and Emeline Leslie Friend-Gray. May you all grow up to have wonderful ideas!

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 PI and Project Director of three National Science Foundation–funded projects, including 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. In addition to NSF projects, she has directed state MSP 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 14 national bestselling books, including four books in the *Curriculum Topic Study* series, 8 volumes in the *Uncovering Student Ideas in Science* series, and both a science and mathematics version of *Formative Assessment: 75 Practical Strategies for Linking Assessment, Instruction, and Learning.* 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 levels. 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 (NSELA) 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, serves on several national advisory boards, and is the Region A Director for NSELA. She is a science education delegation leader for the People to People Citizen Ambassador Professional Programs,

About the Author

leading trips to South Africa in 2009, China in 2010, India in 2011, and China again in 2013.

Prior to teaching, she was a research assistant in immunology at The Jackson Laboratory of Mammalian Genetics in Bar Harbor, Maine. She received her B.S. in life sciences from the University of New Hampshire and her master's degree in science education from the University of Maine. In 2008, Page was elected the 63rd president of the National Science Teachers Association (NSTA), the world's largest professional organization of science educators.

Introduction

"The having of wonderful ideas is what I consider the essence of intellectual development." —Eleanor Duckworth

K–2 Probes as Assessments for Learning

Imagine a first-grade classroom where Miss Ortega's students are sitting in a circle on the science rug to have a science talk about living things. Miss Ortega uses the pictures from the "Is It Living?" probe to have the children share their ideas about which things are living and which things are not living. As Miss Ortega shows the pictures and names the organisms or objects, she has each student turn to his or her partner to talk about ideas. They then discuss each picture as a whole class, with students sharing the rules they used to decide if something is living or nonliving.

At one point, the class is evenly divided about whether a seed is living or nonliving. Shalika argues, "The seed is not living because it can't move. The cat moves and it is alive, so I think living things have to move." Mac disagrees: "A tree is alive, but it can't move around like a cat. I think some things can be living and not move, so maybe a seed is alive." Oscar offers a new idea: "But seeds grow into plants." Miss Ortega asks Oscar to say more about that, and he adds a clarification: "Things that are living can grow. A seed grows into a plant, so that makes it living." Cora argues that some living things stop growing: "My dad is living, but he is done growing. I think you can stop growing and still be living."

Miss Ortega lists two ideas the children have proposed so far: moving and growing. She asks the class if there are other ways to decide if something is living. Albert offers a new idea: "Living things have to eat, so if it eats, then it is alive." Kenny looks puzzled and asks a question to seek clarification: "But what about fire? It grows bigger when it eats wood." Rania responds, "Yeah, it moves around, too. Fire can move through a whole forest!"

The discussion continues for several minutes. The children are deeply involved in sharing their ideas, listening attentively to each other, seeking clarification from the teacher or other students when needed, constructing explanations to use in their arguments, and evaluating the ideas and arguments of others. Throughout the discussion, they are using and practicing speaking and listening skills.

Miss Ortega makes sure that all the children have an opportunity to make claims and express their thinking. Throughout the year, they have been working on claims and evidence during their science time. Her students know that a claim is the statement that answers the probe question, and to share their thinking, they must provide reasons, including evidence, for their claim. As the children are talking, Miss Ortega is carefully listening and making a list of the class's best ideas so far, which she will post on a chart for students to see and refer to while they visit the learning stations she will set up for the children to explore claims and ideas that support their claims. She notes the extent to which students are using scientific ideas or whether they are drawing on their own alternative conceptions or prior experiences.

By taking the time to find out what her students think about characteristics of living things, Miss Ortega collects valuable assessment data that she will use to plan lessons that will confront her students with their ideas and help them resolve some of the inconsistencies between their ideas and the scientific explanation she will guide them toward developing. By taking their ideas seriously and not correcting students' initial misconceptions, Miss Ortega is promoting learning by giving her students the opportunity to use scientific practices as they listen to each other's ideas, justify their own reasoning, and evaluate the validity of each other's arguments. This is the essence of formative assessment where good instruction and assessment are inextricably linked. Formative assessment is an approach to teaching in which students develop deeper conceptual understanding through the development of their own thinking and talking through their ideas, while simultaneously providing a window for the teacher to examine students' thinking and determine next steps based on where the learners are in their conceptual development.

Facilitating this type of approach to learning may sound demanding, and it seems it would be much simpler to just give students the information or engage in a hands-on activity. However, research shows that children learn best when they first surface their ideas before launching into investigations, activities, readings, and other opportunities to learn (Bransford, Brown, and Cocking 1999). Students have to do the thinking; the activity cannot do it for them, nor is the learning in the materials themselves. Surfacing initial ideas and recognizing when their ideas are changing as they construct new understandings is a powerful way to teach and learn. It is the explanation of the probe—not the answer selections the students choose from—that provides important assessment data and supports learning. One of the most effective ways to help students construct new understandings and simultaneously develop reasoning skills (that works particularly well with the formative assessment probes) is to provide children with the opportunity to interact in pairs, small groups, and as a whole class, where they listen to each other's ideas and have to justify their own. Communicating ideas in science is a central feature of using the formative assessment probes and one of the *Next Generation Science Standards (NGSS)* scientific practices. The probes not only provide insights for the teacher about students' understanding or misunderstanding of core ideas in science but also provide a treasure trove of data about students' use of scientific and engineering practices. For example, P-E-O (Predict-Explain-Observe) probes provide an opportunity for young children to make an initial claim (prediction), provide an explanation for their initial claim, test the claim, gather evidence (the data) from the observations, analyze the data to see if they support or refute the initial claim, and propose a new claim and explanation if the observations did not match the initial claim. See Table 2 for examples of ways the formative assessment probes support learning of the practices in the *NGSS*.

This book provides 25 highly engaging formative assessment probes that elicit preconceptions, support the development of young children's understanding of K–2 core disciplinary ideas, and encourage the use of scientific practices in the *NGSS*. However, before you skip ahead and use the probes, read through the rest of this introduction to learn more about children's ideas in science and science talk so that you can best use these probes to inform your teaching and support learning.

Table 2. Link Between K–2 Formative Assessment Probes and the *NGSS* Scientific and Engineering Practices

NGSS Scientific and Engineering Practice	K–2 Probes as Assessments for Learning	Examples
Practice 1: Asking questions and defining problems	The probe begins with an interesting question. Students ask additional questions to seek understanding and determine what they already know or need to know to make a claim and construct explanations to the probe.	**Probe 16, "Do the Waves Move the Boat?"** Students may ask questions of each other and the teacher about water waves. They use the probe question to further explore the science that can provide an explanatory answer to the probe.
Practice 2: Developing and using models	Some probes involve the use of models to develop explanations of the phenomenon. As the teacher listens to children's ideas, he or she is thinking about the best model to use to help them understand the probe phenomenon.	**Probe 24, "What Lights Up the Moon?"** As the teacher listens to students, he notices several students think there is a light glowing inside the moon. He thinks about how he can have the children model the reflection of sunlight using a white ball and a flashlight.
Practice 3: Planning and carrying out investigations	Some probes (P-E-O probes) can be used to launch an investigation and require children to think about how they can best make observations and collect data to test the claims they made in response to the probe.	**Probe 19, "Big and Small Magnets"** Students test their claims using a variety of big and small magnets. They decide how they will determine strength using paper clips, make observations, and record their data.
Practice 4: Analyzing and interpreting data	To support a claim with evidence when using a P-E-O probe, students collect, analyze, and interpret the data to derive meaning.	**Probe 18, "Rubber Band Box"** Students make rubber band box guitars like the one in the probe context and test their ideas about sound. They analyze their data to determine how pitch is related to the thickness of the rubber band.
Practice 5: Using mathematics and computational thinking	Students count and use numbers to find or describe patterns related to the probe. They also use measurement and measurement instruments such as thermometers, rulers, and weighing scales to gather data.	**Probe 12, "Snap Blocks"** Students count the individual blocks and make predictions about how the weight of the blocks snapped together compares to the total weight of the individual blocks weighed together. They try this several times using different numbers of snap blocks, weigh them on a scale, record their data, and notice that the pattern shows the weight is always the same.
Practice 6: Constructing explanations and designing solutions	Every probe requires students to construct an initial explanation (their personal theory) to support their claim (answer choice) and revise their explanations as they gather new evidence and information.	**Probe 10, "Watermelon and Grape"** The initial theory proposed by the class is that large things sink and small things float. After testing a variety of objects, students revise their initial explanation to explain that size alone does not determine whether an object floats or sinks.

Table 2 *(continued)*

NGSS Scientific and Engineering Practice	K–2 Probes as Assessments for Learning	Examples
Practice 7: Engaging in argument from evidence	All the probes are used in a talk format that requires students to explain and defend their reasoning to others and promotes careful listening so that other students can build on a line of reasoning or offer alternative explanations. Together, the class searches for the best explanation from the comments and evidence offered during science talk.	**Probe 1, "Is It Living?"** As in the scenario at the beginning of this chapter, the teacher engages the students in science talk, explaining and defending their reasons for why something is or is not considered living. Later, after the teacher has provided opportunities for students to investigate their ideas, they will engage again in science talk, providing new evidence to support or revise their initial arguments.
Practice 8: Obtaining, evaluating, and communicating information	Following up the use of a probe often involves students seeking additional information that may come from trade books, videos, and other sources to provide information that supports their claims or provides new information to help them change their claim. Students must also be able to communicate information clearly to each other, which sometimes involves the use of drawings and other visual ways to share the information they obtain.	**Probe 6, "Do They Need Air?"** Many students claimed that animals that live in water do not need air, so the teacher obtained several trade books and video clips for children to learn about animals that live in water and how they meet their needs. She also brought in a goldfish that students could observe. Children revisit the probe and explain ways different animals get air and draw pictures of land and water animals, showing different structures they use to get air.

Young Children's Ideas

Children develop ideas about their natural world well before they are taught science in school. For example, many young children think that things like hats, coats, blankets, sweaters, or mittens warm us up by generating their own heat. This makes sense to children because when they put on a sweater or wrap themselves up in a blanket, they get warmer. They have not yet learned that heat moves from warmer to cooler and that materials such as a mitten can slow down the loss of body heat. In other instances, children are novice learners in science and have not yet gained enough background knowledge or been formally introduced to scientific principles to be able to explain a concept scientifically. For example, young children may think that only organisms with fur and four legs are considered animals because they do not yet have enough knowledge about the scientific meaning of animal—such as having to acquire food from the environment—to recognize that organisms such as worms, insects, and even humans are considered animals in a scientific sense.

Some of the ideas young children have may be consistent or partially consistent with the science concepts that are taught. For example, they know when you drop an object, it falls to the ground. They are already developing ideas consistent with the idea of gravity. But often there is a significant gap between children's explanations for natural phenomena or concepts and the explanations that are developed through "school science." For example, failure to recognize that weight is conserved when a whole object is broken into individual pieces illustrates a significant gap between children's ideas about what happens to the total weight of an object when it is changed in some way and the understanding of conservation of matter with "parts and wholes" that is developed in the science class.

Many studies have been conducted of children's commonly held ideas about natural phenomena and science concepts. Most notable among the researchers of children's ideas is Dr. Rosalind Driver and her research group from the University of Leeds in England. This group has contributed extensively to our understanding of commonly held ideas children have about science that may affect their learning. The research into commonly held ideas, which is often referred to by practitioners as misconceptions, has enabled teachers to predict what their own students are likely to think about a phenomenon and how they might respond to an assessment that probes their thinking. The assessment probes in this book were developed from examining the research on children's ideas in science, particularly Driver's contributions (Driver, Squires, Rushworth, and Wood-Robinson 1994). As you use these probes, it is highly likely that your students' ideas will mirror the findings that are described in the Related Research Summaries part of the Teacher Notes that accompany each of the probes. While you may be surprised to find that your students hold many of these alternative ideas, it is important for you to realize that these are highly personal and make sense to the student. Merely correcting them does not make them go away. Students must have access to instructional experiences that will challenge their thinking and help them construct models and explanations that bridge the gap between their initial ideas and the scientific understandings that are achievable at their grade level.

Another important feature of children's ideas in science is that children learn best when knowledge is socially constructed. Much like the way science is done in the real world, children need opportunities to share their thinking, justify the reasons for their ideas, and listen to the ideas of others. Children also need to be aware of the range of ideas others have about the same phenomenon or concept and be able to evaluate them in light of their own ideas and the evidence presented. Scientific theories develop through interaction with other scientists; children's ideas develop through interaction with their classmates and the teacher. The probes provide ample opportunities for children to think through and talk about their ideas with others. Animated science talk and argumentation are the hallmarks of a formative assessment–centered learning environment in which the probes are effectively being used.

Children's Learning Experiences

Hands-on science has not always been minds-on science. The opportunity to ask questions, manipulate materials, and conduct investigations—a major emphasis of inquiry-based science—has not always resulted in deeper conceptual learning. That is because the learning is not in the materials or investigations themselves, but in the sense children make out of their experiences as they use the materials to perform investigations, make observations, and construct explanations. Perhaps the pendulum swung too far to the hands-on side in the last decade or so of elementary inquiry-based science. Inquiry without inquiry for conceptual change did little to help students give up their strongly held alternative ideas. One way to support inquiry for conceptual change is to start with uncovering children's ideas before launching into an investigation. To design probes for this book that could be used to support or enhance children's learning experiences, the following features for developing and using a probe were considered:

- Promoting curiosity and stimulating children's thinking
- Drawing out alternative ideas that could be investigated in the classroom

- Linking to previous experiences in or out of school
- Using familiar objects, phenomena, and situations
- Reducing dependency on reading text
- Improving developmental appropriateness
- Relating to core ideas in the *NGSS* or the *Benchmarks for Science Literacy*
- Supporting the use of the scientific and engineering practices such as constructing explanations and engaging in argument from evidence
- Using models and representations to develop explanations
- Encouraging sense making and reflection on how ideas have changed

Effective teaching and learning do not just happen; they are carefully planned. Using the probes to inform the design of learning experiences for children involves the recognition that children already have ideas about the natural world that they bring with them to their learning experiences. This is significant when planning instructional experiences, particularly when combined with a constructivist view of learning in which the student must take an active role in constructing meaning for himself or herself. When children's existing ideas are acknowledged as you incorporate their ideas from the probes into the lessons, learning takes place as children change their ideas through experiences that allow them to test or discuss their ideas and support them with evidence, in much the same way that scientists develop theories. This may involve supporting an initial idea, modifying an idea, or rejecting an idea in favor of an alternative explanation. Whichever it is, the student needs to "own it," which means the reasoning must be done by the student (not the teacher, although he or she can guide it).

Formative Assessment Probes and Science Talk

> When I first tried listening quietly and taking notes about what I heard students saying as they worked, my insight into their learning was phenomenal! I actually stopped talking and just listened. The data I collected showed some incorrect conceptions as well as understanding. It often opened windows into how a student had learned. The rich data I gathered helped me determine which next steps I needed to take to further learning. (Carlson, Humphrey, and Reinhardt 2003, p. 37)

This quote from an elementary teacher reveals the power of careful listening as students talk about their science ideas. The probes in this book differ from the collection of 215 other formative assessment probes in the *Uncovering Student Ideas* series because they are designed to be used in a talk format rather than having students write explanations to support their answer choice (however, they certainly can be combined with writing, especially with science notebooks). Even the formats used in this book highlight the importance of science talk. For example, you will see that several of the probes in this book use a cartoon format in which the characters share their ideas with each other and the student selects the character whose idea best matches his or her own (e.g., "Sink or Float?"). This format models what we want to encourage children to do: share their claims with one another and provide evidence that supports these claims. The author intentionally uses this format to help students recognize the importance of sharing ideas without passing judgment initially on whether they are right or wrong.

Whether you use the science workshop approach, science conferences, small-group discussions, pair talk, or other ways to involve students in science talk, the probes provide an interesting question that serves to elicit children's initial ideas and draw out their reasons for their thinking. Assessment data is gathered by carefully listening to students, and, when possible, audio-recording dialogue, taking notes, or transcribing parts of conversations as you listen will provide a treasure trove of data you can use to design instruction focused on where the learners are in their understanding.

The first step in using science talk for formative assessment is to ask questions that will capture students' interest, provoke thinking, and encourage explanations that will help you gain insight into their reasoning and understanding. Sometimes it can be challenging for teachers to know what type of question will elicit children's ideas that can provide rich information about a core concept they will be learning. This has been done for you in this book! Each probe is a question specifically designed to draw out children's ideas that will not only support their learning but also inform your teaching. Use the probe as your starting point for learning more about your students' ideas. New questions will spring from the probe and spark further conversation.

Sometimes a probe is used to develop an investigative question and launch into inquiry. Some probes provide an opportunity for students to make predictions and explain the reasons for their prediction before they make observations during their investigations. This type of probe is called a P-E-O (Predict-Explain-Observe) probe, and examples include, but are not limited to, "Snap Blocks" (p. 59), "Marble Roll" (p. 71), and "Seeds in a Bag" (p. 25) (Keeley 2008). P-E-O probes provide an opportunity for children to practice verbal communication to articulate their thoughts prior to the investigation and make their thinking visible to others. In addition, it provides an opportunity for children to discuss the best way to test their ideas and then test them, supporting the *NGSS* scientific practice of designing and carrying out investigations.

Productive classroom talk using a formative assessment probe before launching into an investigation also has the benefit of leading to deeper engagement in the content before and during the investigation. As students collect, analyze, and share their data, they compare their findings with their initial claims and evidence and may become aware of the discrepancies between their own or others' ideas from the evidence gathered during the investigation. For example, the probe "When Is the Next Full Moon?" provides an opportunity for students to make and test a prediction about how long it takes to see a full Moon again (length of a lunar cycle). They examine reasons for their predictions before beginning an investigation that provides the data they need to understand the repeated pattern of Moon phases, a disciplinary core idea in the *NGSS* as well as a crosscutting concept of patterns and cycles. The probe can be revisited again after students have had an opportunity to make sense of their data and use it to explain the lunar cycle. By following the probe with a scientific investigation, the students have actual data from their investigation to construct a scientific explanation to support their new or revised claim. As they engage in talk and argument again with the same probe, the context of the probe—combined with the scientific knowledge they gained through their investigation—provide an opportunity for them to build stronger, evidence-based arguments.

Talk Moves

One of the best resources I recommend that every teacher of elementary science read and become familiar with is *Ready, Set, Science! Putting Research to Work in K–8 Classrooms*

(Michaels, Shouse, and Schweingruber 2008). Since this book is published through our federal taxpayer–supported National Academies of Science, it is available for free as a PDF on the National Academies Press website (*www.nap.edu*), where you can download a copy of the book. It is also available for purchase through the NSTA bookstore. Chapter 5, "Making Thinking Visible: Talk and Argument," is an excellent read for you to deepen your understanding of the role of talk and argument in science as you use the probes in this book.

As students grapple with the ideas elicited by the probes in this book, the role of the teacher is to facilitate productive science talk in ways that will move students' thinking forward and help them clarify and expand on their reasoning. One of the ways to do this is through the use of "talk moves" (Keeley 2012). Table 3 shows six productive talk moves adapted from *Ready, Set, Science!* (Michaels, Shouse, and Schweingruber 2008) that can be used with the formative assessment probes in this book.

Table 3. Talk Moves and Examples

Talk Move (from *Ready, Set, Science!* [Michaels, Shouse, and Schweingruber 2008])	Example of Using the Talk Move with a Formative Assessment Probe
Revoicing	• "So let me see if I've got your thinking right. You're agreeing with Amy because _____?" • "Let me see if I understand. You are saying _____?"
Asking students to restate someone else's reasoning	• "Can you repeat in your own words what Latisha just said about why she agrees with Jamal?" • "Is that right, Latisha? Is that what you said?"
Asking students to apply their own reasoning to someone else's reasoning	• "Do you agree or disagree with Emma's reason for agreeing with Morrie, and why?" • "Can you tell us why you agree with what Sam said? What is your reasoning?"
Prompting students for further participation	• "Would someone like to add on to the reasons why some of you chose Fabian as the person you most agree with in the probe?" • "What about others—what would you like to add to these ideas so far?" • "What do others think about the ideas we have shared so far? Do you agree or disagree?"
Asking students to explicate their reasoning	• "Why do you agree with Penelope?" • "What evidence helped you choose Fabian as the person you most agree with in the probe?" • "Say more about that."
Using wait time	• "Take your time. We'll wait." • "I want everyone to think first, and then I will ask you to share your thinking."

Revoicing

Sometimes it is difficult to understand what the student is trying to say when they struggle to put their thoughts into words. If you, as the teacher, have difficulty understanding what the student is saying, then the students listening are apt to have even greater difficulty. Clarity in expressing ideas is often needed when encouraging young children to share their thinking. Therefore, this move not only helps the child clarify his or her thinking but also provides clarity for the listeners as well—both teacher and students. By revoicing the child's idea as a question, the teacher is giving the child more "think time" to clarify his or her ideas. It is also a strategy for making sure the student's idea is accessible to the other students who are listening and following the discussion.

Asking Students to Restate Someone Else's Reasoning

While the move above (revoicing) is used by the teacher, this move has the students reword or repeat what other students share during the probe discussion. It should then be followed up with the student whose reasoning was repeated or reworded. The benefit to using this talk move during discussions about the science probe ideas is that it gives the class more think time and opportunity to process each student's contribution to the science talk. It also provides another version of the explanation that may be an easier version for the children to understand. This talk move is especially useful with English language learners. As a formative assessment talk move, it provides the teacher with additional clarification of student ideas. Additionally, it acknowledges to the students that the teacher as well as the students in the class are listening to one another.

Asking Students to Apply Their Own Reasoning to Someone Else's Reasoning

The probes encourage students to make a claim and share their reasoning for their claim. This talk move is used with the probes to make sure students have had time to evaluate the claim based on the reasoning that was shared by a student. It helps students zero in and focus on the reasoning. Note that the teacher is not asking the other students whether they merely agree or disagree with someone's claim; they also have to explain why. This talk move helps students compare their thinking to someone else's and, in the process, helps them be more explicit in their own reasoning.

Prompting Students for Further Participation

After using revoicing to clarify the different ideas that emerge during discussion of the probe, the teacher prompts others in the class to contribute by agreeing, disagreeing, or adding on to what was already shared. This talk move encourages all students to evaluate the strength of each other's arguments. It promotes equitable and accountable discussion.

Asking Students to Explicate Their Reasoning

This talk move encourages students to go deeper with their reasoning and be more explicit in their explanations. It helps them focus on the evidence that best supports their claim and build on the reasoning of others.

Using Wait Time

This is actually a silent move, rather than a talk move. One of the hardest things for teachers to do is to refrain from not commenting immediately on children's responses. There are two types of wait time that should be used when engaging students in probe discussions. The first is for the teacher to wait at least five seconds after posing a question so the students have adequate think time. The second is for the teacher, as well as the students, to practice waiting at least five seconds before commenting on a students' response. This strategy is especially important to use with English language learners as well as students who may be shy or reluctant to contribute ideas in front of the whole class. By waiting, even though silence can be agonizing, the teacher supports students' thinking and reasoning by providing more time for them to construct an explanation or evaluate the arguments of others. This strategy provides greater inclusivity for all students in the class to participate in productive science talk by acknowledging the time they need to think through their ideas.

All of these talk moves can be used with the probes in various combinations to facilitate productive science talk in which all the students are accountable for each other's learning and the teacher is able to extract valuable formative assessment data to further plan instruction and support learning. However, to use these moves effectively, it is important to establish the conditions for a respectful learning environment. To do that, teachers should set group norms or ground rules for engaging in productive talk and equitable participation so that students will listen to and talk with one another respectfully and courteously as they use the probes. It is important for them to know that a scientific argument has a different meaning in science than in real life. In science, we argue to examine our ideas and seek understanding rather than argue to win with our point of view. Examples of norms you might establish in your classroom for science talk may include but are not limited to the following:

- Listen attentively as others talk.
- Make sure you can hear what others are saying.
- Speak so others can hear.
- Argue to learn, not to win.
- Criticize the reasoning, not the person.
- Make only respectful comments.

Communicating and listening to scientific ideas contribute to language development, an important goal of teaching in the primary grades, and is consistent with the *Common Core State Standards, ELA* (NGAC and CCSSO 2010). See Table 4 for examples of ways the formative assessment probes support the *Common Core* literacy standards for speaking and listening for primary students.

Formative assessment that supports productive scientific discussions takes time to develop and needs a lot of practice. As you incorporate these probes into your science lessons, I hope you will see the value in productive science talk that emanates from using these probes. By using these probes in talk formats with primary students, you are not only developing conceptual understanding of the life, physical, Earth, and space ideas for grades K–2 included in the *NGSS*, but also revealing and clarifying the ideas they bring to their learning, which you can use to improve and enhance your science teaching. Making students' ideas visible as you use these probes will help you build more effective lessons and support young students in using the scientific and engineering practices in sophisticated ways that show young learners are capable of far more than we often ask of them. In a nutshell, it's about teaching science well and giving your students the best possible start to be successful learners of science as they progress through school!

Table 4. Linking Formative Assessment Probes to the *Common Core* Speaking and Listening Standards

Common Core State Standards (Grades K, 1, and 2)	Formative Assessment Probes
◆ SL.K.1, 1.1, 2.1: Participate in collaborative conversations with diverse partners about kindergarten, grade 1, and grade 2 topics and texts with peers and adults in small and larger groups.	The probes are designed to be used in a talk format in small or large groups discussing ideas with the teacher and with each other about a science topic.
◆ SL.K.2: Confirm understanding of a text read aloud or information presented orally or through other media by asking and answering questions about key details and requesting clarification if something is not understood. ◆ SL.1.2: Ask and answer questions about key details in a text read aloud or information presented orally or through other media. ◆ SL.2.2: Recount or describe key ideas or details from a text read aloud or information presented orally or through other media.	As students talk about and share their ideas related to the probe, they ask questions about and discuss key details related to the probe context or answer choices. They may ask for clarification about the probe context or the answer choices or clarification of each other's explanations as they share their ideas through speaking and listening.
◆ SL.K.3: Ask and answer questions in order to seek help, get information, or clarify something that is not understood. ◆ SL.1.3: Ask and answer questions about what a speaker says in order to gather additional information or clarify something that is not understood. ◆ SL.2.3: Ask and answer questions about what a speaker says in order to clarify comprehension, gather additional information, or deepen understanding of a topic or issue.	Students ask questions about the probe task. They also ask questions of each other and seek clarification of explanations as they share their claims and provide their reasons for their claims. After students have had the opportunity to revisit the probe after the teacher has designed learning experiences, students ask and answer questions to deepen their understanding of the concepts elicited by the probe.
◆ SL.K.4: Describe familiar people, places, things, and events and, with prompting and support, provide additional detail. ◆ SL.1.4: Describe people, places, things, and events with relevant details, expressing ideas and feelings clearly. ◆ SL.2.4: Tell a story or recount an experience with appropriate facts and relevant, descriptive details, speaking audibly in coherent sentences.	The probes provide a context for discussing familiar phenomena, objects, and processes related to a science core idea. Students are encouraged to share their prior experiences connected to the probe and prompted by the teacher to provide details and further information.
◆ SL.K.5: Add drawings or other visual displays to descriptions as desired to provide additional detail. ◆ SL.1.5: Add drawings or other visual displays to descriptions when appropriate to clarify ideas, thoughts, and feelings. ◆ SL.2.5: Create audio recordings of stories or poems; add drawings or other visual displays to stories or recounts of experiences when appropriate to clarify ideas, thoughts, and feelings.	Students are encouraged to use drawings or other visual symbols, where appropriate, to support their ideas, clarify their responses, and communicate relevant details related to the probe.
◆ SL.K.6: Speak audibly and express thoughts, feelings, and ideas clearly. ◆ SL.1.6 and SL2.6: Produce complete sentences when appropriate to task and situation in order to provide requested detail or clarification.	Probes provide an engaging context for students to practice speaking clearly in complete sentences to support their ideas and emerging understanding of science.

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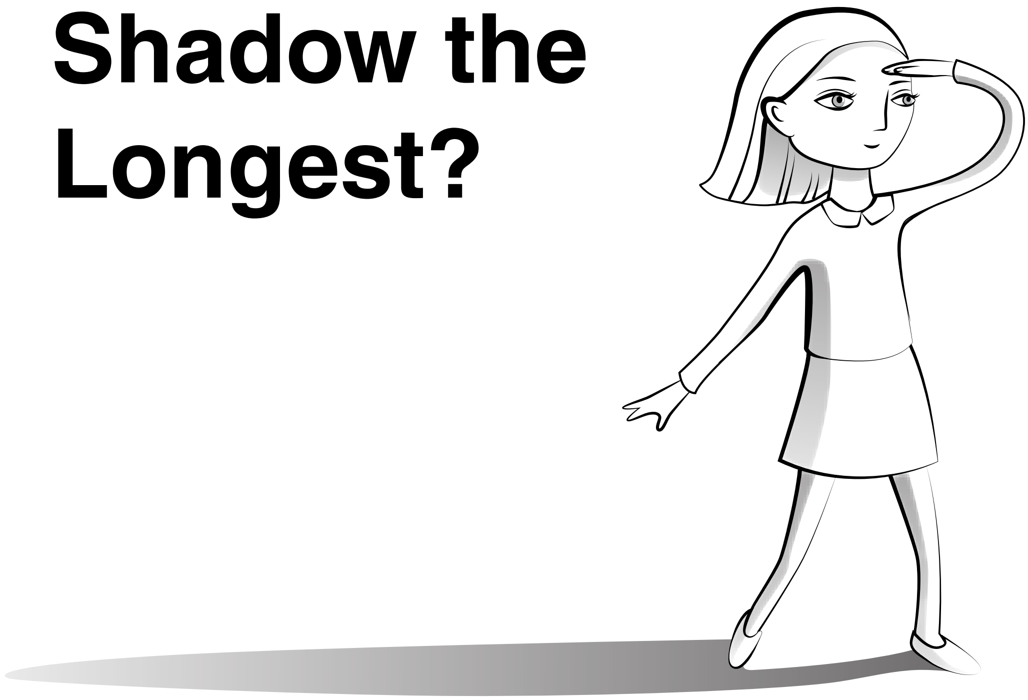
When Is My Shadow the Longest?



- [ ] early morning
- [ ] late morning
- [ ] noon

What are you thinking?

When Is My Shadow the Longest?

Teacher Notes

Purpose
The purpose of this assessment probe is to elicit children's ideas about shadows. The probe is designed to find out how students think shadows change from sunrise to noon.

Related Concepts
Earth-Sun system, shadows

Explanation
The best response is "Early morning." Morning shadows are longest right at sunrise when the Sun is low on the horizon. The angle at which sunlight strikes Earth changes as the Sun appears to move across the sky due to the Earth's rotation. In the early morning, the Sun is seen as low on the horizon and the angle between the Sun's rays and Earth's horizon is small. The shadow that results from blocking the Sun's rays is long. As the angle between Earth's surface and the Sun's rays that strike the Earth's surface increases throughout the morning, the shadow gets shorter. At noon, the time when the Sun is highest in the sky, the size of a shadow is the shortest. After noon, the shadow will begin increasing until it reaches its longest length right before sunset. (*Note:* Solar noon, the time when the Sun is highest in the sky, may be different from "clock noon" [12:00 p.m.], depending on geographic location.)

Curricular and Instructional Considerations for Grades K–2
Observing changes in shadows is an appropriate activity to help primary-age children engage in scientific practices and identify patterns related to the Sun-Earth system. By observing and measuring shadows, students can describe the changing position of the Sun in relation to the Earth throughout the day. In addition to collecting data by observing changes in their shadows on a particular day, students can also collect and analyze data to describe seasonal changes to their shadows.

Administering the Probe
Adapt the probe to fit the hours of your school day. For example, for early morning, have students observe their shadow soon after they arrive at school (e.g., 8:30 a.m.). Wait about two hours before making a late-morning observation (e.g., 10:30 a.m.). List the time for students. Observe again at noon or close to noon. Make sure there is enough time in between to observe or measure the noticeable changes in shadow length. See pages xxviii–xxxiii in the introduction for techniques used to guide "science talk" related to the probe.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 2009)

K–2 The Universe
- The Sun, Moon, and stars all appear to move slowly across the sky.

Related Core Ideas in *A Framework for K–12 Science Education* (NRC 2012)

K–2 ESS1.A: The Universe and Its Stars

- Patterns of the motion of the Sun, Moon, and stars in the sky can be observed, described, and predicted.

K–2 ESS1.B: Earth and the Solar System

- Seasonal patterns of sunrise and sunset can be observed, described, and predicted.

3–5 ESS1.B: Earth and the Solar System

- The orbits of Earth around the Sun and of the Moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily and seasonal changes in the length and direction of shadows; phases of the Moon; and different positions of the Sun, Moon, and stars at different times of the day, month, and year.

Related *Next Generation Science Standards* (Achieve Inc. 2013)

Grade 1: Earth's Place in the Universe

- 1-ESS1-1: Use observations of the Sun, Moon, and stars to describe patterns that can be predicted.

Grade 5: Earth's Place in the Universe

- 5-ESS1-2: Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.

Related Research

- Some researchers have found that children expect the shadow of an object to be the same shape as the object (Driver, Squires, Rushworth, and Wood-Robinson 1994).
- Students seem to have more success in locating where an object's shadow will fall in relation to a light source if the object is a person. They have more difficulty anticipating where a shadow will fall if it is a nonhuman object, such as a tree (Driver, Squires, Rushworth, and Wood-Robinson 1994).
- Plummer and Krajcik (2010) found that children as young as first grade knew that the Sun gets higher in the sky during the day and lower in the sky toward evening, although most were not able to accurately describe the Sun's path. Some even thought the Sun stopped moving during the day.

Suggestions for Instruction and Assessment

- A related probe, "Me and My Shadow," can be adapted for use with primary-grade students (Keeley, Eberle, and Dorsey 2008).
- This probe can be used to launch into inquiry after students have made their predictions about when their shadow would be the longest. Have students observe and measure their shadow throughout the morning until noon and describe the pattern.
- After students have discovered the pattern, relate the pattern to the position of the Sun throughout the day. However, use caution: **Never** allow children to look directly at the Sun.
- Make sure students know what a shadow is before asking them when their shadow will be longest.
- Have students model what happens to a shadow when the position of a light source—and thus the angle at which light strikes an object—changes. Provide

students with a flashlight and an upright object to test their ideas and record observations. Help students link their flashlight findings to the position of the Sun throughout the day.

- Extend the probe to include afternoon shadows. Have students draw a sequence of pictures to show the relationship between a shadow's length and the position of the Sun throughout the day.
- Extend shadow investigations across the school year to show there are seasonal patterns as well as daily patterns.

Related NSTA Resources

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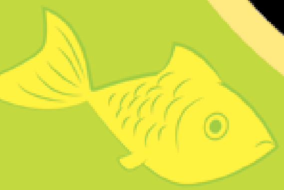
VOL.1

Uncovering Student Ideas in Primary Science

25 New Formative Assessment Probes for Grades K–2



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GRADES K–2

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