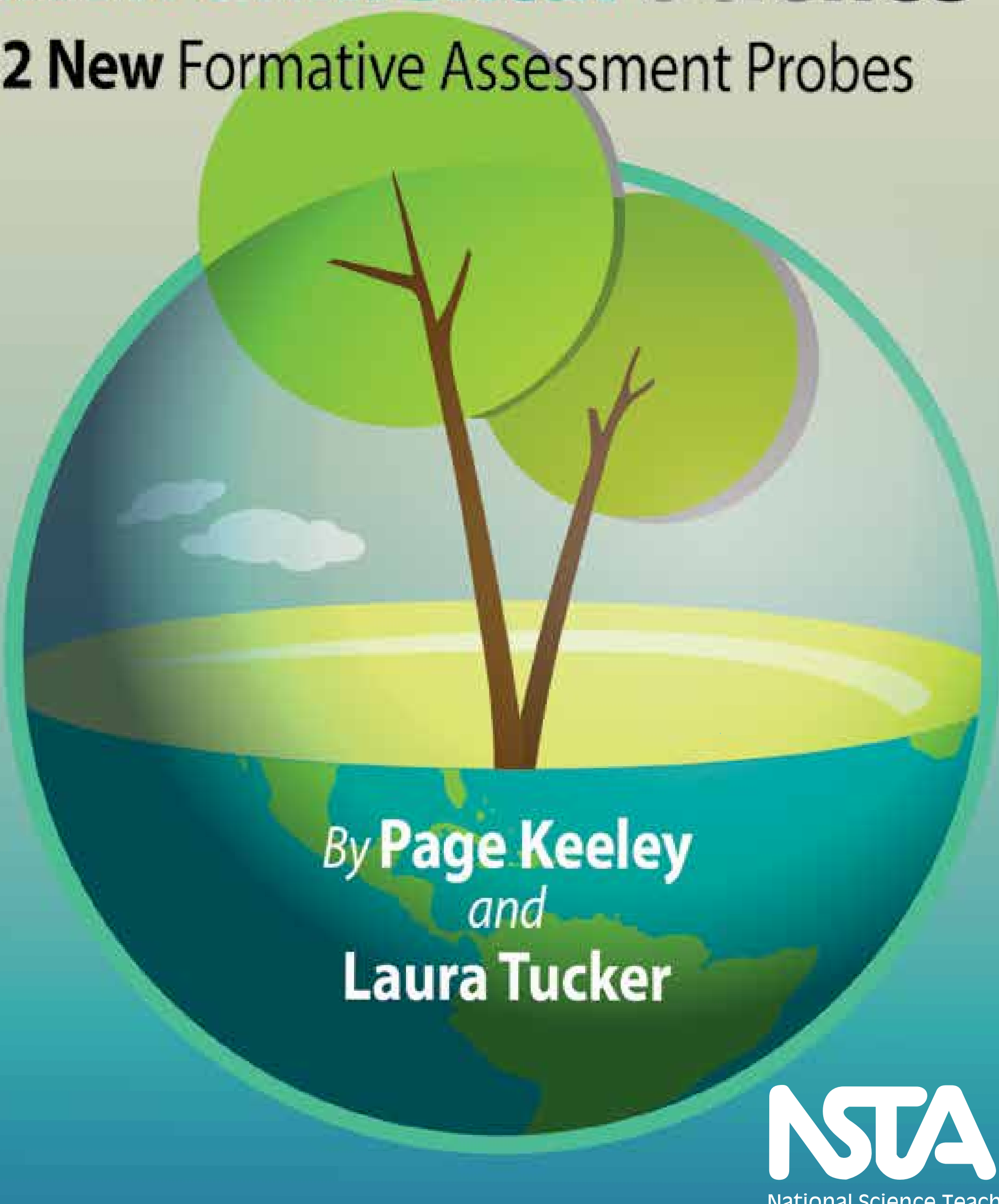
Uncovering Student Ideas in Earth and Environmental Science

32 New Formative Assessment Probes



By Page Keeley
and
Laura Tucker

NSTApress
National Science Teachers Association

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Uncovering

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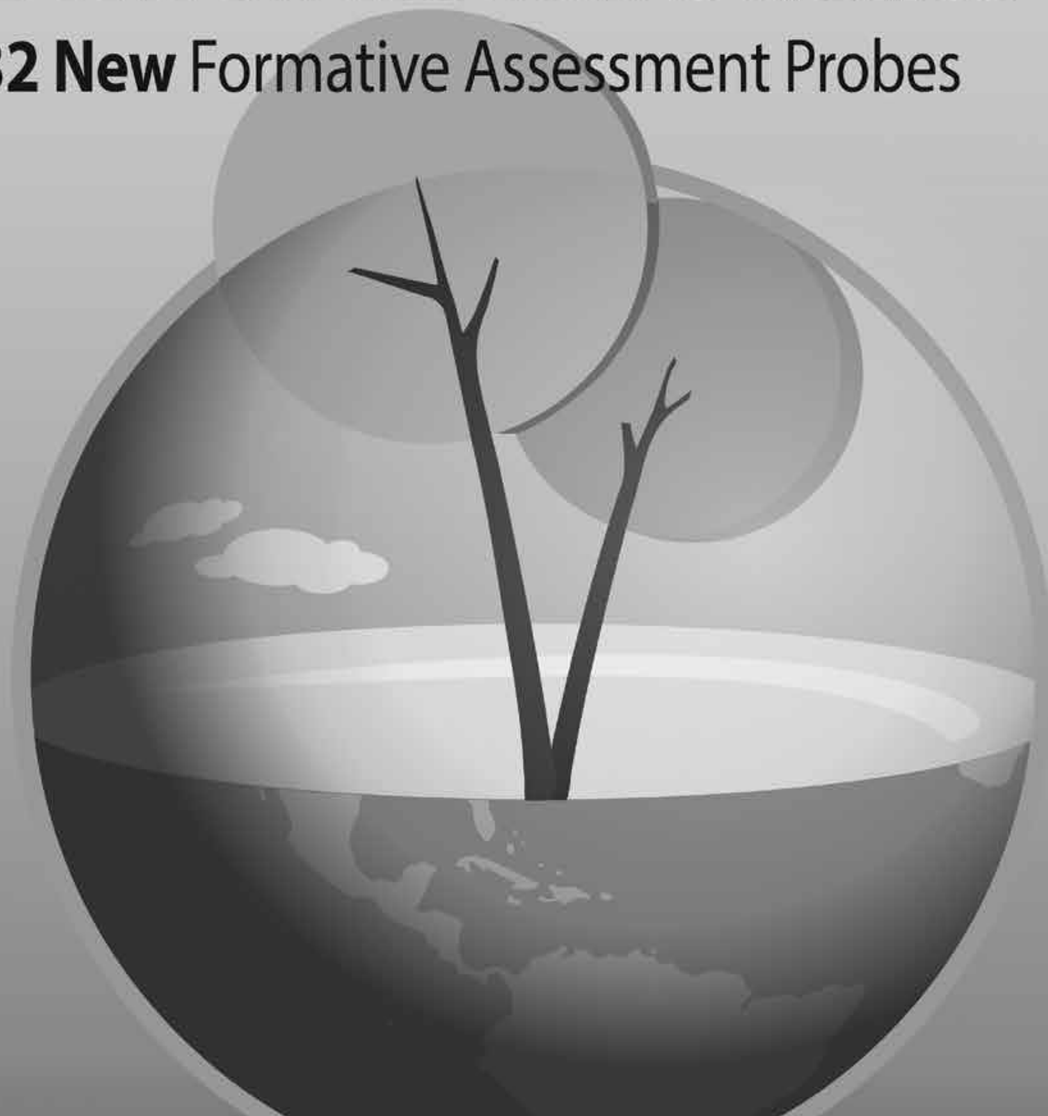

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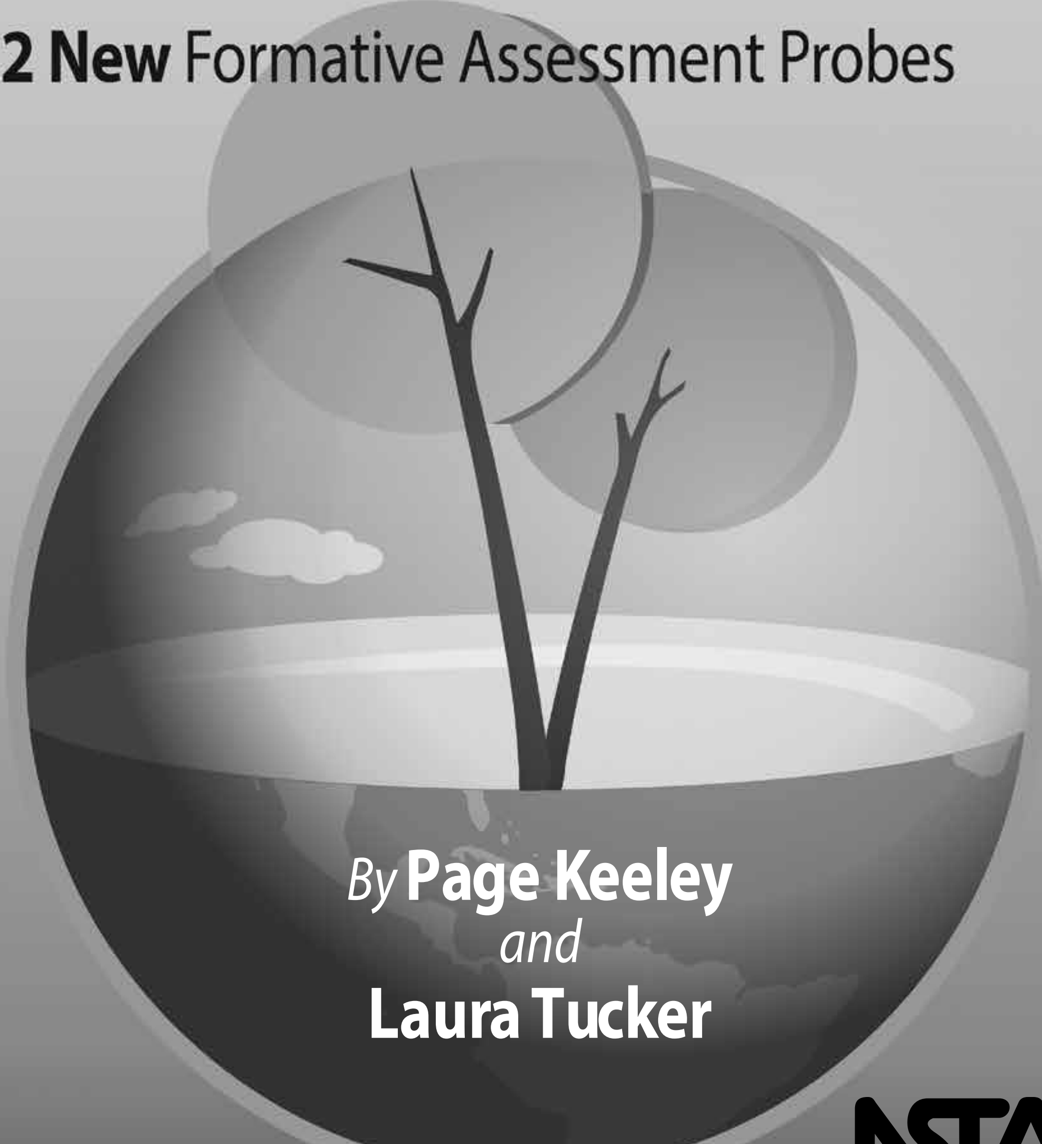

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Laura Tucker

NSTApress
National Science Teachers Association
Arlington, Virginia

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1840 Wilson Blvd., Arlington, VA 22201
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Foreword

In our efforts to use science to improve the quality of our lives, we have learned that our mental models of physical phenomena can be so deeply anchored as to effectively block learning. From the youngest age, we try to explain natural phenomena—the Sun "comes up" in the morning, the Earth casts a shadow on the Moon, rocks are stronger than plants—and we ask questions. Where do birds go at night? How does an acorn become a tree? Why is the ocean cold in sunny Los Angeles but warm in chilly Maryland? Once we have the answers, we tend to hold them fast, regardless of whether what we "learned" was correct.

Many will remember Science Media Group's 1987 video *A Private Universe.* The video revealed that some of our best-educated college students could not apply the science they had learned about familiar occurrences such as the changing seasons or phases of the Moon. The issue identified in the video and in very substantial research is that the presence of misinformation can prevent correct information from taking root. When teaching science, simply presenting the evidence for a more scientifically accurate explanation is not enough. Misconceptions must be explicitly identified to facilitate learning.

The *Uncovering Student Ideas in Science* series addresses this critically important step in science education. With her engaging volumes, Page Keeley gives teachers the tools they need to identify their students' and their own misunderstandings at the beginning of instruction. To ensure deeper learning, she follows up the accessible probes with related research and suggestions for instruction and assessment. *Uncovering Student Ideas in Earth and Environmental Science: 32 New Formative Assessment Probes* is the 10th book of the series and focuses on areas of science where we all have our own misconceptions, such as the formation of rock and soil, the processes of weather and climate, the water cycle, the saltiness of the ocean, and the history of Earth.

As you dive into these probes with your students, I encourage you to keep the importance of addressing misconceptions in mind. The Age of Enlightenment taught us that the use of evidence, logic, and reason—cornerstones of scientific investigation—influences how we understand our world. So ensuring that students have a good understanding of science is far more important than focusing on just memorizing "facts." And given the global challenges we face, science education is fundamental to our survival as a society—and maybe even as a species.

Today, we better understand that human activities impact the whole planet (an idea that many of us find hard to accept). Our role as stewards of the environment is thus more critical than the traditional environmentalist message; the habitat, if not the viability, of our species could be at stake. *Uncovering Student Ideas in Earth and Environmental Science* will help you guide your students in making science-based decisions as responsible members of society. I hope that your emphasis on right scientific thinking will lead to right environmental doing.

—David L. Evans, PhD
Executive Director
National Science Teachers Association

Reference

Harvard-Smithsonian Center for Astrophysics, Science Education Department, Science Media Group. 1987. *A private universe.* Film available at *www.learner.org/resources/series28.html.*

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Preface

This book is the 10th book in the *Uncovering Student Ideas in Science* series and the first one specifically targeting Earth and environmental science. Like its predecessors, this book provides a collection of unique questions, called formative assessment probes, designed to uncover preconceptions students bring to their learning, as well as identify misunderstandings students develop during instruction that may go unnoticed by the teacher. Each probe is carefully researched to surface commonly held ideas students have about the phenomenon or scientific concept targeted by the probe. Each probe includes one scientifically best answer, along with distracters designed to reveal common, research-identified alternative conceptions held by children and adults.

The 32 probes in this book uncover students' thinking about several of the big ideas in Earth and environmental science. Many of the probes are designed to uncover pre-existing ideas, often developed before the concept or idea is even taught. Therefore, we avoid the use of technical terminology in a probe and instead use everyday language students are familiar with in order to uncover their conceptual ideas that do not depend on knowing vocabulary. Some of the probes are intended for use after a concept or idea has been introduced, such as the collection of plate tectonic probes. For example, students may first need to learn the idea that Earth is composed of several plates before probing students' ideas about the characteristics of Earth's plates.

It is impossible to cover all Earth and environmental science ideas in one book. For this first volume in Earth and environmental science, we chose to focus primarily on ideas associated with strongly held misconceptions that follow students from one grade level to the next, often into adulthood. You may wonder why some ideas such as the rock cycle, energy in the Earth system, flow of matter and energy through ecosystems, and atmospheric ideas are not included in this book. Some of these ideas will be included in other books in the *Uncovering Student Ideas in Science* series. Energy in the Earth system will be covered as a crosscutting concept in the future book, *Uncovering Student Ideas about Matter and Energy.* For the environmental science probes, we chose to focus primarily on natural resources and human impact. Probes related to matter and energy in ecosystems and ecosystem dynamics are included in the collection of life science probes in the other books in this series. *Uncovering Student Ideas in Life Science, Volume 2,* to be released in 2017, will contain additional ecosystem-related probes.

Other *Uncovering Student Ideas in Science* Books That Include Earth and Environmental Science–Related Probes

The following is a description of the other books in the *Uncovering Student Ideas in Science* series to date (2016) that include probes related to Earth and environmental science.

Uncovering Student Ideas in Science, Volume 1 (Keeley, Eberle, and Farrin 2005): This first book in the series contains 25 formative assessment probes in life, physical, Earth, and space science. The introductory chapter of the book provides an overview of what formative assessment is and how it is used. Earth and environmental science probes in this book, along with suggested grade levels and related concepts, include the following:

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- "Wet Jeans" (grades 3–12): water cycle and evaporation
- "Beach Sand" (grades 5–12): weathering, erosion, deposition, and beach formation
- "Mountain Age" (grades 5–12): mountain formation

Uncovering Student Ideas in Science, Volume 2 (Keeley, Eberle, Tugel 2007): This second book in the series contains 25 formative assessment probes in life, physical, Earth, and space science. The introductory chapter of this book describes the link between formative assessment and instruction. Earth and environmental science probes in this book, along with suggested grade levels and related concepts, include the following:

- "Is It a Rock? Version 1" (grades 2–5): rock and rock sizes
- "Habitat Change" (grades 3–8): adaptation and habitat change
- "Is It a Rock? Version 2" (grades 3–8): concept of a rock and natural versus human-made rocks
- "Mountaintop Fossil" (grades 3–8): fossils, mountain formation, uplift, and plate tectonics
- "Giant Sequoia Tree" (grades 6–12): photosynthesis and carbon cycle

Uncovering Student Ideas in Science, Volume 3 (Keeley, Eberle, Dorsey 2008): This third book in the series contains 25 formative assessment probes in life, physical, Earth, and space science. It also contains three nature of science probes on hypotheses, theories, and how scientists do their work. The "Is It a Theory?" probe can be combined with the collection of plate tectonics probes. The introductory chapter of the book describes ways to use the probes and student work for professional learning. Earth and environmental science probes in this book, along with suggested grade levels and related concepts include the following:

- "Rainfall" (grades 3–8): rain, precipitation, and weather
- "Rotting Apple" (grades 3–8): decay and decomposers
- "What Are Clouds Made of?" (grades 3–8): clouds and water cycle
- "Where Did the Water Come From?" (grades 3–12): water cycle and condensation
- "Earth's Mass" (grades 5–12): flow of matter through ecosystems and conservation of matter

Uncovering Student Ideas in Science, Volume 4 (Keeley and Tugel 2009): This fourth book in the series contains 25 formative assessment probes in life, physical, Earth, and space science. It also includes two probes that target the crosscutting concepts of models and systems. The introductory chapter of this book describes the link between formative and summative assessment. Earth and environmental science probes in this book, along with suggested grade levels and related concepts include the following:

- "Where Does Oil Come From?" (grades 3–8): fossil fuels
- "Where Would It Fall?" (grades 3–8): land-water distribution
- "Camping Trip" (grades 5–12): Earth's warming and cooling and radiant energy
- "Global Warming" (grades 6–12): global warming and human impact

Uncovering Student Ideas in Life Science, Volume 1 (Keeley 2011b): This sixth book in the series, as well as the first one in the series of life science probes, contains 25 life science formative assessment probes. The introductory chapter of this book describes how formative assessment probes are used in a life science

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context. Environmental science probes in this book, along with suggested grade levels and related concepts include the following:

- "No More Plants" (grades 2–8): role of producers, food chains, and food webs
- "Is It a Consumer?" (grades 3–8): consumer, food web, and food chain
- "Changing Environment" (grades 5–12): adaptation and ecosystem change
- "Food Chain Energy" (grades 5–12): producers, consumers, and flow of energy
- "Ecosystem Cycles" (grades 6–12): matter cycles and energy flows

Uncovering Student Ideas in Astronomy (Keeley and Sneider 2012): This seventh book in the series contains 45 astronomy formative assessment probes. Many Earth science teachers also teach space science and can use these probes to address the space sciences section of their curriculum. The introductory chapter of this book describes how formative assessment probes are used to understand students' mental models in astronomy. In addition to the astronomy probes, probes included in this book that address students ideas about the nature of planet Earth include the following:

- "Is the Earth Really Round?" (grades 2–5): concept of a spherical Earth
- "Where Do People Live?" (grades 2–5): concept of a spherical Earth
- "Falling Through Earth" (grades 6–8): Earth's gravitational attraction

Uncovering Student Ideas in Primary Science, Volume 1 (Keeley 2013): This eighth book in the series contains 25 formative assessment probes designed for K–2 students. The probes are for early or nonreaders as well as English language learners. They can also be used in grades 3–5 to check for prior knowledge. The probes are visual in nature and designed to be used in a talk format. The introductory chapter focuses on how to use the probes to support science talk and how science talk supports students' thinking. Earth and environmental science probes in this book, along with suggested grade levels and related concepts, include the following:

- "Describing Soil" (grades K–5): soil
- "Is a Brick a Rock?" (grades K–5): rock and natural versus human-made materials
- "What Makes Up a Mountain?" (grades K–5): mountains and rock

Format of This Book

This book contains 32 probes for grades 3–12 and is organized in four sections: Section 1, "Land and Water" (7 probes); Section 2 "Water Cycle, Weather, and Climate" (8 probes); Section 3 "Earth History, Weathering and Erosion, and Plate Tectonics" (12 probes), and Section 4 "Natural Resources, Pollution, and Human Impact" (5 probes). The format is similar to the other nine volumes in the *Uncovering Student Ideas in Science* series. The introductory chapter describes how to use the probes and provides an overview of teaching and learning related to Earth and environmental science. Each section begins with a concept matrix that lists the main concepts that each probe addresses. The matrix also lists the related performance expectations from the *Next Generation Science Standards* (*NGSS*) by grade level and related National Science Teachers Association (NSTA) resources, such as journal articles, books, content webinars, and science objects. These resources provide materials for teachers who wish to extend their learning. The Teacher Notes are one of the most important components of the book and should always be read before using a probe. The following pages describe the features of the Teacher Notes that accompany each probe in this book.

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Preface

Purpose

This section describes the purpose of the probe—that is, what you will learn about your students' ideas if you use the probe. It begins by describing the overall concept the probe elicits, followed by the specific idea the probe targets. Before choosing a probe, you must understand what the probe is intended to reveal. Taking time to read the purpose will help you decide if the probe will elicit the information you need to understand your students' thinking.

Type of Probe

This section describes the format of the probe. The probes in this series use 10 different formats. Some of the more common formats are justified lists, friendly talk, and opposing views. The format of a probe is related to how a probe is used. The snapshot vignettes in the Introduction (pp. 1–10) illustrate how a format informs the use of a probe.

Related Concepts

Each probe is designed to target one or more concepts that are often used across multiple grade levels. A concept is a one-, two-, or three-word mental construct used to organize the ideas the probe addresses. Most of these concepts are included in core disciplinary ideas. The concepts are also included on the matrix charts that precede the probes for each section.

Explanation

The best answer choice is provided in this section. We use *best* answer rather than *correct* answer because the probes are not intended to pass judgment on students. Instead, they are used to encourage students to reveal their thinking without the worry of being "wrong." Sometimes there is no single "right" answer because the probe is designed to uncover different ways of thinking. The *best* answer is the one that scientifically addresses the purpose and intent of the probe.

A brief scientific explanation accompanies each probe and clarifies the scientific content that underlies the probe. The explanations are designed to help you identify what the most scientifically acceptable answers are, as well as clarify any misunderstandings about the content. The explanations are not intended to provide detailed background knowledge about the content. They are provided to support teachers' content knowledge; although in some cases, the explanations can be shared with upper middle and high school students as written. Some elementary and middle school science teachers have limited coursework or professional development in science, and some high school instructors teach Earth or environmental science outside of their science major. Therefore, the explanations are carefully written to avoid highly technical language so that you do not have to be a science specialist to understand them. At the same time, the explanations try not to oversimplify the science. Rather, they provide the concise information a science novice would need to understand the content he or she teaches related to the probe. If you need additional background information regarding the content of the probe, refer to the NSTA resources listed for each section to build or enhance your content knowledge.

Administering the Probe

Intended grade levels and suggestions are provided for administering the probe to students, including response methods, ways to use props, the way to demonstrate the probe scenario, modifications for different learners, or use of different formative assessment classroom techniques (FACTs) to gather the assessment data. FACTs are described in the Introduction on pages 3–9.

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Related Core Ideas

This section identifies the learning goals described in the two national documents used to develop the learning goals in most states' standards and curriculum materials—the revised, online version of *Benchmarks for Science Literacy* (AAAS 2009) and *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC 2012), of which the disciplinary core ideas were used to develop the *Next Generation Science Standards* (NGSS Lead States 2013). Because those are the primary source documents on which almost all state standards are or will be based after they are revised, it is important to look at the related learning goals in these documents. Because the probes are not designed as summative assessments, the listed learning goals are not to be considered alignments, but rather ideas that are related in some way to the probe. Additionally, the performance expectations related to probes in each section are listed under the concept matrices at the beginning of each section.

Core ideas across grade spans are included in this section. The ideas are included because seeing the related idea that precedes your grade level is useful when using the probe, as well as seeing the core idea that builds on the probe at the next grade level. In other words, teachers can see how the foundation they are laying relates to a spiraling progression of ideas as students move from one grade level to the next.

Related Research

Each probe is informed by related research when available. Three comprehensive research summaries commonly available to educators are the following: Chapter 15 in the *Benchmarks for Science Literacy* (AAAS 1993), Rosalind Driver's *Making Sense of Secondary Science: Research Into Students' Ideas* (Driver et al. 1994), and recent summaries in the *Atlas of Science Literacy* (AAAS 2007) were drawn on for the research summaries. In addition, recent research from science education journals is cited where available. Although many of the research citations describe studies that have been conducted in past decades and studies that include children in not only the United States but also other countries, most of the results of these studies are considered timeless and universal. Whether students develop their ideas in the United States or other countries, research indicates that many of these commonly held ideas are pervasive regardless of geographic boundaries and societal and cultural influences.

Although your students may have had different backgrounds, experiences, and contexts for learning, the descriptions from the research can help you better understand the intent of the probe and the kinds of thinking your students are likely to reveal when they respond to the probe. The research also helps you understand why the distracters are written a certain way. As you use the probes, we encourage you to seek new and additional published research, engage in your own action research to learn more about students' thinking, and share your results with other teachers to extend and build on the research summaries in the Teacher Notes. To learn more about conducting action research using the probes, read the *Science and Children* article "Formative Assessment Probes: Teachers as Classroom Researchers" (Keeley 2011b), or read Chapter 12 in the book *What Are They Thinking? Promoting Elementary Learning Through Formative Assessment* (Keeley 2014b).

Suggestions for Instruction and Assessment

Uncovering and examining the ideas children bring to their learning is considered diagnostic assessment. Diagnostic assessment becomes formative assessment when the teacher uses the assessment data to make decisions about

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instruction that will move students toward the intended learning target. Thus, for the probe to be considered a formative assessment probe, the teacher needs to think about how to design, choose, or modify a lesson or activity to best address the preconceptions students bring to their learning or the misunderstandings that might surface or develop during the learning process. As you carefully listen to and analyze your students' responses, the most important next step is to choose the instructional path that would work best in your particular context according to the learning goal, your students' ideas, the materials you have available, and the different types of learners you have in your classroom.

The suggestions provided in this section have been gathered from the wisdom of teachers, the knowledge base on effective science teaching, and research on specific strategies used to address commonly held ideas and conceptual difficulties. These suggestions are not lesson plans, but rather brief recommendations that may help you plan or modify your curriculum or instruction to help students move toward learning scientific ideas. It may be as simple as realizing that you need to provide a relevant, familiar context, or there may be a specific strategy, resource, or activity that you could use with your students.

Learning is a very complex process and most likely no single suggestion will help all students learn. But that is what formative assessment encourages—thinking carefully about the instructional strategies, resources, and experiences needed to help students learn scientific ideas. As you become more familiar with the ideas your students have and the multifaceted factors that may have contributed to their misunderstandings, you will identify additional strategies that you can use to teach for conceptual change and understanding. In addition, this section also points out other related probes in the *Uncovering Student Ideas in Science* series that can be modified or used as is to further assess students' conceptual understanding.

When applicable, the Suggestions for Instruction and Assessment section includes safety notes for the proposed activities and investigations. These guidelines need to be adopted and enforced to provide for a safer learning and teaching experience. Teachers should also review and follow local polices and protocols used within their school and school district. For additional safety information, read NSTA's "Safety in the Science Classroom" article (*www.nsta.org/pdfs/SafetyInTheScienceClassroom.pdf*) or visit the NSTA Safety Portal (*www.nsta.org/portals/safety.aspx*).

References

References are provided for the information cited in the Teacher Notes, including the original article referenced in the research summaries.

Formative Assessment Probes in the Elementary Classroom

Formative assessment is an essential feature of a learning-focused elementary science environment. To help teachers learn more about using formative assessment probes with elementary students to inform instruction and promote learning, NSTA's elementary science journal *Science and Children* publishes a monthly column by the author titled, "Formative Assessment Probes: Promoting Learning Through Assessment." Your NSTA membership provides you with access to all of those journal articles, which NSTA has archived electronically. Go to the *Science and Children* website at *www.nsta.org/elementaryschool*. Scroll down to the journal archives, and enter "formative assessment probes" in the keyword search box. This will pull up a list of all of Page Keeley's column articles. You can save the articles in your library in the NSTA Learning Center or downloaded them as a pdf.

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Table 1 lists the journal issue, title of the column, and topic of the column for the articles that have been published to date related to Earth and environmental science. Check back regularly as more articles are added. Professional developers and facilitators of professional learning communities can also use the articles to engage instructors in discussions about teaching and learning related to the probes and the content they teach. In addition, several of the articles are provided in chapter form, along with a link to the probe and discussion questions for professional learning groups in *What Are They Thinking?* (Keeley 2014b).

Table 1. Earth and Environmental Science Formative Assessment Probes: Promoting Learning Through Assessment

Issue	Title	Topic
September 2010	"Doing Science"	Scientific method and how misuse of the "scientific method" affects students' ideas related to the nature of science
December 2010	"To Hypothesize or Not"	Hypothesis making and misconceptions teachers have about the nature of science that can be passed on to students
November 2011	"Teachers as Researchers"	Biological conception of an animal and how formative assessment probes can be used to engage in teacher action research
April/May 2012	"Food for Plants: A Bridging Concept"	Understanding food, photosynthesis, needs of plants; using bridging concepts to address gaps in learning goals; and understanding students' common sense ideas
July 2012	"Where Did the Water Go?"	Using the water cycle to show how a probe can be used to link a core content idea, a scientific practice, and a crosscutting concept
December 2012	"Mountain Age: Creating Classroom Formative Assessment Profiles"	Understanding weathering and erosion and organizing student data using a classroom profile for instructional decisions and professional development
March 2013	"Habitat Change: Formative Assessment of a Cautionary Word"	Adaptation and how formative assessment helps teachers be more aware of the language they use when teaching concepts such as adaptation
April 2013	"Is It a Rock? Continuous Formative Assessment"	Concept of a rock, natural versus human-made materials, and the Group Frayer Model for continuous assessment
September 2014	"Is It a Theory? Speaking the Language of Science"	Scientific theories and how colloquial language affects our understanding of what a scientific theory is
March 2015	"Soil and Dirt: The Same or Different?"	Soil and how our use of everyday language affects understanding of science concepts
April 2015	"No More Plants!"	Understanding producers, food chains, and food webs and uncovering students' ideas about interdependency and ecosystem change
October 2015	"Wet Jeans"	Understanding evaporation and the water cycle and using real world phenomena to uncover ideas
December 2015	"Mountain Top Fossil: A Puzzling Phenomenon"	Understanding how Earth's surface changes over time using a puzzling phenomenon

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Preface

Formative Assessment Reminder

Now that you have the background on the probes and the Teacher Notes in this new book, let's not forget the formative purpose of these probes. Remember that a probe is not formative unless you use the information from the probe to modify, adapt, or change your instruction so that students have the opportunity to learn the important scientific ideas necessary for achieving scientific literacy. As a companion to this book and all the other volumes, NSTA has co-published the book *Science Formative Assessment: 75 Practical Strategies for Linking Assessment, Instruction, and Learning* (Keeley 2008, 2015) and *Science Formative Assessment: 50 More Practical Strategies for Linking Assessment, Instruction, and Learning* (Keeley 2014a). In these books, you will find a variety of strategies to use, along with the probes to facilitate elicitation, support metacognition, spark inquiry and investigation, encourage discussion, monitor progress toward conceptual change, encourage feedback, and promote self-assessment and reflection. In addition, these strategies provide opportunities for students to use scientific practices such as modeling, designing investigations, argumentation, and explanation construction.

Finally, the ultimate purpose of formative assessment is to break away from teaching and assessing disconnected facts to support conceptual learning of science. Because conceptual change is the underpinning of the *Uncovering Student Ideas in Science* series, we highly recommend the book *Teaching for Conceptual Understanding in Science,* which includes chapters on understanding the nature of students' thinking, instructional strategies that support conceptual change, and content that links assessment, instruction, and learning (Konicek-Moran and Keeley 2015).

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Dedications

Page's Dedication

I dedicate this book to Christopher Keeley. I am so proud of all the work you do at the University of New Hampshire Sea Grant program to help communities understand and adapt to climate change. I also dedicate this book to Christine Anderson-Morehouse, Jean-May Brett, and Margo Murphy—three long-time friends, colleagues, extraordinary science education leaders, and passionate environmentally concerned citizens in Maine and Louisiana who have worked with and supported me in uncovering student ideas for almost two decades. I am so proud of all the work you continue to do to support students and teachers and help others appreciate and protect the pristine beauty of my former home state of Maine and the Louisiana wetlands.

Laura's Dedication

This book is dedicated to my husband, Hank—my dear friend since 1970, who is a never-ending source of support and encouragement through all life's challenges, including book deadlines. I also dedicate this body of work to the staff and students of Exploring New Horizons and Port Townsend's Students for Sustainability for bringing such meaning to my life, enriching my soul, and serving as a source of inspiration for me every day.

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About the Authors

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 (NSF)–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-funded national projects, she has designed and directed several state projects, including TIES K–12: Teachers Integrating Engineering into Science K12 and a National Semiconductor Foundation grant project called L-SILL (Linking Science, Inquiry, and Language Literacy). She also founded and directed four cohorts of the Maine Governor's Academy for Science and Mathematics Education Leadership, which is a replica of the National Academy for Science and Mathematics Education Leadership of which she is a Cohort 1 Fellow.

Page is the author of 18 national best-selling books on formative assessment, teaching for conceptual understanding, and curriculum topic study. 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 and teach for conceptual understanding. 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, was a District II NSTA Director, and served as the 63rd President of NSTA in 2008–2009. 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 American Association for the Advancement of Science /Project 2061 Professional Development Program, and has served on several national advisory boards. She is a science education delegation leader for the People to People Citizen Ambassador Professional Programs, leading the trip to South Africa in 2009, China in 2010, India in 2012, Cuba in 2014, and Peru in 2015.

Before 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

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About the Authors

in secondary science education from the University of Maine. She currently resides in Fort Myers, Florida, where in her spare time she dabbles in nature and food photography, culinary art, and cultural travel.

Laura Tucker has been a science educator for 38 years. Initially studying to be a wildlife biologist, she found her passion in teaching students in the outdoors, founding a nonprofit educational organization in 1979 (Exploring New Horizons). The program was designed to provide a comprehensive outdoor environmental science program for K–8 grade students and a summer camp program for children ranging from age 9 to 18. During her tenure, she helped develop a variety of programs, which combined environmental science curricula (redwood, coastal, and Sierra Nevada natural history and ecology, marine biology, botany, zoology, geology, and astronomy) with music, dance, drama, art, and team building. The programs blended the teaching skills and talents of staff naturalists with classroom teachers to incorporate the outdoor school experience into the classroom. Approximately 60,000 students attended the programs while Laura was the executive director. Exploring New Horizons continues to this day, serving about 6,000 students per year on three campuses in the Santa Cruz Mountains of California.

In 1992, she became the professional development coordinator for Great Explorations in Math and Science (GEMS), a nationally acclaimed resource for activity-based science and mathematics at the Lawrence Hall of Science at the University of California, Berkeley. She worked with a variety of educators, including preservice teachers; classroom teachers; district, regional, and state curriculum coordinators; university faculty members; and nonformal educators from museums, zoos, nature centers, and so on. She was a leader in establishing the GEMS Network, which comprises approximately 72 sites and centers around the United States and 11 at international locations. Laura served as a curriculum developer and reviewer for many of the GEMS publications, including *Aquatic Habitats* (Barrett and Willard 1998), *Dry Ice Investigations* (Barber, Beals, and Bergman 1999), *River Cutters* (Sneider and Barrett 1999), and *Schoolyard Ecology* (Barrett and Willard 2001) teacher guides and the GEMS kits and handbooks for leaders, literature, and assessment.

Laura has been actively involved with NSTA and has presented short courses, preconference symposia and workshops at 22 national conferences and 14 regional conferences, including a NASA/NSTA symposium on "Successful Strategies for Involving Parents in Education." Her engaging workshops have also been featured at numerous other conferences, including at science education association meetings in California and Washington.

Laura has been focusing a great deal of her energy on climate education. In 2012, she was selected as a Climate Reality Project presenter and joined former vice president Al Gore and 1,000 educators from 59 countries for three days of intensive training. She is an NOAA Climate Steward as well as a team member with the Climate Change Environmental Education Project-Based Online Learning Community Alliance in partnership with Cornell University, the North American Association for Environmental Education, and the EECapacity Project. She serves as a mentor with Students for Sustainability, a group from Port Townsend High School that is taking action to mitigate climate change at their school, in their community, in their state, and at the national level. They received the

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Environmental Protection Agency's President's Environmental Youth Award for Region 10 in 2013. She serves on the Jefferson County/City of Port Townsend Climate Action Committee and chairs the L2020 Climate Action Outreach Group. She attended the Paris Climate Conference, COP21, in December 2015.

Currently, she wears two hats. She is the waste reduction education coordinator for Jefferson County, Washington, teaching the community to reduce, reuse, and recycle. She is also a consultant, providing custom professional development for formal and informal educational programs in hands-on, inquiry-based environmental and STEM (science, technology, engineering, and mathematics) education.

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Groundwater

Water found below Earth's surface is called groundwater. Five friends wondered what they would see if they could look underground and see groundwater. This is what they said:

Tyson: I think I would see a moving underground stream or river.

Yalena: I think I would see water in the tiny cracks and spaces between soil, sand, and rocks.

Jake: I think I would see a pool of water, sort of like an underground lake.

Betsy: I think I would see water spouting up from a vent or opening deep under the ground.

Armando: I think I would see chunks of ice that slowly melt and release water.

Who do you agree with the most? ______________________ Explain your thinking.

____

____

____

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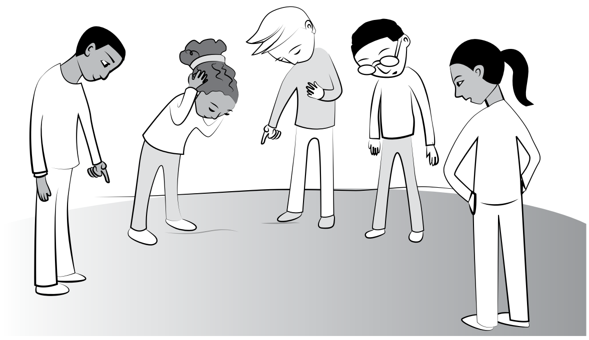
Groundwater

Teacher Notes



Purpose
The purpose of this assessment probe is to elicit students' ideas about a major freshwater resource, groundwater. The probe is designed to find out how students visualize groundwater.

Type of Probe
Friendly talk

Related Concepts
Aquifer, fresh water, groundwater

Explanation
The best answer is Yalena's: "I think I would see water in the tiny cracks and spaces between soil, sand, and rocks." Groundwater is water found below the surface of Earth. It is the major source of water for drinking and agriculture. Groundwater is found in the pores, cracks, and spaces between earth material such as soil, fractured rock, gravel, and sand. It moves slowly through a formation called an *aquifer*.

Administering the Probe
This probe is best used with upper elementary, middle, and high school students. The probe can be extended by asking students to draw a conceptual model showing what they think groundwater looks like from a cross-sectional view below Earth's surface.

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

6–8 The Earth

- Water evaporates from the surface of the Earth, rises and cools, condenses into rain or snow, and falls again to the surface. The water falling on land collects in rivers and lakes, soil, and porous layers of rock, and much of it flows back into the oceans.

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

3–5 ESS2.C: The Role of Water in Earth's Surface Processes

- Nearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere.

Related Research

- A common misconception of both students and teachers is that water under the ground flows in river-like systems or in large underground lake-like reservoirs. Students who think this sometimes assume that wells will provide water forever because they are filled by underground rivers. The scale of the spaces water fills also varies from micro to macro, with some older students thinking that groundwater fills spaces the size and depth of skyscrapers. (Dickerson et al. 2007).
- The common misconception that groundwater is like an underground lake may come from the level of abstraction that is needed to understand hidden phenomena and processes that take place underground. Research indicates that students' mental model of groundwater as a static sub-surface lake results from their actual experience with the upper water system (Ben-zvi-Assarf and Orion 2005).

Suggestions for Instruction and Assessment

- Use a sponge to represent how water falling on the surface of Earth seeps into the ground and fills empty spaces. The sponge and water model the porous rock, soil, and sand and the empty spaces between the earth material. (Safety note: Immediately wipe up any spilled water to avoid slips and falls.)
- Student and teacher information about groundwater can be found on the Groundwater Foundation's website at *http://groundwater.org*.
- Visualizing groundwater can be challenging for students, as it is very different from water resources they see on the surface of Earth. Have students draw a conceptual model of the form and location of groundwater.
- A video of sixth graders discussing their ideas about groundwater (including misconceptions) can be viewed at *http://education.nationalgeographic.com/media/what-groundwater*.
- Water cycle diagrams may interfere with students' understanding of groundwater as part of the water cycle because many water cycle diagrams show only surface water. Use water cycle diagrams that also show groundwater or have students create water cycle diagrams that include groundwater as part of the cycle.
- Include the use of rock specimens when teaching about groundwater. Students can examine rocks to observe differences between rock types found in aquifers. (Safety note: Instruct students to handle rock specimens cautiously because some rocks may have sharp edges that can cut skin.)

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