VOL. 4

Uncovering Student Ideas in Science

25 NEW Formative Assessment Probes

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25 NEW Formative Assessment Probes

By Page Keeley
and Joyce Tugel

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Contents

Preface ix

Acknowledgments xvii

About the Authors xix

Introduction 1

Physical Science and Unifying Themes Assessment Probes

Concept Matrix 10
1 Sugar Water 11
2 Iron Bar 17
3 Burning Paper 23
4 Nails in a Jar 31
5 Salt Crystals 39
6 Ice Water 45
7 Warming Water 53
8 Standing on One Foot 61
9 Magnets in Water 67
10 Is It a Model? 73
11 Is It a System? 81

Life, Earth, and Space Science Assessment Probes

Concept Matrix 90
12 Is It Food? 91
13 Biological Evolution 99

14 **Chicken Eggs** 105

15 **Adaptation** 113

16 **Is It "Fitter"?** 119

17 **Catching a Cold** 125

18 **Digestive System** 131

19 **Camping Trip** 137

20 **Global Warming** 143

21 **Where Does Oil Come From?** 151

22 **Where Would It Fall?** 157

23 **Moonlight** 161

24 **Lunar Eclipse** 167

25 **Solar Eclipse** 173

Index 179

Dedication

This book is dedicated to Dr. Richard Konicek-Moran, professor emeritus at the University of Massachusetts-Amherst, for his 50 years of service to the science community in raising awareness of the importance of students' conceptions; to his wife, Kathleen, a botanist and botanical illustrator extraordinaire; and to Dr. Bob Barkman, our "Earth Is (Not) Flat" friend and colleague. Who would have predicted that a phone call made years ago to inquire about the "probes" would have led to such a rewarding partnership and cherished friendship among the authors and these three individuals who have inspired us in our work.

Preface

This book is the fourth in the highly successful *Uncovering Student Ideas in Science* series. The addition of 25 more formative assessment probes has now expanded the collection to a total of 100 science elicitation questions that provide teachers with insights into student thinking seldom revealed through standard science assessment questions. In this book, a new addition to the Earth, space, physical, and life science probes is the inclusion of two probes that target important unifying themes in science models and systems. Collectively, these 100 probes focus on important fundamental ideas in science that cut across multiple grade spans.

Regardless of whether you teach elementary, middle, or high school science, students' preconceptions can be tenacious and often follow students from one grade span to the next. Taking the time to elicit and examine student thinking is one of the most effective ways to support instruction that leads to conceptual change and enduring understanding. It is also the starting point for differentiating instruction to meet the content needs of all students.

Since Volume 1 was released in October 2005, Volume 2 in 2007, and Volume 3 in 2008, thousands of K–12 teachers, university faculty, and professional developers have used these probes to bring to the surface the ideas students and teachers have that they might not even be aware of. The response to these probes has been very encouraging. Teachers have frequently remarked to us that they now know much more about their students and student learning. They also report that the probes have significantly changed their instruction as well as their classroom environments. Teachers spend more time letting their students do the talking, listening carefully to their ideas, and constantly thinking about the next steps they need to take to move their students from where they are to where they need to go in order to develop conceptual understanding. Old habits, such as the need to grade every piece of student work or acknowledge only right answers, have changed to allow students the opportunity to express their thinking safely—that is, in classroom cultures that welcome and value new ideas.

Not only are teachers using the probes to elicit students' ideas and inform their instructional practices, but teachers are also using the probes to transform their own learning. In our work at the Maine Mathematics and Science Alliance, we provide professional development to many school districts, math-science partnership projects, and other teacher enhancement initiatives throughout the United States that use these probes in their teacher professional development programs. The insights we have gained from working with teachers show that the probes have challenged teachers' own thinking about ideas in science, brought to the

Preface

surface long-held misconceptions that many teachers were unaware they held, and revealed how some instructional activities and methods can lead to reinforcing common misconceptions without teachers realizing it. In addition, the Teacher Notes that follow each probe have increased teachers' ability to see the link among key ideas in the standards, developmentally appropriate instruction, students' commonly held ideas, and strategies for addressing students' ideas. All of this information gained from using the probes has led to profound changes in teachers' content knowledge, pedagogy, and beliefs about how students learn science.

In Volume 4, we decided to focus on ways to balance formative assessments with summative assessments (e.g., classroom-based, district, and state assessments) because of the widespread interest in this balancing challenge. We believe it is important to distinguish between these two types of assessment, recognize the link between them, and stay true to the purposes of each.

As the interest in formative assessment has skyrocketed and has become more prominent in local, state, and national efforts to improve science learning, the term *formative assessment* is being "hijacked" in the name of more practice for test taking. Publishers market sets of drill questions to prepare students for standardized tests and call them formative assessments. These questions are nothing more than a wolf in sheep's clothing. You can dress the wolf up in a sheepskin so it looks like a sheep, but underneath it still behaves like a wolf. Likewise, you can package test preparation questions as "formative assessments," but underneath they are nothing more than questions limited in scope and depth that diminish quality instructional time and do little to promote learning and enduring understanding.

While you are probably most interested in using the 25 probes provided in this book, don't overlook the Introduction (pp 1–8) or the introductions in Volumes 1–3. Each introduction will expand your understanding of formative assessment and its inextricable link to instruction and learning. Volume 1 gives an overview of formative assessment. It also provides background on probes as specific types of formative assessments and how they are developed. Volume 2 describes the link between formative assessment and instruction and suggests ways to embed the probes into your teaching. Volume 3 describes how you can use the probes and student work to deepen your understanding of teaching and learning. This volume (Volume 4) describes the relationship between formative assessment and summative assessment. Collectively, the introductions in all four volumes will increase your assessment literacy and instructional repertoire. In addition, they will deepen your understanding of effective science teaching and learning.

The Teacher Notes that accompany each probe are made up of the following 10 elements.

Purpose

This section describes the general concept or topic targeted by the probe and the specific idea that is being elicited. It is important to be clear as to what the probe is going to reveal.

Being clear about the purpose of the probe will help you decide if the probe fits your intended learning target.

Related Concepts

Each probe is designed to target one or more related concepts that cut across grade spans. These concepts are described in the Teacher Notes and are also included on the matrix charts on pages 10 and 90. A single concept may be addressed by multiple probes. You may find it useful to use a cluster of probes to target a concept or specific ideas within a concept. For example, there are three probes in this volume that target the concept of natural selection.

Explanation

A brief scientific explanation, reviewed by scientists and content specialists, accompanies each probe and provides clarification of the scientific content that underlies the probe. The explanations are designed to help you identify acceptable or "best" answers (sometimes there is no "right" answer) and to clarify any misunderstandings you might have about the content. The explanations are not intended to provide detailed background knowledge on the concept, but they do provide enough explanation to connect the idea(s) in the probe with the science concept it is based on. If you need further explanation of the content, the Teacher Notes also list NSTA resources, such as the series *Stop Faking It! Finally Understanding Science So You Can Teach It* or Science Objects in the NSTA Learning Center, that will enhance and extend your understanding of the content.

Curricular and Instructional Considerations

The probes in this book do not target a single grade level as summative assessments do. Rather, they provide insights into the knowledge and thinking your own students may have regarding a topic as they developmentally progress or move from one grade span to the next. Some of the probes can be used in grades K–12 while others may cross over just a few grade levels. Teachers from two grade spans (e.g., elementary and middle school) might decide to use the same probe and come together and discuss their findings. To do this it is helpful to have insight into what students typically experience at a given grade span as it relates to the ideas elicited by the probe. Because the probes do not prescribe a specific grade level for use, you are encouraged to read the curricular and instructional considerations and decide if your students have had sufficient experience and the readiness to make the probe useful.

The Teacher Notes also describe how the information gleaned from the probe is useful at a given grade span. For example, it might be useful for planning instruction when an idea in the probe is a grade-level expectation or it might be useful at a later grade to find out whether students have sufficient prior knowledge to move on to the next level. Sometimes the student learning data gained through use of the probe indicate that you might have to back up several grade levels to teach ideas that are not really clear to students.

We deliberately chose not to suggest a grade level for each probe. If the probes were intended to be used for summative purposes, a grade level, aligned with a standard, would be suggested. However, these probes have a different purpose. Do you want to know more about the ideas your students are expected to learn in your grade-level standards? Are you interested in how preconceived ideas develop and change across multiple grade levels in your school, sometimes even before they are formally taught? Are you interested in whether students have acquired a scientific understanding of previous grade-level ideas before you introduce higher-level concepts? The descriptions of grade-level considerations in this section can be coupled with the section that lists related ideas in the national standards in order to make the best judgment about grade-level use.

Administering the Probe

In this section, we suggest ways to administer the probe to students, including a variety of modifications that may make the probe more useful at certain grade spans. For example, we might recommend eliminating certain examples from a justified list for younger students who may not be familiar with particular words or examples or adding more sophisticated examples for older students. The notes also include suggestions for demonstrating the probe context with artifacts or ways to elicit the probe responses while students interact within a group. This section often refers to techniques described in *Science Formative Assessment: 75 Practical Strategies for Linking Assessment, Instruction, and Learning* (Keeley 2008) that move the probes beyond paper-and-pencil tasks to interactive classroom strategies.

Related Ideas in the National Standards

This section lists the learning goals stated in the two national documents generally considered the "national standards": *Benchmarks for Science Literacy* (AAAS 1993) and *National Science Education Standards* (NRC 1996). Because the probes are not designed as summative assessments, the learning goals listed from these two documents are not intended to be considered as alignments but rather as related ideas connected to the probe. Some targeted ideas, such as a student's conception of the difference between weight and pressure, as seen in the probe "Standing on One Foot" on page 61, are not explicitly stated as learning goals in the standards but are clearly related to national standards concepts that address specific ideas about forces. When the ideas elicited by a probe appear to be a strong match with a national standard's learning goal, these matches are indicated by a star symbol (★).

Related Research

Each probe is informed by related research when it is readily available. Because the probes were not designed primarily for research purposes, an exhaustive literature search was not conducted as part of the development process. We drew primarily on three comprehensive research summaries commonly available to educators: Chapter 15 in *Benchmarks for Science Literacy* (AAAS 1993), *Making Sense of Secondary Science: Research Into Children's*

Ideas (Driver at al. 1994), and the research notes in the *Atlas of Science Literacy, Volume 2* (AAAS 2007). Although the first two resources describe studies that have been conducted in past decades and involved children not only in the United States but in other countries as well, many of the results of these studies are considered timeless and universal. Many of the ideas students held that were uncovered in the 1980s and 1990s research still apply today.

It is important to recognize that geography and cultural and societal contexts can influence students' thinking, but research also indicates that many of the ideas students have are pervasive regardless of geographic boundaries and societal and cultural influences. Hence the descriptions from the research can help you better understand the intent of the probe and the variety of responses your students are likely to have. As you use the probes, you are encouraged to seek new and additional research findings. One source of updated research can be found on the Curriculum Topic Study (CTS) website at *www.curriculumtopicstudy.org.* A searchable database on this site links each of the CTS topics to additional research articles and resources.

Suggestions for Instruction and Assessment

After analyzing your students' responses, it is up to you to decide on appropriate interventions and instructional strategies for your students. We have included suggestions gathered from the wisdom of teachers, the knowledge base on effective science teaching, and our own collective experience as former teachers and specialists involved in science education. These are not exhaustive or prescribed lists but rather suggestions that may help you modify your curriculum or instruction in order to help students learn ideas that they may be struggling with. It may be as simple as realizing that you need to be careful how you use a particular word in science. Learning is a very complex process and most likely no single suggestion will help all students learn the science ideas. But that is part of what formative assessment encourages—thinking carefully about the variety of instructional strategies 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.

Related NSTA Science Store Publications, NSTA Journal Articles, NSTA SciGuides, NSTA SciPacks, and NSTA Science Objects

NSTA's journals, books, SciGuides, SciPacks, and Science Objects are increasingly targeting the ideas students bring to their learning. We have provided suggestions for additional readings that complement or extend the use of the individual probes and the background information that accompanies them. For example, Bill Robertson's *Stop Faking It!* series of books may be helpful in clarifying concepts teachers struggle with. A journal article from one of NSTA's elementary, middle school, or high school journals may provide additional insight into students' misconceptions or provide an example of an effective instructional strategy or activity that can be used to develop understanding of the ideas targeted by a probe. Other resources listed in this section provide a more comprehensive overview of the topic addressed by the probe.

Related Curriculum Topic Study Guides and References

NSTA is copublisher of the book *Science Curriculum Topic Study: Bridging the Gap Between Standards and Practice* (Keeley 2005). This book was developed as a professional development resource for teachers with funding from the National Science Foundation and is available through NSTA Press. It provides a set of 147 curriculum topic study (CTS) guides that can be used to learn more about a science topic's content, examine instructional implications, identify specific learning goals and scientific ideas, examine the research on student learning, consider connections to other topics, examine the coherency of ideas that build over time, and link understandings to state and district standards. The CTS guides use national standards and research in a systematic process that deepens teachers' understanding of the topics they teach.

The CTS guides that were used in the development of the probes in this book are listed before each reference list. Teachers who wish to delve deeper into the standards and research-based findings that were used to develop the probes may wish to use the CTS guides for further information.

In addition, Chapter 4 in the CTS book describes the process for developing an assessment probe that links standards and research on learning. Teacher educators, assessment developers, and others who want to engage groups in developing their own assessment probes will find professional development materials in *A Leader's Guide to Science Curriculum Topic Study: Designs, Tools, and Resources for Professional Learning* (Mundry, Keeley, and Landel 2009).

References are provided for the standards and research findings cited in the Teacher Notes.

We hope this fourth volume of probes will be as useful to you as the other three volumes. If the interest continues in the *Uncovering Student Ideas in Science* series, we will continue to produce new books and assessment tools. If there are particular ideas you would like to see targeted in future volumes of *Uncovering Student Ideas in Science*, please contact the primary author of the series, Page Keeley, at *pagekeeley@gmail.com* or *pkeeley@mmsa.org*. Beginning in the spring of 2009, visit the Uncovering Student Ideas website—http://*uncoveringstudentideas.org*—where the author shares new information and updates related to assessment probes and maintains a blog on formative assessment in science.

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About the Authors

Page Keeley is the primary author and assessment probe developer of the *Uncovering Student Ideas in Science* series. She is the senior science program director at the Maine Mathematics and Science Alliance, where she has worked since 1996 developing and leading various leadership and professional development initiatives and projects in New England and nationally. Page consults with school districts, math-science partnership programs, and various initiatives throughout the United States in the areas of formative assessment, leadership, curriculum topic study (CTS), coaching and mentoring, and conceptual change instruction and is a frequent speaker at national conferences. She has authored numerous books on formative assessment and curriculum leadership and served as principal investigator and project director of three National Science Foundation grants, *Science Curriculum Topic Study: A Systematic Approach to Utilizing National Standards and Cognitive Research; The Northern New England Co-Mentoring Network;* and *PRISMS: Phenomena and Representations for Instruction of Science in Middle Schools*. Page is a former high school and middle school teacher and received the Presidential Award for Excellence in Secondary Science Teaching in 1992 and a Milken National Educator Award in 1993. In addition, Page Keeley is the 2008–2009 president of the National Science Teachers Association.

Joyce Tugel is a coauthor of two books in the *Uncovering Student Ideas in Science* series. She has been a science specialist at the Maine Mathematics and Science Alliance since 2005, where she directs projects in professional development, conceptual change teaching, environmental literacy, and engineering design. She is the project director of four Maine State Math-Science Partnership grants and a National Oceanic and Atmospheric Administration–funded tri-state environmental literacy project called Earth as a System is Essential: Seasons and the Seas. Joyce consults with school districts and organizations throughout the United States in professional development related to science curriculum, instruction, and assessment. Joyce has worked as a high school chemistry teacher and as a researcher in microbial biogeochemistry. She received the Presidential Award for Excellence in Secondary Science Teaching in 1998, a Milken National Educator Award in 1999, and the New England Institute of Chemists Secondary Teaching Award in 1999. Joyce is a former NSTA Division Director for Professional Development.

Introduction

When teachers are asked how they assess their students, they typically talk about tests, examinations, quizzes, and other formal methods. When they are asked how they know whether their students have learned what they have taught, the answers are very different.

—Dylan Wiliam, *Assessing Science Learning* (2008, p. 6)

Our districtwide K–12 science team came back from a National Science Teachers Association conference last spring all fired up. We had gone to a session on formative assessment and learned about the *Uncovering Student Ideas in Science* series of assessment probes and a variety of science formative assessment classroom techniques (FACTs) we could use with the probes. The presenter started the session by asking us to call out the first word that came to mind when we heard the word *assessment*. In unison, most of the people in the room called out "testing!" As the presenter then pointed out, *assessment,* and particularly formative assessment, is not necessarily about testing; it is about what you can do to improve learning and, ultimately, get better test results.

During the session, we, as learners, used the probes and the FACTs and came to realize how powerful they are. We had heard the phrase *assessment* ***for*** *learning* before, and for the first time, we felt we really knew what it meant. The speaker talked about the importance of using assessments like the probes and FACTs to create a balanced system of assessment that provides useful information at the beginning of instruction to promote thinking and inform instruction. This "front-end" assessment leads to better results at the "back end," when students are tested on what they have learned.

This approach to assessment started to make sense to us. All the concepts and ideas from the practice tests our students were taking to prepare for the state assessment were quickly forgotten by the students, even when it came time to take the test. We knew drilling with sample test questions wasn't the best solution for raising test scores, but we had always hoped it would help a little. We now realized that maybe formative assessment was what we needed to do more of at the beginning and throughout a lesson so that students—rather than memorize a lot of discrete facts—would have an opportunity to confront and work through their ideas before taking a test. After all, science is different from other subjects—it's about ideas that explain the natural world and processes that help us make sense of that world.

Many of the people in the audience had been using the probes and shared their stories. We connected with several folks from districts like ours and got all kinds of good ideas about how to use these tools to improve student learning and teacher practice. Before we left the conference we went to the NSTA bookstore and bought copies of the *Uncovering Student Ideas in Science* series. We started reading them on the plane ride home. We couldn't stop talking about them and our ideas for using them! We felt we had finally found a solution to the struggles we face in our district in balancing accountability and reporting with students' opportunity to learn.

Teaching and assessing for understanding aren't about more teaching, more materials, and more testing; they are about more opportunities to learn by promoting thinking and bringing students' ideas to the surface. Here was a set of assessments already developed for us to use with links to the key ideas in the standards, descriptions of the research that the probe was based on, and suggestions for things to do in the classroom to help students learn. These assessments would save us months of work that might have been spent developing our own formative assessments.

When we got back to our district we shared what we had learned in our grade-level teams with teachers and administrators. We argued over what *formative assessment* really meant and whether our current practices were consistent with what the research describes as good assessment practice. We all decided we wanted to move beyond practice for test taking and deadly drill sessions. Our superintendent surprised us with her enthusiasm and her offer to provide funding to support stipends and copies of the series for after-school professional learning communities. These groups would come together and study this new assessment technique, try it out in the classroom, examine student results, and report back.

After several months of exploring the theory and practice of formative assessment in collaborative groups, the broad consensus of our learning communities was that formative assessment worked! Students were more engaged in learning science, they began to write more extensively and to converse scientifically about their ideas, and they took more ownership in the learning process. Their explanations became much richer and we knew better how to then tailor learning to address the students where they were, rather than where our textbook and pacing guide said they should be. Our classroom questioning had changed from an ongoing monologue back and forth between the teacher and students to one in which there was rich dialogue among students working together with guidance from us in resolving their ideas. All students were involved and felt safe to share their thinking.

As we tried out formative assessment, we also looked at our summative assessments. We quickly found that released items from prior state assessments, our district-developed standardized tests, and even our own classroom tests did not give us the kind of data we needed to know exactly what the students' learning problems were. We knew our students weren't doing well in some areas such as matter and energy interactions or Earth systems, but we didn't know exactly what the learning problems were until we used the formative assessment probes as well as other new teaching strategies that probe students' thinking.

We decided to match up the probes with the assessment reporting categories aligned to our state standards, administer the probes across grade levels, analyze the results, and match the results to our district test data. Lo and behold, we found that the problem areas for tenth graders weren't much different from the problems of our middle school and elementary students.

Good data about student learning are at the core of improvement in student achievement. We began to use the Collaborative Inquiry into Examining Student Thinking (CIEST) protocol to look at student work from the probes (Mundry, Keeley, and Landel 2009). The probes revealed not only information we could use to inform our instruction but also a lot about the gaps in our K–12 curriculum that were affecting learning from one grade level to the next. No wonder certain problems continued after the fourth-grade test and the eighth-grade test. As a district, we had never collected the rich kind of formative data that could be used to pinpoint what the learning problems were, how they originated, and why they persisted from one grade to the next. Instead of looking at test scores—a single snapshot in time—and saying we needed to reteach the same material, we could now see just what we needed to focus on better. And just as important, our students began to experience the conceptual change that happens when they realize that their preconceptions no longer make sense to them and they start to construct new explanations.

Now we use the probes to try to improve the quality of our district assessments, and we look for evidence that students understand key ideas in science that may have been riddled with misconceptions in the past. We match our summative data to our formative data and identify patterns and discrepancies. *Accountability* isn't such a scary word anymore. We now have the right tools and processes to take the guesswork out of assessment and ensure that our students are ready to "show what they know."

As for the future, although we realize that not all of our students are going to leave our district with plans to be scientists, the chances are now much better that they will leave being science literate, ready to use their knowledge and skills to understand real-world issues and problems that require an understanding of the basic principles of science.

The above vignette is a composite account, drawn from the many stories we have heard from science educators who are using the *Uncovering Student Ideas in Science* series. It shows how formative assessment can provide valuable information to teachers and students to promote learning and inform instruction, creating a more balanced system of assessment that does not overly rely on summative assessment. Assessment isn't only about testing, and this book is not about assessments that are graded and then used to pass judgment on students about the extent to which they have achieved a learning goal. This book is about using a type of assessment, called a *probe*, for diagnostic and formative purposes.

The probes are selected-response items specifically designed to reveal student misconceptions that the research literature on student learning has documented. Throughout this book and the other three books in the series, we use the word *misconception* in a general way to refer to the ideas students bring to their learning that are not yet fully formed and not scientifically correct at the level we would expect. Other words to describe students' ideas include *preconceptions, naive ideas, partially formed ideas, facets of understanding,* and *alternative conceptions*. Although teachers tend to use the word *misconception* in a pejorative way to describe students' ideas that are not the same as the scientific ideas we want them to understand, misconceptions can be useful if we use them to build a bridge between where students are in their thinking and where we eventually want them to be.

The assessment probes in this book are designed to help teachers build that bridge. The bridge begins with finding out what students think about important ideas in science that they will use throughout their learning. Although the probes were written primarily to target a K–12 student audience, they can be used with adult learners as well, including university students and science teachers participating in professional development. The previous three volumes provided background information for teachers on formative assessment. We encourage you to collect all the books in the series and read the introductory material to expand your understanding of assessment and its role in teaching, learning, and professional development.

In addition to the 25 probes in each volume, Volume 1 contains an overview of formative assessment—what it is and how it is used. Volume 2 introduces ways to integrate assessment with instruction, and Volume 3 provides an introduction to using the probes, including in professional learning communities. Because we often get the question "But what about testing?"—by which teachers generally mean summative assessment—in the introduction we address the link between formative and summative assessment.

Summative assessment is a pervasive topic that includes everything from statewide accountability tests, to local assessments and district benchmark tests, to everyday classroom tests. To grapple with what seems to be an overuse of graded quizzes and testing, educators need to change their view of assessment to one that is about information. The more information we have about students, from both summative and formative assessments, the clearer the picture we have about student learning.

It is important to remember that these probes are used to elicit students' ideas, engage students in discussion about their ideas, and monitor how students' conceptions are changing throughout instruction. They are not intended to be graded. Once you pass judgment on the student with a grade, research shows that the student's learning often shuts down (Black et al. 2003). Use these probes to gather information about your students and motivate them to open up and share their ideas. Grading a formative assessment often does the opposite. When low achievers get back their papers with low scores, the message is, "You are not good enough," and their desire to learn fades. Likewise a good grade also shuts down students' thinking. As long as students see a passing grade, they often ignore the teachers' comments that may indicate ways to improve their work or challenge them to think further. If we are going to use formative assessment effectively, and distinguish it from summative assessment, it is important to get over the pervasive habit of grading every piece of work. Although there are times when it is important to grade work, the probes are not intended for that purpose.

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

But what about the third type, diagnostic assessment? Diagnostic assessment is used to uncover a misconception or learning difficulty. When used just for this purpose, it is diagnostic. However, diagnostic assessment becomes formative when the information revealed by the assessment is applied to a situation. Another way to look at the three types and their purposes is to use an analogy.

Have you ever watched the Fox television medical drama *House*? Dr. House is a curmudgeonly medical genius who works with an accomplished group of medical diagnosticians who assess a variety of mysterious illnesses in a teaching hospital. What Dr. House does is very similar to what a teacher does when using the probes. Dr. House and his team collect a variety of data to diagnose an illness a patient has. They often use medical probes to look into the body and see things they would not ordinarily be able to see. The data reveal to Dr. House and his team the cause of the illness. Similarly, the teachers' use of the probes uncovers a variety of problems that may not be obvious to other practitioners who do not have the right tools or deep understandings about student learning.

Naturally, Dr. House and his team do not stop with the diagnosis. They want the patient to get better, so they prescribe the best course of treatment that will take care of the medical problem. The treatment is informed by the diagnosis and any additional data on the patient's condition. Dr. House and his team closely monitor the patient for improvement. In educational assessment, this would be the formative assessment—moving beyond the diagnosis to inform the instructional strategies and direction a teacher will use to help students with their learning problems and achieve conceptual understanding.

At the end of a course of treatment, the patient often comes back for a follow-up checkup to see if he or she is cured. This usually happens after the treatment has ended. In education, summative assessment is usually given after a sequence of instruction or at the end of a course to find out how well a student has learned.

Of course, science assessment is not a life or death decision-making process, and today's teachers would not communicate with their students in the way Dr. House abruptly confronts his patients. Teachers' assessments, however, do involve carefully made choices that have a potentially huge impact on student learning. Assessment is not about just testing anymore, and practicing for test taking may not lead to constructive changes in the classroom. Relying on external test results doesn't help much to improve learning in the immediate sense. Traditionally, summative assessments have not helped teachers adjust instruction for individual students because it takes too long for the data to be returned to schools. Formative assessment, such as the probes in this book, can be used on a regular basis to monitor student progress and modify instruction when it is needed.

Teachers and schools are now looking at classroom assessment more closely and at how to best improve teaching and learning so that the assessments we give at the end of a unit or at the end of a year are better matched to what students have been learning, not what they memorized for a test. By linking diagnostic and formative assessments, such as the probes in this book, to the standards being assessed on summative assessments, teachers get a better picture of what they need to do to move students toward the development of conceptual understanding so that students can be successful on summative assessments.

As depicted in the vignette at the beginning of this introduction, some schools are beginning to shift away from a rigid accountability system and move toward the use of more assessments, such as the ones in this book, that look at the whole picture of student learning. When teachers and districts begin to align these formative assessments with the standards assessed on summative assessments, the student data from these probes can provide powerful predictors of readiness for summative assessment. When teachers design their summative assessments with the standards in mind and a picture of what success is, they can use the assessment probes prior to and throughout instruction to monitor how well students are moving toward the learning targets—and adjust their teaching accordingly. As students become more metacognitive about what they know, think they know, and do not know, they take more responsibility for their learning, which eventually improves their performance on measures of achievement.

As a noted superintendent once succinctly said, "Schools are data rich and information poor" (DuFour, Dufour, and Eaker 2005 p. 40). We hope that the probes in this book will uncover information about your students' thinking that will provide a gold mine of useful data for your classroom and for the improvement of your school's science program. Forging a stronger link between formative and summative assessment will create a better assessment balance and lead to your desired results. Are the desired results improved test scores? They may be the "trees" you are looking at, but the real aim is to look through the trees to see the whole forest. In that forest is the "big picture" of learning that will produce science-literate adults. As you use these probes, remember to look beyond the trees and into the forest!

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Catching a Cold

Have you ever been sick with a cold? People have different ideas about what causes a cold. Check off the things that cause you to "catch a cold."

___ having a fever

___ being wet

___ being wet and cold

___ germs

___ spoiled food

___ not getting enough sleep

___ lack of exercise

___ cold weather

___ dry air

___ imbalance of body fluids

Explain your thinking. Describe how people "catch a cold."

____

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Catching a Cold

Teacher Notes

Purpose

The purpose of this assessment probe is to elicit students' ideas about infectious disease. The probe is designed to find out whether students use the germ theory to explain what causes an infectious disease like the common cold.

Related Concepts

common cold, germ theory, infectious disease

Explanation

The best answer is "germs." The common cold is an infectious disease caused by a virus and transmitted between two people—one who is contagious and one who picks up the contagion (virus). The *cause* is the virus (germs), *transmission* is how it is spread, and other factors contribute to a weakened immune system that is less effective in fighting off the virus in the human body. The virus is transmitted through respiratory secretions. The virus can be picked up by breathing in the virus when it is spread in an aerosol form generated by the sick person's coughing or sneezing. It can also be picked up from direct contact with saliva or nasal secretions containing the virus as well as indirectly from surfaces that have been contaminated by a person's saliva, respiratory aerosols, or nasal secretions. This is why hand washing is so important. Most cold germs are picked up by touching contaminated surfaces and transferring the virus from an object to the mouth. In all of these cases of transmission, what causes the cold is the virus.

A fever is a physiological response to the virus, not a cause. Feeling cold and chilled, being wet, being wet and cold, and not getting enough sleep or exercise are all factors that can contribute to a weakened immune system that is less effective in fighting off the virus as it multiplies inside the body's cells. These factors that lower resistance are not the actual cause of a cold. For example, one does not catch a cold merely by being wet and cold. A virus must enter the body in order to cause a cold. Food spoils as a result of bacterial growth and results in a bacterial infection that causes gastrointestinal problems, not a common cold.

Although colds occur more often in the winter months, the cold weather itself does not cause the common cold. During cold weather months, people spend more time inside in close proximity to each other, thus spreading the virus more easily. Also the hot, dry air that results from heating during the wintertime dries out the mucus membranes of the throat and nose and makes them less effective barriers against infection by the common cold virus.

Curricular and Instructional Considerations

Elementary Students

In the elementary grades, students should have a variety of experiences that provide initial understandings of various science-related personal and societal health challenges (NRC 1996). Children at this age use the word *germs* for all microbes, as they may not yet be ready to distinguish between bacteria and viruses. They develop an understanding of good health factors, such as nutrition, exercise, keeping warm and dry, and sleep, but they have difficulty distinguishing between the factors that promote good health in general and the causes of infectious diseases. At this stage they should be taught how communicable diseases such as colds are transmitted, and the reason for hand washing should be explained, reinforced, and practiced in school and at home. Later in the elementary grades, students begin to learn about some of the body's defense mechanisms that prevent or overcome infectious diseases such as colds.

Middle School Students

In the middle grades, students build upon their K–4 understandings of health and disease to recognize the role of microorganisms in causing illness. This is a good time to introduce the germ theory of diseases from the historical perspective of Louis Pasteur's discovery and to discuss how technology (microscopes) has made germs visible.

High School Students

By high school, students have a fairly solid foundation in understanding human body systems such as the digestive, circulatory, and respiratory systems and recognize viruses as agents of infection. However, they may not have as clear an understanding of the immune system and thus have difficulty with understanding mechanisms and processes associated with infectious diseases.

Administering the Probe

This probe is appropriate at all grade levels. The last distracter on the list—"imbalance of body fluids"—comes from a predominant historical belief that subsequently led people to treat illness by inducing vomiting, bleeding, or purging in order to adjust body fluids. As this phrase may be unfamiliar to younger students, consider eliminating it from the list when used with younger children. For older students who can distinguish between different types of microbes, you might consider deleting "germs" and adding two responses—"viruses" and "bacteria."

Related Ideas in *National Science Education Standards* (NRC 1996)

K–4 Personal Health

★ Individuals have some responsibility for their own health. Students should engage in personal habits—dental hygiene, cleanliness, and exercise—that will maintain and improve their health. At this level, children should come to understand how communicable diseases, such as colds, are transmitted and that some of the body's defense mechanisms prevent or overcome transmission.

5–8 Structure and Function in Living Systems

★ Disease is a breakdown in structures or functions of an organism. Some diseases are the result of intrinsic failures of the system. Others are the result of damage by infection by other organisms.

9–12 Personal and Community Health

- The severity of disease symptoms is dependent on many factors, such as human resistance and the virulence of disease-producing organisms. Many diseases can be prevented, controlled, or cured.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 1993 and 2008)

Note: Benchmarks revised in 2008 are indicated by (R). New benchmarks added in 2008 are indicated by (N).

K–2 Physical Health

- Eating a variety of healthful foods and getting enough exercise and rest help people to stay healthy.

★ Some diseases are caused by germs, and some are not. Diseases caused by germs may be spread by people who have them. Washing one's hands with soap and water reduces the number of germs that can get into the body or that can be passed on to other people.

3–5 Physical Health

- Some germs may keep the body from working properly. For defense against germs, the human body has tears, saliva, and skin to prevent many germs from getting into the body and special cells to fight germs that do get into the body.

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

6–8 Physical Health

- ★ Viruses, bacteria, fungi, and parasites may infect the human body and interfere with normal body functions. A person can catch a cold many times because there are many varieties of cold viruses that cause similar symptoms.
- Specific kinds of germs cause specific diseases. (N)

6–8 Discovering Germs

- ★ Throughout history, people have created explanations for disease. Some have held that disease has spiritual causes, but the most persistent biological theory over the centuries was that illness resulted from an imbalance in the body fluids. The introduction of germ theory by Louis Pasteur and others in the 19th century led to the modern belief that many diseases are caused by microorganisms—bacteria, viruses, yeasts, and parasites.

Related Research

- The folklore about how an individual "catches" a common cold is very tenacious. The condition is not regarded as a disease, and the word *cold* reinforces the connection with environmental causes (Driver et al. 1994, p. 56).
- In a study by Brumby, Garrard, and Auman (1985), some students saw health and illness as two different concepts with different causes rather than as a continuum. Another sample of students saw illness as the negative end of a health continuum of "lifestyle diseases" with no mention of infectious diseases (Driver et al. 1994).
- Exposure to TV and publicity on AIDS might influence modern children's ideas about infectious disease and predispose them more toward the germ theory of disease (Driver et al. 1994).
- Students have been known to hold conflicting ideas concurrently—at the same time, for example, believing that "all diseases are caused by germs" and that you can "catch a cold by getting cold and wet" (Driver et al. 1994).
- Research suggests that children often think of disease and decay as properties of the objects affected. They do not appear to hold a concept of microbes as agents of change (Driver et al. 1994, p. 55).

Suggestions for Instruction and Assessment

- When teaching about infectious diseases, distinguish among cause, transmission, and factors that lower resistance to disease.
- Engage older students in a debate regarding the many myths of the common cold. Encourage students to use their knowledge of cells, the immune system, and personal health to back up their claims with evidence.
- Use the story of Louis Pasteur and his contribution to the development of the germ theory. This historical episode is particularly relevant at the middle school level. In addition to tracing the development of ideas related to infectious diseases, it pro-

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

vides an excellent opportunity to highlight the nature of science.

Related NSTA Science Store Publications, NSTA Journal Articles, NSTA SciGuides, NSTA SciPacks, and NSTA Science Objects

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Related Curriculum Topic Study Guides

(Keeley 2005)

"Infectious Disease"

"Health and Disease"

"Personal and Community Health"

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Index

ABC (“activity before concept”), 49
absolute zero, 56
acclimatization, 118
accountability, and formative assessment, 4
acid rain, 145
adaptation. *See also* evolution
  “Adaptation” probe, 113–18
  “Biological Evolution” probe
  “Is It Fitter?” probe, 120, 122
“Adaptation” probe, 90, 113–18
AIDS, and infectious disease, 129
air pollution, 145, 148
alternative conceptions, and students’ ideas about science, 4
alternative energy, 146
American Association for the Advancement of Science (AAAS), 85, 148
assessment. *See* assessment for learning; formative assessment; paper and pencil assessment; diagnostic assessment; summative assessment
assessment for learning, 1–2
asteroids, 157, 159
astronomy. *See* space science
Atlas of Science Literacy, Volume 2 (AAAS 2007), xiii
atoms
  “Burning Paper” probe, 26, 27
  “Iron Bar” probe, 18
  models of, 78
  “Nails in a Jar” probe, 34
  “Salt Crystals” probe, 40, 41
Auman, J., 129
Australia, and student survey, 42

ball and ring apparatus, 21
ball and stick models, 42
Bar, V., 70
Barrow, L., 70
beach ball, as model of Earth, 160
behavior
  “Adaptation” probe, 116
  “Chicken Eggs” probe, 108
  “Is It Fitter?” probe, 122
Benchmarks for Science Literacy (AAAS 1993), xii
“Biological Evolution” probe, 90, 99–104
biology. *See* life science
body, basic functions of. *See also* health
  “Digestive System” probe, 134
  “Is It Food?” probe, 95
Brumby, M., 129
“Burning Paper” probe, 10, 23–29, 34
Butts, B., 42

“Camping Trip” probe, 90, 137–42
carbohydrates, 96
carbon dioxide, 144–45
carbon footprint, 148
card sort, and “Is It a System?” probe, 83
“Catching a Cold” probe, 90, 125–30
cells
  “Chicken Eggs” probe, 108, 109
  “Digestive System” probe, 132, 134
  “Is It Food?” probe, 94
characteristic properties. *See* properties of matter
characteristics of organisms
  “Adaptation” probe, 115–16
  “Biological Evolution” probe, 102
  “Chicken Eggs” probe, 108
  “Digestive System” probe, 133
  “Is It Fitter?” probe, 122
  “Is It Food?” probe, 94
chemical change, 24, 32
chemical evolution, 100, 103
chemical reactions, 26, 27, 34
chemistry. *See* physical science
“Chicken Eggs” probe, 90, 105–11
Climate Change 2007: Synthesis Report (IPCC 2007), 149
climate and climate change, and “Global Warming” probe, 144, 146. *See also* temperature; weather
closed system, 24, 32, 110
coal, 152–53
cold, 129. *See also* temperature
Collaborative Inquiry into Examining Student Thinking (CIEST), 3
combustion, 24
common cold, 126, 129
computers, and mathematical models, 75, 77. *See also* websites
concept matrices, for probes. *See also* scientific principles
  Earth science, 90
  life science, 90
  physical science, 10
  space science, 90
conceptual models, 74, 78
conservation of energy, 19, 48, 56
conservation of mass, 13, 109
conservation of matter, 24, 32, 106
Cosgrove, M., 15
crystal, 40
crystalline lattice, 40
culture, and influences on students’ thinking, xiii
Curriculum Topic Study (CTS), xiii, xiv

Darwin, Charles, 101, 104

diagnostic assessment, 6–7
"Digestive System" probe, 90, 131–36
dipole forces, 12
disease, and "Catching a Cold" probe, 126, 128, 129
dissolving, and "Sugar Water" probe, 12
diversity, of organisms
  "Adaptation" probe, 116
  "Biological Evolution" probe, 102
  "Is It Fitter?" probe, 122
drawings, as models, 74
Driver, R., 49
DuFour, R., 7

Eaker, R., 7
Earth. *See* Earth history; Earth science; geography; properties of Earth's materials; structure of Earth system
Earth history, 158
Earth science
  "Camping Trip" probe, 137–42
  concept matrix, 90
  "Global warming" probe, 143–49
  "Where Does Oil Come From?" probe, 151–56
  "Where Would It Fall?" probe, 157–60
electricity
  "Magnets in Water" probe, 69
  "Moonlight" probe, 163
electromagnetism, 69
elementary school students. *See* grade levels; *specific probes*
embryo development, 106
energy. *See also* energy transfer; energy transformations; flow of matter and energy; fossil fuels; heat energy; potential energy; thermal energy
  "Camping Trip" probe, 140
  "Chicken Eggs" probe, 108
  "Digestive System" probe, 135
  "Global Warming" probe, 146, 147
  "Ice Water" probe, 46
  scientific use of term, 58
  "Warming Water" probe, 54, 55
  "Where Does Oil Come From?" probe, 151–56
energy transfer
  "Camping Trip" probe, 139–40
  "Ice Water" probe, 46, 48
  "Iron Bar" probe, 19
  "Moonlight" probe, 163
  "Warming Water" probe, 54, 56
energy transformations
  "Camping Trip" probe, 140
  "Global Warming" probe, 147
  "Ice Water" probe, 48
  "Iron Bar" probe, 20
  "Warming Water" probe, 56–57
environment
  "Adaptation" probe, 116
  "Biological Evolution" probe, 102
  "Global Warming" probe, 146
enzymes, 134
evolution. *See also* adaptation; heredity; natural selection; stellar evolution; variation
  "Adaptation" probe, 115, 116, 117
  "Biological Evolution" probe, 99–104
  "Is It Fitter?" probe, 120, 121, 122
  use of term, 103
explanation. *See* concept matrices; P-E-O and P-E-O-E strategies; scientific principles

facets of understanding, and students' ideas about science, 4
fat, and food, 96
feedback mechanisms, and "Is It a System?" probe, 83
fever, 126
field tests
  "Chicken Eggs" probe, 109
  "Is It Fitter?" probe, 123
  "Where Would It Fall?" probe, 159
First Word–Last Word strategy, 86
fit and fitness, use of terms, 120, 121, 123
flow of matter and energy
  "Chicken Eggs" probe, 108, 109
  "Is It Food?" probe, 94, 95
  "Where Does Oil Come From?" probe, 154
folklore, and common cold, 129
food
  "Chicken Eggs" probe, 106
  "Digestive System" probe. 132
  "Is It Food?" probe, 92, 96
forces
  "Magnets in Water" probe, 69–70
"Standing on One Foot" probe, 62, 63, 64
formative assessment. *See also* formative assessment classroom techniques; probes
  approach to in *Uncovering Student Ideas in Science* series, 1–4
  definition of, 5–6
  diagnostic assessment, 7
  grading of, 5
  standardized testing and, x
  summative assessment, x, 5, 7
formative assessment classroom techniques (FACTs), 1, 2, 86
fossil fuels, 145, 146, 148, 152, 155
fossils, 102, 103, 154, 155
Frayer Model, 86

Garrard, J., 129
gases, and "Burning Paper" probe, 24–25. *See also* greenhouse effect
genetics. *See* heredity; variation
geochemical cycles, 154
geography
    "Camping Trip" probe, 139
influences on students' thinking, xiii
"Where Would It Fall?" probe, 157–60
geology. *See* Earth science
germs and germ theory, 126, 127, 129
Gilbert, J., 58
"Global Warming" probe, 90, 143–49
grade levels, and use of probes, xi–xii. *See also* elementary students; high school students; middle school students
grading, of formative assessment, 5
gravity, 62, 70
greenhouse effect, 144, 147, 148

health
    "Catching a Cold" probe, 125–30
    "Is It Food?" probe, 94, 95
heat. *See also* heat energy; heat transfer; temperature
    "Magnets in Water" probe, 69
    "Moonlight" probe, 163
    use of term, 47
    "Warming Water" probe, 54
heat energy, 55, 56, 57
heat transfer, 138
heredity. *See also* evolution
    "Adaptation" probe, 116, 117
    "Is It Fitter?" probe, 122
high school students. *See* grade levels; *specific probes*
House (television program), 6
hydroxyl groups, 12

"Ice Cubes in a Bag" (Volume 1), 36
"Ice Water" probe, 10, 45–51
illustrations, as models, 74
immune system, 126
infectious disease, and "Catching a Cold" probe, 126, 128, 129
inquiry-based investigation
    "Burning Paper" probe, 28
    "Camping Trip" probe, 141
    "Standing on One Foot" probe, 64
    "Sugar Water" probe, 15
intent, and adaptation, 114
interdependence of life, 116
Intergovernmental Panel on Climate Change (IPCC), 148–49
ionic bond, 40
"Iron Bar" probe, 10, 17–22
"Is It Fitter?" probe, 90, 119–24
"Is It Food for Plants" (Volume 2), 96
"Is It Food?" probe, 90, 91–97
"Is It a Model?" probe, 10, 73–80
"Is It a System?" probe, 10, 81–87

journal articles, and NSTA publications, xiii–xiv

Keeley, Page, xiv
kinetic energy, 47, 54, 57
kinetic molecular theory, 18, 20

Lamarckian interpretations, 117
Lavoisier, Antoine, 28
Leader's Guide to Science Curriculum Topic Study: Designs, Tools, and Resources for Professional Learning, A (Mundry, Keeley, and Landel 2009), xiv
life. *See* origin of life
life cycles of organisms, and "Chicken Eggs" probe, 108
life science
    "Biological Evolution" probe, 99–104
    "Catching a Cold" probe, 125–30
    "Chicken Eggs" probe, 105–11
    concept matrix, 90
    "Digestive System" probe, 131–36
    "Is It Fitter?" probe, 119–24
    "Is It Food?" probe, 91–97
light
    "Magnets in Water" probe, 69
    "Moonlight" probe, 163
    reflection, 162
"Lunar Eclipse" probe, 90, 167–71

"Magnets in Water" probe, 10, 67–71
magnifiers, 42
magnetism, 68, 163
Maine Mathematics and Science Alliance, ix–x
Making Sense of Secondary Science: Research Into Children's Ideas (Driver et al. 1994), xii–xiii
mass, use of term, 26. *See also* conservation of mass
mathematical models, 74–75, 77, 78
matter. *See* conservation of matter; flow of matter and energy; phases of matter; properties of matter; structure of matter; transformation of matter
meteorites, 157
methane, 144
middle school students. *See* grade levels; PRISMS (Phenomena and Representations for Instruction of Science in Middle School); *specific probes*
minerals, 96

Mintzes, J., 134–35
misconceptions
eclipses, 175
fossil fuels, 155, 156
students' ideas about science, 4
mixtures, 12, 13
models and modeling
"Camping Trip" probe, 141
"Is It a Model?" probe, 74
"Lunar Eclipse" probe, 170
"Moonlight" probe, 164
"Solar Eclipse" probe, 175, 176
"Where Would It Fall?" probe, 160
molecules
"Digestive System" probe, 133
models of, 78
"Sugar Water" probe, 12
"Warming Water" probe, 54
Moon
"Lunar Eclipse" probe, 167–71
"Moonlight" probe, 161–65
phases of, 162, 170
solar eclipse, 174
"Moonlight" probe, 90, 161–65
motion
"Lunar Eclipse" probe, 170
"Magnets in Water" probe, 69
"Moonlight" probe, 164
"Solar Eclipse" probe, 176
"Standing on One Foot" probe, 63
myths, about common cold, 129

"Nails in a Jar" probe, 10, 26, 31–37
naive ideas, and students' preconceptions about science, 4
NASA, and websites, 170, 176
National Science Digital Library (NSDL), 43, 170, 176
National Science Education Standards (NRC 1996). *See Benchmarks for Science Literacy* (AAAS 1993)
National Science Teachers Association (NTSA), and resources for probes, xiii–xiv
natural resources, 152, 154
natural selection. *See also* evolution
"Adaptation" probe, 114, 115, 117, 118
"Biological Evolution" probe, 100, 101, 103
"Is It Fitter?" probe, 120, 121
nitrous oxide, 144
nonrenewable resource, 152
nutrients
"Digestive System" probe, 132
"Is It Food?" probe, 92, 96

objects in sky, and "Moonlight" probe, 163. *See also* asteroids; meteorites
observation. *See* P-E-O and P-E-O-E strategies
oceans, 158
On the Origin of Species (Darwin), 104
organic chemistry, 96
organisms. *See* characteristics of organisms; diversity; environments; life cycles
origin of life, and "Biological Evolution" probe, 100, 103
Osborne, R., 15
oxidation, 32
ozone depletion, 145

paper and pencil assessment, and "Is It a System?" probe, 83
partially formed ideas, of students about science, 4
parts–and–whole relationships, and systems, 83
Pasteur, Louis, 127, 129
penumbra, and lunar eclipse, 168
P–E–O (Predict, Explain, Observe) and P–E–O–E strategies (Predict, Explain, Observe, Explain)
"Camping Trip" probe, 141
"Chicken Eggs" probe, 110
"Ice Water" probe, 49
"Magnets in Water" probe, 70
petroleum, 153
phase change, 46
phase–change graphs, 50
phases of matter, 46
phases of Moon, 162, 170
physical change, 12
physical models, and "Is It a Model?" probe, 74, 77, 78. *See also* models and modeling
physical science
"Burning Paper" probe, 23–29
concept matrix, 10
"Ice Water" probe, 45–51
"Iron Bar" probe, 17–22
"Is It a Model?" probe, 73–80
"Is It a System?" probe, 81–87
"Magnets in Water" probe, 67–71
"Nails in a Jar" probe, 31–37
"Salt Crystals" probe, 39–43
"Standing on One Foot" probe, 61–65
"Sugar Water" probe, 11–16
"Warming Water" probe, 53–59
plants, and concept of food, 96
pollution, and greenhouse effect, 148. *See also* air pollution
potential energy, 54, 57
preconceptions, and students' ideas about science, 4
prediction. *See* P-E-O and P-E-O-E strategies

pressure, and "Standing on One Foot" probe, 62, 65
PRISMS (Phenomena and Representations for Instruction of Science in Middle School), 21, 43, 79, 170, 176
probability, and "Where Would It Fall?" probe, 160
probes. *See also* concept matrices; Earth science; formative assessment; life science; physical science; space science; *specific probes*
administering, xii
concept matrices, 10
curricular and instructional considerations, xi–xii
definition of, 4
purpose of, x–xi
related concepts, xi
related research, xii–xiii
response of teachers to, ix
scientific content and explanations, xi
suggestions for instruction and assessment, xiii
properties of Earth materials
"Biological Evolution" probe, 102
"Where Does Oil Come From?" probe, 153
"Where Would It Fall?" probe, 159
properties of matter
"Burning Paper" probe, 26
"Chicken Eggs" probe, 108
"Nails in a Jar" probe, 34
"Sugar Water" probe, 14
properties of objects and materials
"Burning Paper" probe, 26
"Ice Water" probe, 48
"Iron Bar" probe, 19
"Magnets in Water" probe, 69
"Nails in a Jar" probe, 34
"Salt Crystals" probe, 41
"Standing on One Foot" probe, 63
"Warming Water" probe, 56
protein, 96

real-life examples
"Ice Water" probe, 49
"Iron Bar" probe, 19
regulation
"Adaptation" probe, 116
"Chicken Eggs" probe, 108
"Is It Fitter?" probe, 122
resources, types of, 153–54. *See also* natural resources
Resources for Science Literacy (AAAS 1997), 85–86
Robertson, Bill, xiii
Russell, T., 49, 109
rusting, and oxidation, 32
"Rusty Nails, The" (Volume 1), 34

safety
"Chicken Eggs" probe, 110
"Nails in a Jar" probe, 36
solar eclipse, 174
"Salt Crystals" probe, 10, 39–43
science. *See also* Earth science; life science; physical science; scientific inquiry; scientific principles; space science
role of models in, 75
students' preconceptions about, ix, 4
understanding nature of, 148
Science Curriculum Topic Study: Bridging the Gap Between Standards and Practice (Keeley 2005), xiv
Science Formative Assessment: 75 Practical Strategies for Linking Assessment, Instruction, and Learning (Keeley 2008), xii, 16
scientific inquiry
"Ice Water" probe, 48
"Standing on One Foot" probe, 63–64
scientific principles, and explanations in probes, xi. *See also* concept matrices; science
"Scientists' Idea" strategy, 16, 86
"Seedlings in a Jar" (Volume 1), 36
"seeing is believing" principle, 21
"Seeing the Cell as a System" (AAAS Project 2061 lesson), 85–86
Smith, R., 42
societal contexts, and influences on students' thinking, xiii
sodium chloride, 40
solar corona, 174
"Solar Eclipse" probe, 90, 173–77
solar radiation, 138
solar system. *See also* Moon; Sun; universe
"Camping Trip" probe, 140
"Global Warming" probe, 146
"Lunar Eclipse" probe, 169
"Moonlight" probe, 163
"Solar Eclipse" probe, 175
solutions, 12
space science
concept matrix, 90
"Lunar Eclipse" probe, 167–71
"Moonlight" probe, 161–65
"Solar Eclipse" probe, 173–77
species, 102
standardized tests and testing, and formative assessments, x
"Standing on One Foot" probe, xii, 10, 61–65
stellar evolution, 103
Stop Faking It! Understanding Science So You Can Teach It series, xi, xiii

structure of Earth system, and “Where Would It Fall?” probe, 159
structure of matter
“Burning Paper” probe, 26–27
“Chicken Eggs” probe, 109
“Iron Bar” probe, 20
“Nails in a Jar” probe, 34–35
“Salt Crystals” probe, 42
“Standing on One Foot” probe, 64
“Sugar Water” probe, 14–15
students. *See also* grade levels; misconceptions; safety; teachers and teaching
cultural, societal, and geographic influences on thinking, xiii
preconceptions about science, ix, 4
subsystems, 83
“Sugar Water” probe, 10, 11–16
summative assessment, x, 5, 6, 7
Sun. *See also* solar system
“Camping Trip” probe, 138, 139
“Solar Eclipse” probe, 173–77
“Warming Water” probe, 56
surface of the Earth, 158
“survival of the fittest,” 120, 121
systems. *See also* solar system; structure of Earth system
“Chicken Eggs” probe, 106
“Is It a Model?” probe, 79
“Is It a System?” probe, 82

Teacher Notes, x, xi. *See also specific probes*
teachers and teaching, and responses to use of probes, ix. *See also* field tests; inquiry-based investigation; P-E-O and P-E-O-E strategies; real-life examples; students; Teacher Notes
temperature. *See also* cold; heat
“Camping Trip” probe, 138
“Ice Water” probe, 46, 49
“Warming Water” probe, 54
terminology, and use of words
cold, 129
energy, 58
evolution, 101, 103
fit and fitness, 120, 121, 123
food, 96
fossils and fossil fuels, 155
heat, 47
molecules, 133
natural selection, 101
thermal energy
“Ice Water” probe, 46
“Warming Water” probe, 54, 56
thermal expansion, 18
toys, and models, 78
transformation of matter, 106
transmission, of infectious disease, 126

umbra, and lunar eclipse, 168
Uncovering Student Ideas in Science series, ix, xiv, 1–4
unifying themes
“Is It a Model?” probe, 76, 78
“Is It a System?” probe, 84, 86
physical science probes, 10
universe. *See also* Moon; solar system; Sun
“Lunar Eclipse” probe, 170
“Moonlight” probe, 163
“Solar Eclipse” probe, 175–76

variation. *See also* evolution
“Adaptation” probe, 114
“Is It Fitter?” probe, 120
virus, 126
vitamin, 96
vocabulary. *See* terminology

“Warming Water” probe, 10, 53–59
water distribution, on Earth, 158
Watt, D., 58, 109
waves, 56
weather, 138, 147. *See also* climate and climate change
websites. *See also* computers
American Association for the Advancement of Science, 86, 148
Curriculum Topic Study, xiii
embryological development of chick, 110
Intergovernmental Panel on Climate Change, 149
Java simulation on formation of oil, 155
NASA, 170, 176
NSDL (National Science Digital Library), 43, 170, 176
NTSA on evolution, 104
PRISMS (Phenomena and Representations for Instruction of Science in Middle School), 21, 43, 79, 170, 176
Uncovering Student Ideas, xiv
weight
mass, 26
pressure, 62
“Where Does Oil Come From?” probe, 90, 151–56
“Where Would It Fall?” probe, 90, 157–60

Zinn, B., 70