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.

Preface

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*

Preface

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

Preface

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.

References

American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy.* New York: Oxford University Press.

American Association for the Advancement of Science (AAAS). 2007. *Atlas of science literacy,* Vol. 2. Washington, DC: AAAS.

Driver, R., A. Squires, P. Rushworth, and V. Wood-Robinson. 1994. *Making sense of secondary science: Research into children's ideas.* London: RoutledgeFalmer.

Keeley, P. 2005. *Science curriculum topic study: Bridging the gap between standards and practice.* Thousand Oaks, CA: Corwin Press.

Keeley, P. 2008. *Science formative assessment: 75 practical strategies for linking assessment, instruction, and learning.* Thousand Oaks, CA: Corwin Press.

Mundry, S., P. Keeley, and C. Landel. 2009. *A leader's guide to science curriculum topic study: Designs, tools, and resources for professional learning.* Thousand Oaks, CA: Corwin Press.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academy Press.