PRIORITIES *in* PRACTICE

The Essentials of Science, Grades K–6

Effective Curriculum, Instruction, and Assessment

Rick Allen

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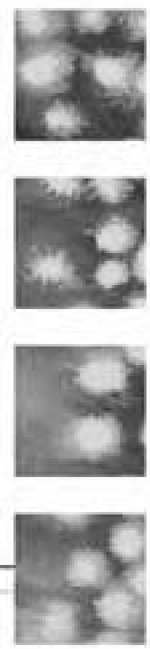

Rick Allen

ASCD Association for Supervision and Curriculum Development • Alexandria, Virginia USA

Association for Supervision and Curriculum Development
1703 N. Beauregard St. • Alexandria, VA 22311-1714 USA
Phone: 800-933-2723 or 703-578-9600 • Fax: 703-575-5400
Web site: www.ascd.org • E-mail: member@ascd.org
Author guidelines: www.ascd.org/write

About the Author: Rick Allen is a writer and project manager at ASCD. He has worked as a writer and editor in education journalism for 12 years.

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The Essentials of Science, Grades K–6

Preface

The Essentials of Science, Grades K–6 is intended to help elementary teachers and instructional leaders get a handle on the best ways to teach science to young children. Research shows that elementary teachers, who typically have the heavy responsibility of teaching multiple subjects, often believe that they don't have enough time to teach science, feel themselves inadequately trained for the task, or aren't particularly fond of the subject. It's with those difficulties in mind that I offer elementary educators some classroom examples of expert science teachers at work, along with practical information to help readers reflect on their own approaches to teaching science.

Although relying for the most part on classroom observations and interviews with award-winning elementary school science teachers and science education experts, this book also makes extensive use of widely available research examining the state of science education. To show that concern about science education crosses borders, I highlighted some studies that examine science education practices outside the United States. Promising research-based developments, including concept cartoons in the United Kingdom and lesson study in Japan, are already being used in the United States and other countries.

The Essentials of Science, Grades K–6 is divided into six chapters that seek to give readers a basic grasp of the following topics: trends in elementary science teaching, curriculum planning, best practices in the elementary science classroom, the engagement and motivation of students, ongoing assessment, and professional development.

As I gathered information for this book, I was continually reminded of the reality that science, rooted as it is in the certainties of the physical world, is a process that necessarily unfolds over time. In school, science classes tend to work according to this linear model; there's a "beginning, middle, and end" to science investigations, no matter how hard teachers may fight the "cookbook" reductionism that threatens true scientific inquiry. Yet, in probing further, I came to understand that science cannot be defined in terms of a sequence. Science is recursive. It might be described as having a cyclical nature with a twist—spiraling upward, looking back on itself, and changing as necessary. Thus, scientists—and ideally, students in science class—continually look back on what they have observed, analyzed, and evaluated to see whether their conclusions still make sense or raise new questions to pursue.

These processes of wondering, questioning, predicting, observing, and data gathering can lead to one person's flash of insight, the "aha!" that cuts through the seeming tedium of the processes themselves. Such revelations can be as lofty as Einstein's equation of mass with energy or as humble as the realization that those painful burrs pricking through your jeans on the playground are in fact seeds.

The Essentials of Science, Grades K–6 would not have been possible without the generosity of the many science educators and researchers who agreed to share their knowledge, classroom practice, and insights for this book as an encouragement to their colleagues in schools here and abroad.

Trends in Elementary Science Education

Science is a wonderful thing, if one doesn't have to earn one's living at it.

—Albert Einstein

Many elementary school teachers, the proverbial jacks-of-all-trades, face a trio of issues when it comes to teaching science: they don't like science, they don't feel confident in their knowledge of science, and they don't know how to teach science effectively.

That's exactly what science education professor Alan Colburn tells his undergraduate education students at California State University, Long Beach. "People in general don't like science, and elementary school teachers are no different from the rest of the general public," explains Colburn.

Working under those circumstances, it's no wonder that teachers tend to treat science as an afterthought, say veteran science educators. Bobbie Sierzant, an elementary science teacher for 32 years, notes that "science is one of the first things to be let go of in an elementary school day because the teachers are so overwhelmed with language arts, math, and social studies and all the other duties they have. They'll keep on saying, 'I'll get to it, I'll get to it.' They realize science takes more time—but they never find that extra time."

A New Springtime for Science?

But there is hope. Colburn, who is training a new crop of science teachers and helping midcareer educators to advance their practice, promises to launch his students on the road to becoming exemplary science teachers. Such teachers, says the syllabus for his science class for prospective elementary teachers, "like science, have an accurate understanding of major science content and processes, feel confident in their ability to learn science, and teach science using an age-appropriate inquiry-based approach" (Colburn, 2005).

The question for elementary teachers who are already teaching science, however, is "How do I get there?" Now that the academic spotlight of No Child Left Behind (NCLB) is being trained on science education in the United States, these teachers might need to find answers to that question—fast.

NCLB is driving schools to take a closer look at how they teach science and to improve their practices accordingly. Science testing under NCLB is slated to begin in the 2007–2008 school year, prompting a flurry of activity among educators. State departments of education have been busily devising standards-based tests that will be administered annually within grade bands at the elementary, middle, and high school levels. And school administrators have looked up from their students' reading and math scores just long enough to realize that yet another test is on the horizon.

Additional concerns have joined in the push to improve science teaching. In many countries, public and private groups are demanding better science education at all levels because they see science and technology as the keys to economic advantage in the global village. Europe has recognized the importance of science and math education for economic success (Wellcome Trust, 2005), and even Asian nations, consistently high achievers in international comparisons of math and science, are not immune from worry. During the last decade, while U.S. reformers have looked to Asia as the "promised land" of education practice for high student achievement, reformers in East Asian countries have been experimenting with child-centered, constructivist practices, seeing them as the U.S. secret to economic success (Zhao, 2005).

Ironies in international education reform aside, one thing is clear: not since the years after Sputnik's launch in 1957, when U.S. schools dramatically increased the rigor of their science curricula, have U.S. public and private sectors voiced such interest in improving the quality of K–12 science education.

For example, a committee of leading scientists and business leaders working under the National Academy of Sciences recently recommended recruiting 10,000 science and math teachers annually by offering the nation's smartest students four-year college scholarships. The same group wants government and private grants to fund professional development for science and math teachers, including summer institutes, master's degree programs, and training programs for advanced placement and International Baccalaureate programs. This committee has even called for the convening of a national panel that would research and develop a "world-class standard" voluntary K–12 curriculum (Committee on Science, Engineering, and Public Policy, 2006).

Ultimately, improvements in science education—and educators' willingness to embrace change—will depend on how well schools, the government, and even the private sector provide teachers with the necessary resources and professional development to teach hands-on, inquiry-based science. Experts say the national science education standards developed by the National Research Council (NRC) in 1996 have not yet gained a strong foothold in the science teaching practices found in most U.S. schools. Nonetheless, science educators and education policymakers see the NCLB spotlight as one additional opportunity to ensure that science remains on everyone's academic radar screen.

Why Standards Matter

The underlying goal of the NRC's *National Science Education Standards* (1996) is to create scientifically literate students. Although it's understood that not every student will grow up to be a scientist, scientific literacy is essential in a highly technological society in which the fruits of scientific research can have a major effect on such aspects of society as health care, food, transportation, and communication.

According to the standards, a scientifically literate individual can "ask, find, or determine answers to questions derived from curiosity about everyday experiences"; explain natural phenomena; and understand science news in the popular media. Further, as a boon to civic life, scientific literacy "implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed" (NRC, 1996, p. 22).

Leon Kass, past chair of the President's Council on Bioethics, says that such controversial scientific topics as cloning, genetic screening, and genetic engineering are "issues of enormous importance, not just for now but for the future." Students should understand science not just as knowledge for its own sake, but also as a means to become thoughtful citizens who can weigh in on scientific matters that directly affect society. "It's very important that young people come to understand that there are important moral concerns raised by genetics and biology," Kass says, pointing to just one branch of science. "It's never too early to introduce them to these questions" (Allen, 2002, p. 7).

A Need to Distill Standards

As senior program director in the education and human resources directorate at the National Science Foundation (NSF), Janice Earle evaluates the cutting-edge science education research programs that the NSF funds with taxpayer money allotted by the U.S. Congress.

Earle believes that despite the dissemination of *National Science Education Standards* and *Benchmarks for Science Literacy* (published by the American Association for the Advancement of Science in 1993), science education in the United States "has not taken the standards deep enough." Part of the problem is the standards themselves, which she describes as "tons of stuff" that's neither well connected across topics nor well articulated across grade levels. "Most states just took their own standards and added the national standards—it's accretion instead of distilling and refining. They've added, added, added, so now what they have is a cluttered landscape of stuff," Earle contends. She notes that "there's a lot of work that remains to be done" to strengthen the standards, including making decisions about what knowledge is most essential for students to have.

The State of State Science Standards 2005, a recent study commissioned by the Thomas B. Fordham Institute in Washington, D.C., evaluated the state science standards for 49 states and for the District of Columbia. Only 19 states earned a top grade of *A* or *B* with "clear and rigorous standards." The standards for the 22 states that earned only a *D* or an *F* were characterized by excessive length, lack of coherence, an overemphasis on open-ended approaches to inquiry-based learning, inadequate content knowledge requirements, and insufficient attention to evolutionary theory (Gross et al., 2005).

Some standards-based curricula have created other problems as well, say the authors of the Fordham survey. They are particularly worried about state standards that create a false dichotomy between "rote" and "hands-on" learning. In a solid science curriculum, the accumulation of facts and concepts should go hand in hand with laboratory or field investigations. As the investigators note, the real problem lies "in determining reasonable demands on student memory. It is not at all a matter of 'just memorizing' versus 'doing' science. You can't just 'do' science, or any other intellectual work, without a minimum acquaintance with the facts" (Gross et al., 2005, p. 24).

Calling On the Cognitive Sciences

The next step in science education reform makes use of research within the cognitive sciences, which seek to uncover the mental processes of learning. According to this promising model, concepts, facts, and inquiry (in both its intellectual and hands-on aspects) play mutually supportive roles in learning science.

For example, one key research finding emphasizes the importance of understanding "domain-specific conceptual frameworks." Broadly, this means that the application of such concepts as *evidence* or *change* will look different within the context, or domain, of science than within the context of another subject, such as history. Within each domain, conceptual frameworks promote organization and understanding. In science, for instance, the concept of the adaptation of species gives new meaning to what a student already knows about the characteristics of fish, birds, and mammals. The concept of adaptation, in turn, is fleshed out and enriched by the factual details of the species that students have studied (Donovan & Bransford, 2005).

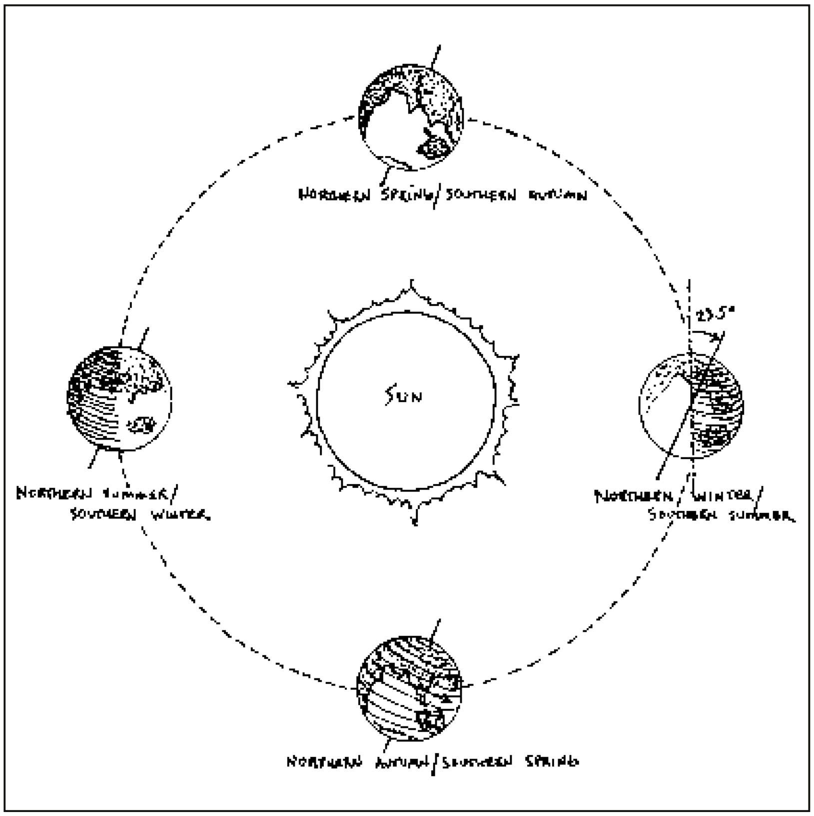
In *How Students Learn: Science in the Classroom*, Donovan and Bransford (2005) distill three principles from cognitive and developmental research that can help science teachers strengthen their classroom instruction and boost their students' learning:

- **Address preconceptions.** First, find out what students already know.
- **Know what it means to "do science."** Understand how constructing knowledge in this subject may differ from constructing knowledge in other subjects.
- **Use metacognitive strategies.** Help students reflect on their learning process.

Addressing Preconceptions

Students enter the classroom with their own ideas about how the world operates. These preconceptions may come from a variety of informal sources, including students' own observations. Some incomplete ideas persist as misconceptions into adulthood. One well-known study (Harvard-Smithsonian Center for Astrophysics, 1987) showed that a majority of randomly chosen Harvard University graduates, faculty, and alumni could not give correct explanations for either the change in seasons or the phases of the moon. One featured misconception held that the earth has a pronounced elliptical orbit that swings closer to the sun during summer and farther from the sun in winter. The study also showed that such fixed personal understandings are hard to root out, even after teachers provide correct information (see illustration on facing page).

Accordingly, teachers who understand the individual preconceptions that students bring to a science topic can address misunderstandings directly and thus better focus their lessons. In addition, teachers



The tilt of the earth's axis means that the angle of the sun's rays and the intensity of their energy vary during the planet's revolution around the sun. Typical depictions of the earth's orbit as a pronounced ellipse (to show three dimensions) can mislead students into thinking that the earth swings closer to the sun during summer and farther away during winter—a childhood preconception that can persist into adulthood. (Drawing: Rick Allen)

must be ready to address preconceptions that students hold about the science field itself and the procedures within it. For example, Donovan and Bransford (2005) point out that many students believe experiments are performed mainly to attain a certain outcome or that data correlation is itself sufficient to show a causal relationship.

"Doing" Science

Such misconceptions about the processes of science tend to occur when the processes become ends in themselves, divorced from core concepts of science. For students to learn how to "do" science, they need to understand the roles of observation, imagination, and reasoning.

Donovan and Bransford point out that research has shown that experts in a field acquire and retain knowledge differently from novices.

Experts add knowledge to their existing conceptual framework of "big ideas," which makes acquisition of new ideas or facts easier, and recall and application of knowledge more productive. Students, too, must "have a deep foundation of factual knowledge" to gain mastery in a scientific topic, which they must then link to a conceptual framework (Donovan & Bransford, 2005, p. 1).

Janice Earle finds promise in the reform efforts that highlight both scientific thinking and science's big ideas. She further notes that if science's domain-specific thinking is a way of reasoning based on evidence about the natural world, then schools need to give students opportunities to experience the natural world. "Cookbook labs" that involve step-by-step directions leading to certain outcomes don't satisfy the perennial call for inquiry-based learning in science. "Inquiry can be good, bad, or indifferent, just as curriculum or assessment can be good, bad, or indifferent," Earle asserts.

Using Metacognitive Strategies

The third principle for effective science instruction involves teaching students to use metacognitive strategies to monitor their own thinking. Such strategies can be as simple as having students compare outcomes of an experiment or leading a class discussion that exposes students to different viewpoints on a topic. With guidance and support from skilled teachers, students will reconsider and refine their own ideas.

A metacognitive strategy called *reflective assessment* involves giving students a framework, such as a rubric, for evaluating their inquiry. For example, students may rate their understanding of the main ideas, understanding of the inquiry process, systematicness, inventiveness, careful reasoning, application of the tools of research, teamwork, and communication skills. Donovan and Bransford found that when given a reflective framework for their thinking, academically disadvantaged students, in particular, made significant gains (2005).

Elementary science teachers can promote deep knowledge only if they give students chances to rethink how to observe and reason about the world, moving them from an everyday way of thinking to a scientific one (Magnusson & Palincsar, 2005). Such a shift is not easy, however.

It requires that teachers have a solid grounding in the topic so that they can help students use their reasoning abilities to question their prior understanding.

Inquiry in the Science Classroom

Age-Appropriate Inquiry

The standards set by the NRC call for K–12 students to both understand and be able to engage in scientific inquiry. For early elementary students, “full inquiry involves asking a simple question, completing an investigation, answering the question, and presenting the results to others” (1996, p. 122). For upper-elementary students and those entering middle school, inquiry calls for students to become more attuned to the role that evidence plays in forming their explanations.

Even young schoolchildren can engage in scientific inquiry, says Chris Ohana, field editor for *Science and Children* magazine and science education professor at Western Washington University. “I’ve seen really elegant things done by 1st and 2nd graders,” notes Ohana, also a former schoolteacher. In one instance, two 2nd grade girls were not convinced that air was “something” rather than “nothing.” So they took two balloons—one filled with air and one deflated—and weighed them on a well-calibrated balance. The students’ experiment allowed them to understand that air has mass—that even though they cannot see air, it is in fact “something” rather than “nothing.”

To encourage age-appropriate classroom inquiry, authors of the national standards take great pains to point out that the inquiry standard does not advocate a “scientific method.” That’s because inquiry can take many forms, such as “describing objects, events, and organisms; classifying them; and doing a fair test” that changes one variable at a time. Indeed, the commonly understood model of the scientific method can even distort the scientific understanding of “theory” and “law” (Colburn, 2003, p. 87).

The NRC’s science education standards list abilities that elementary students need to effectively engage in inquiry in the classroom (1996). Students in grades K–4 should be able to

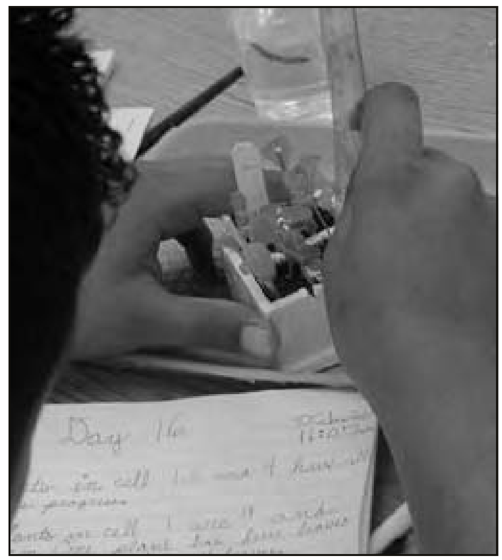
Is air "something" or "nothing"? These students weigh a balloon to find out. (Photo: Rick Allen)

• Ask a question about objects, organisms, and events in the environment.
• Plan and conduct a simple investigation.
• Employ simple equipment and tools to gather data and extend the senses.
• Use data to construct a reasonable explanation.
• Communicate investigations and explanations.

Students in grades 5–8 should be able to

• Identify questions that can be answered through scientific investigations.
• Design and conduct a scientific investigation.
• Use appropriate tools and techniques to gather, analyze, and interpret data.
• Use evidence to develop descriptions, explanations, predictions, and models.
• Think critically and logically to relate evidence and explanations.

• Recognize and analyze alternative explanations and predictions.
• Communicate scientific procedures and explanations.
• Use mathematics in all aspects of scientific inquiry. (NRC, 1996, pp. 122–123, 145, 148)



Left: Scientific inquiry for students can involve using simple tools like magnifiers to extend the senses. (Photo courtesy of Valle Imperial Project in Science)

Right: Students' inquiry includes observing, gathering or quantifying data, and thinking and writing about their investigations. (Photo courtesy of Valle Imperial Project in Science)

Implementing the Inquiry Approach

Science education reformers have recommended inquiry as the preferred instructional method for elementary science classes because it directly engages students' thinking about a problem, usually in the form of a scientific investigation. The buzz phrase "hands-on, minds-on" science encapsulates the philosophy of many science educators who want to move classroom practice beyond the isolated use of science textbooks or predigested verification labs. (See "Inquiring Teachers Ought to Know: What Is Inquiry?" on page 12 for more information about the inquiry approach.)

Although science teaching varies in elementary schools, what often "counts" as science is reading from a science textbook or a science-related trade book, Alan Colburn points out. He explains that "those of us in the science ed biz tend to favor hands-on activities that are open-ended—something where you have to think and figure out a little bit for yourself and interpret data. You don't see a lot of that at any level." On the other hand, Colburn adds, hands-on, open-ended science is more common

Inquiring Teachers Ought to Know: What Is Inquiry?

Alan Colburn

Inquiry-based instruction encourages students to learn inductively through concrete experiences and observation rather than rote memorization, gaining problem-solving skills that will help them throughout life. In science, inquiry-based instruction is founded on several assumptions:

- Learning to think independently and scientifically is a worthy instructional goal.
- *Learning* to think independently means that students must actually *think* independently.
- Thinking is not a context-free activity. To gain a deep understanding of scientific concepts, learners must actively grapple with the content.

The inquiry approach represents a broad range of instructional possibilities. At one end of the spectrum, students make few independent decisions; at the other end, students make almost all the decisions. Science educators commonly refer to three different kinds of inquiry-based instruction: structured inquiry, guided inquiry, and open inquiry.

Structured inquiry. The teacher or lab manual might give students step-by-step instructions, but students must decide for themselves which observations are most important to record and must figure out, to some extent, the meaning of their data.

Guided inquiry. Students not only choose what data to record and interpret the meaning of those data but also design the procedure that will address the activity's main question.

Open inquiry. Students make almost all the decisions. In the quintessential open inquiry activity, a student thinks of a question to investigate, considers how to investigate the question and what data to collect, and decides how to interpret those data.

Implementation

Teachers may face challenges in implementing inquiry-based teaching practices, largely because many students are not used to figuring out so much on their own. Teachers can make the transition by implementing changes gradually. For example, a teacher accustomed to students performing verification lab activities could remove any ready-made data tables, conduct a preliminary classroom discussion to point students in the right direction, and, after the experiment, ask students to share information about the variety and significance of the data they collected. Or if an activity's directions tell students to pour 10 milliliters of liquid in a test tube, the teacher can instead direct the students to pour "a little" liquid in the tube. Students will inevitably place a variety of volumes in their test tubes. Consequently, results may vary—prompting great possibilities for class discussion on how and why the results varied as they did.

Assessment

Formative assessment of student understanding helps teachers decide when it's time to move on to more open-ended activities and when it's time to backtrack and scaffold student understanding. Teachers' assessments in inquiry-based classrooms must stress scientific reasoning and critical thinking in addition to content knowledge. A teacher could assess students' abilities to

- **Generate open-ended, researchable queries.** Extend the experiment by having students develop further questions to investigate after interpreting their data.
- **Devise scientific procedures.** Have students come up with a procedure to address a question and situation similar to the question already investigated.

• **Interpret data.** Provide students with sample data from a given scenario and ask them to analyze the data's meaning and implications.

Source: Adapted from "Inquiring Scientists Want to Know," by A. Colburn, 2004, *Educational Leadership, 62*(1), pp. 63–66. Copyright © 2004 by Association for Supervision and Curriculum Development.

at the elementary school level than at the secondary level, where the emphasis is on learning content: "Really good elementary school science will be a hands-on kind of activity, because at that level, the emphasis is on learning to like science."

But in reality, inquiry "hasn't really infiltrated the classroom in a major way," observes Chris Ohana. Because inquiry is sophisticated and complicated, it's hard to pull off in the classroom while also covering the curriculum, she notes.

Kit-based curriculum series—like Full Option Science System (FOSS) and Science and Technology for Children (STC)—are popular, says Ohana, but they are "essentially cookbook lessons" that tell students what to do yet fail to provide insight into how science is constructed. "Their strength is that the kits motivate kids, and the hands-on experience makes science more memorable. Some kits will help kids develop inquiry skills—some are strong—but some are dogs," she concludes.

To ensure that kits promote inquiry-based teaching rather than merely entertain requires that teachers receive training in inquiry-based approaches. "Inquiry-based science is difficult to teach sometimes, even though teachers like it and want to teach it," says Alan Colburn. "It's not something that any of us were raised with, so it represents a new set of skills. The approach could also be new to students—or principals and parents—who may not be comfortable with it," so it's easy for teachers to "go back to the old ways," he adds.

Professional development is one way in which teachers can gain theoretical and practical knowledge about implementing the inquiry approach, as well as other innovative instructional practices. Many states and schools are already using NCLB funds targeted at the preparation, training, and recruitment of highly qualified teachers to help teachers better engage in such practices.

Preparing for NCLB Science Testing

Slated to begin in 2007–2008, NCLB science testing is the next piece of the science education reform puzzle. As state education officials feverishly work on designing the annual assessments, the big question on everyone's mind is, Can such state science testing be approached as business as usual?

Most educators agree that standardized tests have a limited capacity to convey what students know. The shortcomings of a 60-minute paper-and-pencil exam become even more apparent when it comes to science, researchers say.

"Critical aspects of science—inquiry, for example—cannot be well measured or well assessed on a single, time-limited test," says Meryl Bertenthal, coeditor of *Systems for State Science Assessment.* That report, the culmination of a two-year $1.8 million National Research Council study, offers state education departments suggestions to help them reassess K–12 science testing under NCLB.

Science education researchers, like Bertenthal, have high hopes that upcoming tests will at least mark the beginning of change in how schools assess science—and ultimately influence curriculum and instruction. Whittling down and streamlining the science standards could only help the cause of learning science, the report concludes: "A potentially positive outcome of a reorganization in state standards from discrete topics to big ideas is a shift from breadth of coverage to depth of coverage around a relatively small set of foundational principles" (Wilson & Bertenthal, 2005, p. 3).

Classroom-Level Assessments

To test inquiry—that central component of good science teaching—*Systems for State Science Assessment* asks states to consider creating a system of multiple tests that assess students' abilities to frame appropriate questions for investigation, make predictions, and evaluate claims based on evidence. One such test might be a classroom assessment that teachers could conduct over a longer stretch of time than a class period.

"Teachers could observe students doing an inquiry and evaluate their work as they continue it," Meryl Bertenthal says. "So much science requires revision and rethinking. You're gathering evidence to see what that tells you, then trying to synthesize and pull things together. That's really hard to capture on a multiple-choice test." She notes that "right now there's no ready mechanism for recording these kinds of assessments into the scores reported as part of NCLB." Nonetheless, Bertenthal says, although standardized classroom-level assessments may be hard to implement in the short term, states should make them part of a system of multiple science assessments.

Aligning Tests with Standards

According to NCLB, state assessments must be aligned with learning standards. This requirement compels states to take a hard look at how they select and organize those standards.

Typically, state science standards overwhelm educators with a welter of topic-based information to teach—mostly disconnected facts, formulas, and procedures. The study committee behind *Systems for State Science Assessment* wants this to change, suggesting that standards—and therefore instruction and testing—should help students focus on big ideas in science (Wilson & Bertenthal, 2005).

Big ideas, in turn, are often best understood within the context of a "learning progression" of other big ideas. For example, to eventually understand the concepts of matter and atomic molecular theory, a student at the elementary school level should first understand that the physical world around her consists of material that can be described, measured, and classified according to its properties. Next, the student learns that such matter can be transformed—but not created or destroyed—by chemical and physical processes, such as decay or erosion (or, closer to home, chewing her food).

At the secondary level, the student builds on these earlier notions, moving her understanding to the molecular level. She learns that matter consists of atoms bound together into molecules, which determine the properties of the material; that such properties can alter due to both changes and underlying continuity in the atoms and molecules; and, finally, that the properties of atomic and molecular transformations are distinguished from the physical changes that occur (Wilson & Bertenthal, 2005). This learning progression takes into account the development of a student's thinking as it moves from the concrete to the general to the abstract, an important capacity for understanding atomic-molecular theory (Smith, Wiser, Anderson, Krajcik, & Coppola, 2004).

Although *Benchmarks for Science Literacy* has mapped out learning progressions for major science concepts, further research is necessary to determine the age-appropriate introduction of material recommended by standards documents (Smith et al., 2004). States also need to solve the potential problem of the disconnect between the "cognitive demands" of the standards and the reality of the actual test, says Meryl Bertenthal. "In science, a lot of standards ask that students be able to analyze, understand, conduct, *do* things," she points out, but standardized tests tend to take the low cognitive road of "identifying, defining, and calculating."

It's unlikely that most states will iron out all these issues in the early rounds of state science testing, but as testing continues and "states have time to think about it," the recommendations of *Systems for State Science Assessment* will have more influence and be more useful, says Bertenthal.

Reflections ◆ ◆ ◆

In this chapter, we learned that various forces both from within education (such as NCLB) and from without (such as global competition) are combining to give a new push to K–12 science education reform. Through the practice of inquiry-based science, a reform promoted by *National Science Education Standards,* even young students can learn about the authentic enterprise of science: reasoning based on evidence from the natural world.