Why Teach Science?

In the previous chapter we helped you clarify your definition of science and how it differs from other subjects studied in school. As you gain experience working in schools, you will find that time is at a premium and every teacher has a different opinion about which subjects are the most important for students to study. At the secondary level, where teachers specialize in particular subjects, the competition about the different areas is even greater. Even though you will most likely be teaching numerous subjects in a self-contained classroom, you will no doubt have to consider how much time to spend on each subject matter area relative to the others. One of the subjects you will be expected to teach is science. Although policy makers decide what to include in the required curriculum
for a wide variety of reasons, we do believe that it is important, at this point, to carefully consider why science is part of the elementary curriculum. In addition to providing you with a summary of the current reform efforts in science education, this chapter will also help you develop some personal beliefs about why science should have a significant place in the required curriculum. Unless you are convinced that it is important, your attention to science may not be as dedicated as it could be. This chapter will assist you in developing some very compelling reasons for the teaching of science. If you are still skeptical about this conclusion and need some convincing, the contents of this chapter will do that as well.

Why Require Science for All Students?

Pretend for a moment that a parent has asked you why science is included in the third-grade curriculum. What would you say? Take a few minutes to make a list of your reasons, starting with the most important first. When we have asked this question of beginning and experienced teachers in the past, we have received the following reasons in no particular order of importance:

1. It helps teach critical thinking.
2. It develops problem-solving skills.
3. It develops analytical reasoning.
4. It helps students learn to think.
5. It develops logical thinking.
6. It will help students make better decisions.
7. Science is, increasingly, a part of our lives.
8. It helps to explain the world we live in.
9. Science is relevant to our daily lives.

How does your list compare to what we have listed? The first five items on our list are the most common reasons teachers, as well as others, provide as a justification for the inclusion of science in school curriculum at all levels, not just the elementary grades. It would not be at all surprising if some of these ideas showed up on the list you created. You may be interested to know that these are quite similar to the reasons that were used to justify the inclusion of science as part of the required curriculum in the late 1800s in the United States. More specifically, the learning theory in vogue during that time was known as mental discipline (a.k.a. faculty psychology), which has its roots in the teachings of Plato and Aristotle. The theory postulates the existence of the following mental faculties that distinguish humans from the rest of the living world: reason, knowing, perception, feeling, free will, and memory, among others. The expression “the mind is a muscle” is the most concrete way to explain mental
Plato and Aristotle as depicted by the artist Raphael.

discipline theory and its implications for teaching and learning. Education amounted to exercising, training, and disciplining the mind. Just like a muscle, it was believed that the more we use our brains, the stronger our brains became. What was exercised in this theory of learning were the mental faculties we have listed. Therefore, the value of any particular subject matter in the school curriculum was directly related to its ability to exercise certain mental faculties and had nothing to do with relevancy or the curriculum's motivational aspects.

Plato believed that mental training or discipline in mathematics and philosophy was the best preparation for participation in the conduct of public affairs, a view that gave mathematics a longer history as a required subject in educational curricula than science. Greek and Latin continued to be required in school curricula long after their usefulness as languages had passed on the grounds that these languages improved thinking skills. Have you heard this before? Is the
logic similar to what you used in justifying science to the questioning parent we mentioned before? At the turn of the century, scientific method was viewed as an effective way to develop the faculties of reason, knowing, and perception and science in general was advocated as an excellent way to develop the faculty of observation. In addition, those detailed laboratory notebooks you may have had to keep during your college courses were believed to be an excellent way to develop the faculties of observation, perception, reason, and memory at the turn of the century.

Psychologists, such as E. L. Thorndike, tested the validity of mental discipline theory in the early 1900s and found that drill or training in certain tasks did not strengthen the faculties associated with the tasks (e.g., training in estimating string lengths did not strengthen estimation skills, and developing neatness in math papers did not lead to neatness in other areas). Other studies showed that general intelligence was not influenced by students’ courses of study in school (e.g., science versus humanities). More recently, researchers studying transfer of knowledge have consistently found that learning is situated, or specific, to certain contexts and does not readily transfer to other situations. Although mental discipline theory was debunked almost a century ago, we still see its remnants in movements calling for “back to the basics,” cultural literacy, or those that extol the virtues of drill and practice. You will soon find that fads die hard in education.

What this means is that the justification of the inclusion of science in a curriculum on the grounds that it helps develop various higher-level thinking skills, such as logic, is erroneous. The view is intuitive but not correct. Just because your students learn to design an experiment within a science lesson does not mean that they will also approach other problems in their lives more systematically. Thus, we ask again, why should science be a required part of the curriculum at all grade levels? The truth of the matter is that science must be taught because it is the law. We are not being cynical. The lawmakers in power when such decisions were made valued science over other subjects such as Latin.

Okay, it’s the law. Are there any other, more satisfying justifications you can provide to querying parents or to those students who wonder why they are being asked to learn science? Perhaps the most persistent phrase you will hear regarding the goal of contemporary science curriculum is “scientific literacy.” In short, there is a fairly strong agreement among scientists, educators, and politicians that the primary goal of science education should be to produce a scientifically literate citizenry. The basis for this agreement is the recognition that science is becoming increasingly more intertwined with our daily lives and not being educated in science will condemn us to an overreliance on those who have such knowledge. That is, we will have to base our decisions on what such individuals tell us without any means of determining the validity of what we are told and, in a way, being ignorant is analogous to being in prison.
What Is Scientific Literacy?

Many definitions for scientific literacy are available, but perhaps the National Science Teachers Association (NSTA, 1982) said it best over 20 years ago in its statement about scientific and technological literacy. The NSTA defined the literate person as one who:

1. uses science concepts, process skills, and values in making responsible everyday decisions
2. understands how society influences science and technology as well as how science and technology influence society
3. understands that society controls science and technology through allocation of resources
4. recognizes the limitations as well as the usefulness of science and technology in advancing human welfare
5. knows the major concepts, hypotheses, and theories of science and is able to use them
6. appreciates science and technology for the intellectual stimulus they provide
7. understands that the generation of scientific knowledge depends on the inquiry process and on conceptual theories
8. distinguishes between scientific evidence and personal opinion
9. recognizes the origin of science and understands that scientific knowledge is tentative and subject to change as evidence accumulates
10. understands the applications of technology and the decisions entailed in the use of technology
11. has sufficient knowledge and experience to appreciate the worthiness of research in the use of technology
12. has a richer and more exciting view of the world as the result of science education
13. knows reliable sources of scientific and technological information and uses these sources in the process of decision making

Although the attributes listed by NSTA include science and the closely related field of technology, the list has served as a basis for more current statements about the aspects of scientific literacy. The list should also be familiar to you in terms of the definition of science provided in Chapter 1. The three components of science, body of knowledge, method/process, and way of knowing or constructing reality, are all visible in the thirteen components listed by NSTA. Can you identify which of the listed items are related to nature of science? In our opinion, items 2, 3, 4, 7, and 9 are closely related to what we described as the nature of science.
According to NSTA, the scientifically literate individual is a person with an in-depth understanding of scientific knowledge, the processes used to develop the knowledge, and the nature of science. Most heavily emphasized is the ability to use this knowledge to make informed decisions about the scientifically and technologically based issues that we face on a daily basis. Although there is no research to support that such decisions are improved by virtue of one’s attainment of the items on NSTA’s list, this list is a good starting point on the way to justifying science as part of the curriculum. In our minds, we think that science can be justified as part of the curriculum simply on the grounds that scientific knowledge empowers the individual and provides him or her with the freedom of not being overly reliant on others.

**Contemporary Reform Efforts in Science Education**

There have been three major attempts to reform science education during the past century, each driven by a different set of circumstances and goals. At the beginning of the 1900s, reform was primarily driven by concerns related to significant increases in industrialization, urbanization, and immigration. The second reform effort followed the Soviet Union’s launching of Sputnik in 1957, with concerns related to national security being the primary driving force. By most accounts, neither of the previous reform efforts produced much change. The third and current effort to reform the quality of our nation’s science education has been driven by economic concerns, as well as those related to our society’s ever increasing reliance on science and technology. It is the current reform effort that has used scientific literacy for all students as a battle cry. There are actually two different reform efforts being masterminded by two separate scientific organizations, the American Association for the Advancement of Science and the National Academy of Sciences. The creation of the current reforms began quietly in 1985 when the American Association for the Advancement of Science (AAAS) began a long-term initiative, known as *Project 2061*, to reform K through 12 education in natural and social science, mathematics, and technology. The first publication of *Project 2061* appeared in 1989. The second reform effort in science education was initiated by the National Research Council (NRC) of the National Academy of Sciences. This reform effort is known as the *National Science Education Standards (NSES)* and was first published in 1996. What makes the current reform efforts different than past efforts is that they are strongly supported by two well-established scientific organizations, and it is for this reason that science educators are more optimistic about the potential effects of the current reforms.

Prior to our discussion of the two reform efforts, it is important for you to keep in mind that, for all the supposed confusion created by two separate ef-
forts, the two reform efforts are quite parallel, with estimates of overlap being as high as 90 percent. As a teacher, you should consider the two sets of reform documents as resources that can guide your instruction and curriculum development almost interchangeably.

**Project 2061**

This project was launched in 1985 under the direction of F. James Rutherford. The project began during the last appearance of Halley’s comet and the hope is that “today’s young people will, as adults, greatly influence what life on earth will be like in 2061, the year Halley’s comet next returns.” Hence, the derivation of the project’s name should be obvious. *Project 2061* is guided by six assertions:

1. Reform must be comprehensive and center on all children, grades, and subjects and represent a long-term commitment.
2. Curriculum reform should be dictated by our collective vision of the lasting knowledge and skills needed by our students and future citizens. Included in the knowledge and skills is a common core of learning and opportunities for learning to serve the particular needs and interests of individual students.
3. The common core of learning in science, mathematics, and technology should focus on science literacy, as opposed to preparation of students for careers in science. The core curriculum should emphasize connections among the natural and social sciences, mathematics, and technology. The connections with these areas and the arts, humanities, and vocational subjects should be clear as well.
4. School should teach less and teach it better. Superficial coverage of specialized terms and algorithms should be eliminated. This is the source of the oft-quoted phrase, “less is more.”
5. Reform should promote equity in science, mathematics, and technology education, serving all students equally well.
6. Reform should allow more approaches for organizing instruction than are currently common. This diversity of approaches provides the flexibility necessitated by state and local circumstances and diversity in student backgrounds.

In 1989, *Project 2061* published its first document, *Science for All Americans*. This text set forth the vision of the project concerning the goals of science literacy. In 1993, *Benchmarks for Science Literacy* translated the vision of *Science for All Americans* into expectations (i.e., benchmarks) for what students should know and be able to do classified by grades K–2, 3–5, 6–8, and 9–12. These specified outcomes, along with the vision of *Science for All Americans*, will be of most value to you as a beginning teacher. The *Benchmarks*, in particular, will be used as a reference point whenever subject matter issues and decisions are discussed.
throughout the rest of this text. The total of 855 benchmarks is distributed into the following major and subordinate categories:

1. Nature of Science
   A. The Scientific World View
   B. Scientific Inquiry
   C. The Scientific Enterprise
2. The Nature of Mathematics
   A. Patterns and Relationships
   B. Mathematics, Science, and Technology
   C. Mathematical Inquiry
3. The Nature of Technology
   A. Technology and Science
   B. Design and Systems
   C. Issues in Technology
4. The Physical Setting
   A. The Universe
   B. The Earth
   C. Processes That Shape the Earth
   D. Structure of Matter
   E. Energy Transformations
   F. Motion
   G. Forces of Nature
5. The Living Environment
   A. Diversity of Life
   B. Heredity
   C. Cells
   D. Interdependence of Life
   E. Flow of Matter and Energy
   F. Evolution of Life
6. The Human Organism
   A. Human Identity
   B. Human Development
   C. Basic Functions
   D. Learning
   E. Physical Health
   F. Mental Health
7. Human Society
   A. Cultural Effects on Behavior
   B. Group Behavior
   C. Social Change
   D. Social Trade-Offs
   E. Political and Economic Systems
   F. Social Conflict
   G. Global Interdependence

8. The Designed World
   A. Agriculture
   B. Materials and Manufacturing
   C. Energy Sources and Use
   D. Communication
   E. Information Processing
   F. Health and Technology

9. The Mathematical World
   A. Numbers
   B. Symbolic Relationships
   C. Shapes
   D. Uncertainty
   E. Reasoning

10. Historical Perspectives
    A. Displacing the Earth from the Center of the Universe
    B. Uniting the Heavens and Earth
    C. Relating Matter and Energy and Time and Space
    D. Extending Time
    E. Moving the Continents
    F. Understanding Fire
    G. Splitting the Atom
    H. Explaining the Diversity of Life
    I. Discovering Germs
    J. Harnessing Power

11. Common Themes
    A. Systems
    B. Models
    C. Constancy and Change
    D. Scale
12. Habits of Mind
   A. Values and Attitudes
   B. Computation and Estimation
   C. Manipulation and Observation
   D. Communication Skills
   E. Critical-Response Skills

The specific content of the expected outcomes should be invaluable in your lesson planning and curriculum development. We strongly encourage you to obtain a copy of the *Benchmarks for Science Literacy* or download a copy from the AAAS website (i.e., www.AAAS.org). The third published aspect of the project is *Resources for Science Literacy: Professional Development* (1997). This book is a professional development tool that is designed to help educators develop curricula, select materials and activities, design instruction, and plan for assessment. The curriculum analysis tool included in this resource is highlighted in Chapter 7. In 1998, the project published *Blueprints for Reform*, a text designed to focus on systemic reform of education. Twelve expert panels were assembled throughout the nation to prepare blueprint papers on all aspects of the education system that must change to accommodate the curriculum reforms proposed by Project 2061. Blueprint papers for the following areas are included: equity, policy, finance, research, school
organization, curriculum connections, materials and technology, assessment, teacher education, higher education, family and community, and business and industry. In addition to those already mentioned the project has also published *Designs for Science Literacy*, which assists educators in the development of local curricula, *Curriculum Materials Resource*, which is a companion to *Resources for Science Literacy: Professional Development*, and the *Atlas of Science Literacy*.

Again, for detailed information concerning specified student outcomes (i.e., benchmarks) or any other information related to *Project 2061*, we strongly recommend that you view AAAS’s website at www.AAAS.org or write to *Project 2061*, AAAS, 1333 H Street, NW, Washington, DC 20005.

**National Science Education Standards**

The origin of the *National Science Education Standards* (NSES) can be traced back to the publication of the mathematics standards by the National Council for Teachers of Mathematics (NCTM) in 1989. The National Science Teachers Association (NSTA) began to develop its own science standards but realized that, because of the diversity of the science education community, it could not continue to lead the development of national standards. Any standards that NSTA produced would be politically viewed as company rather than industry standards. In May 1991, the National Research Council (NRC) of the National Academy of Sciences was asked by the NSTA board of directors, the presidents of several scientific societies, the U.S. secretary of education, the assistant director for education and human resources of the National Science Foundation, and the co-chairs of the National Education Goals Panel to assume responsibility for the development of science education standards. In January 1996, the NRC published the *National Science Education Standards*.

At first glance, it appears that the *NSES* is a more comprehensive endeavor than *Project 2061*, but this is simply because the *NSES* is all placed in a single volume and most individuals do not know that *Project 2061* has numerous documents other than the *Benchmarks*. Both reform efforts have attempted to provide a vision for scientific literacy and a framework for the realization of the vision. The goals for school science specified in the *NSES* are to educate all students so that they are able to (1) use scientific principles and processes appropriately in making personal decisions; (2) experience the richness and excitement of knowing about and understanding the natural world; (3) increase their economic productivity; and (4) engage intelligently in public discourse and debate about matters of scientific and technological concern.

The *NSES* is based on the following four basic principles:

1. Science is for all students.
2. Learning science is an active process.
3. School science reflects the intellectual and cultural traditions that characterize the practice of contemporary science.
4. Improving science education is part of systemic education reform.
Two teachers use the National Science Education Standards to plan their curriculum.

A total of six sets of standards is delineated in the NSES and comprises the overwhelming majority of the published document:

2. *Standards for Professional Development for Teachers of Science* set forth criteria for making judgments about the quality of professional development programs for science teachers.
3. *Assessment in Science Education* offers criteria for making judgments about the quality of assessment practices.
4. *Science Content Standards* outline what students should know, understand, and be able to do in natural science.
5. *Science Education Program Standards* set forth criteria for judging the quality of and conditions for school science programs.
6. *Science Education System Standards* provide criteria for judging the performance of the components of the science education system responsible for providing schools with the financial and intellectual resources necessary to achieve the vision delineated by the standards in the aforementioned areas.

As mentioned before, the NSES places in a single volume what *Project 2061* is attempting to do in multiple publications. As a beginning teacher, one set of
standards that you may find to be particularly useful is the teaching standards. Such standards are not included in any of the Project 2061 publications. A summary of these standards follows:

A. Teachers of science plan an Inquiry-Based Science Program for their students. In doing this, teachers:
   1. Develop a framework of yearlong and short-term goals for students.
   2. Select science content and adapt and design curricula to meet the interests, knowledge, understandings, abilities, and experiences of students.
   3. Select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners.
   4. Work together as colleagues within and across disciplines and grade levels.

B. Teachers of science guide and facilitate learning. In doing this, teachers:
   1. Focus and support inquiries while interacting with students.
   2. Orchestrate discourse among students about scientific ideas.
   3. Challenge students to accept and share responsibility for their own learning.
   4. Recognize and respond to student diversity and encourage all students to participate fully in science learning.
   5. Encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science.

C. Teachers of science engage in ongoing assessment of their teaching and of student learning. In doing this, teachers:
   1. Use multiple methods and systematically gather data about student understanding and ability.
   2. Analyze assessment data to guide teaching.
   4. Use student data, observations of teaching, and interactions with colleagues to reflect on and improve teaching practice.
   5. Use student data, observations of teaching, and interactions with colleagues to report student achievement and opportunities to learn to students, teachers, parents, policy makers, and the general public.

D. Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science. In doing this, teachers:
   1. Structure the time available so that students are able to engage in extended investigations.
2. Create a setting for student work that is flexible and supportive of science inquiry.
3. Ensure a safe working environment.
4. Make the available science tools, materials, media, and technological resources accessible to students.
5. Identify and use resources outside the school.
6. Engage students in designing the learning environment.

E. Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning. In doing this, teachers:
   1. Display and demand respect for the diverse ideas, skills, and experiences of all students.
   2. Enable students to have a significant voice in decisions about the content and context of their work and require students to take responsibility for the learning of all members of the community.
   3. Nurture collaboration among students.
   4. Structure and facilitate ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse.
   5. Model and emphasize the skills, attitudes, and values of scientific inquiry.

F. Teachers of science actively participate in the ongoing planning and development of the school science program. In doing this, teachers:
   1. Plan and develop the school science program.
   2. Participate in decisions concerning the allocation of time and other resources to the science program.
   3. Participate fully in planning and implementing professional growth and development strategies for themselves and their colleagues.

Although the teaching standards are extremely valuable for all teachers, attention is typically placed on the content standards in the NSES. This is the set of standards most comparable to what is found in the Benchmarks for Science Literacy. To ease your initial comparison efforts, the manner in which the NSES organizes the content standards follows.

I. Grades K–12

A. Unifying Concepts and Processes
   1. Systems, order, and organization
   2. Evidence, models, and explanation
   3. Change, constancy, and measurement
   4. Evolution and equilibrium
   5. Form and function
II. Grades K–4
   A. Science as Inquiry
      1. Abilities necessary to do scientific inquiry
      2. Understandings about scientific inquiry
   B. Physical Science
      1. Properties of objects and materials
      2. Position and motion of objects
      3. Light, heat, electricity, and magnetism
   C. Life Science
      1. Characteristics of organisms
      2. Life cycles of organisms
      3. Organisms and environments
   D. Earth and Space Science
      1. Properties of earth materials
      2. Objects in the sky
      3. Changes in earth and sky
   E. Science and Technology
      1. Abilities of technological design
      2. Understandings about science and technology
      3. Abilities to distinguish between natural objects and objects made by humans
   F. Science in Personal and Social Perspectives
      1. Personal health
      2. Characteristics and changes in populations
      3. Types of resources
      4. Changes in environments
      5. Science and technology in local challenges
   G. History and nature of science
      1. Science as a human endeavor

III. Grades 5–8
   A. Science as Inquiry
      1. Abilities necessary to do scientific inquiry
      2. Understandings about scientific inquiry
   B. Physical Science
      1. Properties and changes of properties in matter
      2. Motions and forces
      3. Transfer of energy
C. Life Science
   1. Structure and function in living systems
   2. Reproduction and heredity
   3. Regulation and behavior
   4. Populations and ecosystems
   5. Diversity and adaptations of organisms

D. Earth and Space Science
   1. Structure of the earth system
   2. Earth's history
   3. Earth in the solar system

E. Science and Technology
   1. Abilities of technological design
   2. Understandings about science and technology

F. Science in Personal and Social Perspectives
   1. Personal health
   2. Populations, resources, and environments
   3. Natural hazards
   4. Risks and benefits
   5. Science and technology in society

G. History and Nature of Science
   1. Science as a human endeavor
   2. Nature of science
   3. History of science

IV. Grades 9–12
A. Science as Inquiry
   1. Abilities necessary to do scientific inquiry
   2. Understandings about scientific inquiry

B. Physical Science
   1. Structure of atoms
   2. Structure and properties of matter
   3. Chemical reactions
   4. Motions and forces
   5. Conservation of energy and increase in disorder
   6. Interactions of energy and matter

C. Life Science
   1. The cell
   2. Molecular basis of heredity
3. Biological evolution
4. Interdependence of organisms
5. Matter, energy, and organization in living systems
6. Behavior of organisms

D. Earth and Space Science
1. Energy in the earth system
2. Geochemical cycles
3. Origin and evolution of the earth system
4. Origin and evolution of the universe

E. Science and Technology
1. Abilities of technological design
2. Understandings about science and technology

F. Science in Personal and Social Perspectives
1. Personal and community health
2. Population growth
3. Natural resources
4. Environmental quality
5. Natural and human-induced hazards
6. Science and technology in local, national, and global challenges

G. History and Nature of Science
1. Science as a human endeavor
2. Nature of scientific knowledge
3. Historical perspectives

As we mentioned following our summary of Project 2061, specific details about what the various standards actually expect of students have not been presented here. We strongly encourage you to obtain a copy of the NSES by downloading a copy from its website at www.NAS.edu or writing to National Academy Press, 2101 Constitution Avenue, NW, Lockbox 285, Washington, DC 20055.

Common Themes in the Reforms

You may be feeling a bit overwhelmed by all that is included in the two primary science reform documents. We are sure you are well aware that such documents exist in the other subject areas you will be teaching as well (e.g., mathematics). Fortunately, there are some common themes that transcend the various reform documents that may make you feel a bit more at ease. These themes are important and rather global in nature. They are general statements and characterizations of what is desired and known relative to teaching, learning, curriculum,
and assessment, as opposed to specific content included in the reform documents. The common themes are:

1. constructivism
2. integration
3. nature of science (or nature of other subject matter area)
4. problem solving
5. critical thinking
6. relevancy
7. students' interests
8. communication
9. alternative and authentic assessment

We have already discussed the nature of science in detail in Chapter 1, and you should see it again throughout the instructional examples presented in this text. You will also see numerous references to the remaining eight ideas in the list we have provided. Constructivism and integration are, perhaps, two of the most commonly cited ideas when differences between current and past reforms are discussed. They are also two of the most widely misunderstood aspects of the current reforms, and we think it would be a good idea to quickly clarify the perspective we have taken in this text.

Constructivism is actually not a new idea. It has its roots in the writings of Giambattista Vico in 1710. It has been referred to as a teaching approach, learning theory, and philosophy. Herein lies the first misconception about constructivism. Technically it is an epistemology, which is a branch of philosophy usually referred to as the theory of knowledge. It is concerned with the nature and limits of human knowledge. More specifically, epistemology is concerned with the nature of cognitive processes, sources of human knowledge, and methods of validating ideas. Piaget is probably the most well-known contemporary constructivist. Theoretical notions and jargon aside, what constructivism boils down to is the idea that students, as well as all humans, actively construct their understandings of the world and these constructions are significantly influenced by prior knowledge, beliefs, attitudes, and experiences. According to the constructivist viewpoint, we as humans are limited in our ability to know reality in any absolute sense and are limited to our mental constructions of the world in which we live. If you need a biological description, everything that enters our brains as electrochemical impulses is somehow transformed (i.e., constructed) into the images, sensations, and knowledge we possess. All of the ideas concerning the nature of science and the development of scientific knowledge presented in the preceding chapter are examples of the constructivist perspective.

The first misconception about constructivism is that it is a teaching approach, which implies that students' construction of knowledge depends on whether the teacher uses the correct teaching approach. In actuality, students will construct knowledge whether you lecture or provide them with a hands-on
activity. The key point is whether you accommodate the fact that students are always actively constructing knowledge into your teaching approach. For the teacher, this elevates the importance of finding out what students know about a topic in advance and of consistently monitoring their understanding as instruction proceeds. It also means that if a student thinks that all gases are lighter than air, simply telling the student that he or she is wrong will not be particularly effective. The student needs to experience the behavior of a gas that is not lighter than air (e.g., carbon dioxide) so he or she can reevaluate the validity of such a view and actively revise his or her knowledge.

Closely related to the first misconception is the view that all students’ answers and views are acceptable. It is believed, therefore, that the teacher should not intervene when a student arrives at a conclusion inconsistent with current scientific knowledge. The logic used is that since none of us can know reality in any absolute sense, it would be incorrect to presume one perception is any more valid than any other perception. In short, anything goes. This is not the message of constructivism. Different views of reality are not equally useful. The correct view, in a constructivist framework, is the one that is most consistent with our experiences and prior knowledge. Consequently, the teacher is perfectly justified to intervene, but the intervention should be one that places the student in a situation that causes him or her to reconsider what he or she believes. You will
notice this particular view of constructivism in the instructional examples provided throughout the remainder of this text.

Integration is a second landmark of current reforms and it is as misunderstood as constructivism. To many, integration refers to the total blurring of distinctions among the various subject matter disciplines. For example, students would not know whether they were learning mathematics, science, art, or language arts. The integrated curriculum is typically organized around a real-world problem to be investigated. The philosophy behind the approach is that real-world problems are not solely concerned with one discipline or another, so there is no need to arbitrarily divide the school curriculum into the traditional subject matter areas. The goal is to achieve a school curriculum that realistically reflects the real world. However, this perception of the real world could not be further from the truth. The expansion of knowledge has necessitated specialization. Without exception, every area of study has consistently been divided and subdivided over time. These divisions may be arbitrary distinctions, but this does not argue against their necessity. There is simply too much knowledge for any one individual to know. Consequently, in the real world, there are clearly specialists, and research in science involves teams of individuals with varying specialties. The same is true in the business world. In short, the basic assumption of those who support true integration is simply inaccurate. There are also many other theoretical and practical problems associated with this type of integration. You may also be interested to know that research on the effectiveness of true integration does not support its effectiveness relative to discipline-based instruction. We say true integration, because many use the word imprecisely and are actually talking about interdisciplinary instruction.

Interdisciplinary instruction is an approach that makes clear the interactions and connections among the various disciplines, while remaining aware of the differences between mathematics, science, art, and literature. The perspective provided in the instructional examples presented in this text supports an interdisciplinary view and we think such a view is most feasible for the elementary teacher. Consequently, you will notice a strong attempt to make connections between science instruction and instruction in language arts without any attempt to blur the distinctions between the two disciplines.

Specific Comparisons between the Science Reforms

Take a few moments to review our summaries of Project 2061 and the National Science Education Standards. List any specific similarities or differences that you can see, keeping in mind that we have only provided an overview of each, with few specifics. Were they more similar than different or more different than similar? Perhaps the clearest difference between the two is that the NSES attempts to provide standards for content as well as the rest of the educational system in a
single volume, whereas Project 2061 tries to present the same information across several publications. One advantage that the NSES clearly has over Project 2061 is its clear delineation of teaching standards. Project 2061 has a short section on science teaching in *Science for All Americans*, but it is not as extensive as the NSES. You may have also noticed that the content standards of each are organized a bit differently. Project 2061 specifies four grade-level clusters whereas NSES specifies only three. In each case, what is listed is what students should know and be able to do upon completion of the highest grade level within each cluster. If you teach second grade, *Project 2061* may be more useful to you since it has a K–2 grade cluster, whereas the NSES has a K–4 cluster. You may also have noticed that the NSES uses grade levels to organize its content standards, whereas *Project 2061* uses general topic areas to organize its standards. There is probably no specific advantage of one organizing approach versus the other. Again, let us remind you that the specific learning outcomes were not presented in our summary. To learn more about the specific standards or benchmarks you will need to get a copy of the documents. *Project 2061* has performed a systematic comparison between the two reform documents relative to the specified content standards and has determined that there is an overlap exceeding 90 percent. So, if you remain unsure about which reform documents to use, either one will probably suffice in terms of what students are expected to know and do.

You may have noticed within the language of the NSES content standards the use of phrases such as "abilities necessary to" and "understandings about." Within the actual standards, counterparts of this language take the form of "know that" and "be able to." Similar phrases are used in the stems of the *Project 2061* Benchmarks. This language is not used loosely and is critically important to the message of the NSES and *Project 2061*. Both of the reform documents specify two types of learning outcomes for students. These are what *students should know* as well as what *students should be able to do*. Although the content standards of the two reform efforts overlap much more than they differ, the most significant difference between the two is with respect to this language use when it comes to scientific inquiry. It is important to note at this point that scientific inquiry is used in three different ways within the reform documents. It is viewed as a teaching approach, a set of skills and processes to be performed, and as a cognitive outcome. Both NSES and *Project 2061* advocate the use of an inquiry-oriented approach to instruction. This approach is consistent with constructivism and the goals advocating the importance of problem solving and critical thinking. The two reforms also specify that students should know about scientific inquiry (i.e., the cognitive outcome). However, the NSES is more ambitious because it also expects all students to be able to *do* scientific inquiry. That is, the NSES expects all students to be able to develop a research question, develop an appropriate research design, carry out the design, and report the results of an independent scientific investigation. Although *Project 2061* values such experiences, it only specifies that students should know about inquiry as a learning outcome.
A Few Words about the Teaching of Scientific Inquiry

The teaching of scientific inquiry in terms of skills and processes to be performed is rather straightforward and has been a goal of science instruction for many years. Students need to see these skills performed and modeled by the teacher, and they then need plenty of opportunities to practice what they have learned how to do in many different contexts. However, the knowledge about inquiry is an instructional objective that is emphasized more in the current reforms than ever before and it presents some of the same problems we mentioned regarding the teaching of the nature of science. In particular, it is not uncommon for teachers to assume that if students are performing scientific inquiry they will necessarily reflect on what they have done and implicitly learn about inquiry. For example, if students perform an investigation that includes a control group, it is assumed that students will also come to know the importance of a control group to experimental design. It is assumed that if students perform scientific investigations that are designed in a variety of ways and never follow the same procedures, then they will implicitly learn that there is no single scientific method. In reality, this is not what occurs. The situation is no different than breathing. You have been breathing all your life, but can you necessarily explain the mechanics of breathing? Probably not, unless your area of interest is life science. If you want your students to learn about inquiry, you will need to explicitly address understandings about inquiry while your students are doing inquiry. Simply put, doing is not the same as understanding. However, it is our opinion that students are much more likely to do a better job of doing if they understand something about what it is they are doing.

Instructional outcomes pertaining to knowledge about inquiry have the same requirements as instructional outcomes pertaining to the nature of science. Both of these topics and ideas need to be explicitly addressed during instruction. Experiencing science will not necessarily promote understandings of the nature of science or scientific inquiry. As you read through the various lessons in the chapters that follow, try to keep in the back of your mind those places where understandings about scientific inquiry and the nature of science could be incorporated into what we have presented.

Summary

Our discussion of scientific literacy and how it relates to the contemporary needs of your students and future voting citizens should have helped you begin the process of developing a vested interest in the teaching of science in the elementary school grades. We think you should see its importance above and beyond preparing your students for the science courses they will take in middle school.
You are preparing your students for all of life, not just to pass a course they will take in future grades.

Although it may be reassuring to note that your views are supported by current reform documents, you may well be wondering why you should know anything about these reform efforts because the state in which you work will undoubtedly have its own standards for you to follow. Although many states have chosen to develop their own content standards, they have used one or both of the national reform efforts as a guiding framework. Consequently, you will not find a significant difference between what your state requires and what is specified in either of these reform documents. In some states the deviation may be more than others, but there is a general consistency. Knowledge of NSES and Project 2061 will be very useful to you as it will best prepare you to work in any state across the nation. A complete listing of publications currently available from NSES and Project 2061 can be found at the end of this chapter. If nothing else, the reform documents will help you make decisions concerning the appropriateness of specific learning outcomes at the grade level that you teach. Furthermore, we will connect all learning outcomes specified in the latter sections of this text to both reform efforts whenever possible.

**Suggested Readings**


rooms have risen to the challenge and produced a superb
Rodger W. Bybee, Executive Director BSCS, Colorado Springs, CO
friendly compendium of educational theory, teaching
and have extensive experience in teaching all aspects of
Sandra K. Abell University of Missouri, Columbia
arithmetic and Science Teaching Foundation, Haddonfield, NJ
and have extensive experience in teaching all aspects of
and Benchmarks for Science Literacy, this new
classroom instruction through the authors' unique
Goal Setting: Materials Development and Selection;
commended to national reform recommendations.
including the National Science Education Standards and
are featured in Chapter 6.
alistic glimpse of a teacher's planning and instructional
incorporated as feature boxes throughout each of the Teaching
Science and Science Education at the Illinois Institute of Technology:
inquiry and the nature of science. He has worked extensively
in the Department of Mathematics and Science Education
nationally and internationally on the teaching and learning
ost proud of the years she has spent teaching science in
in the Curry School of Education at the University of Virginia.
Bell taught middle and high school science in Oregon, where
of the Year" in 1991.

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