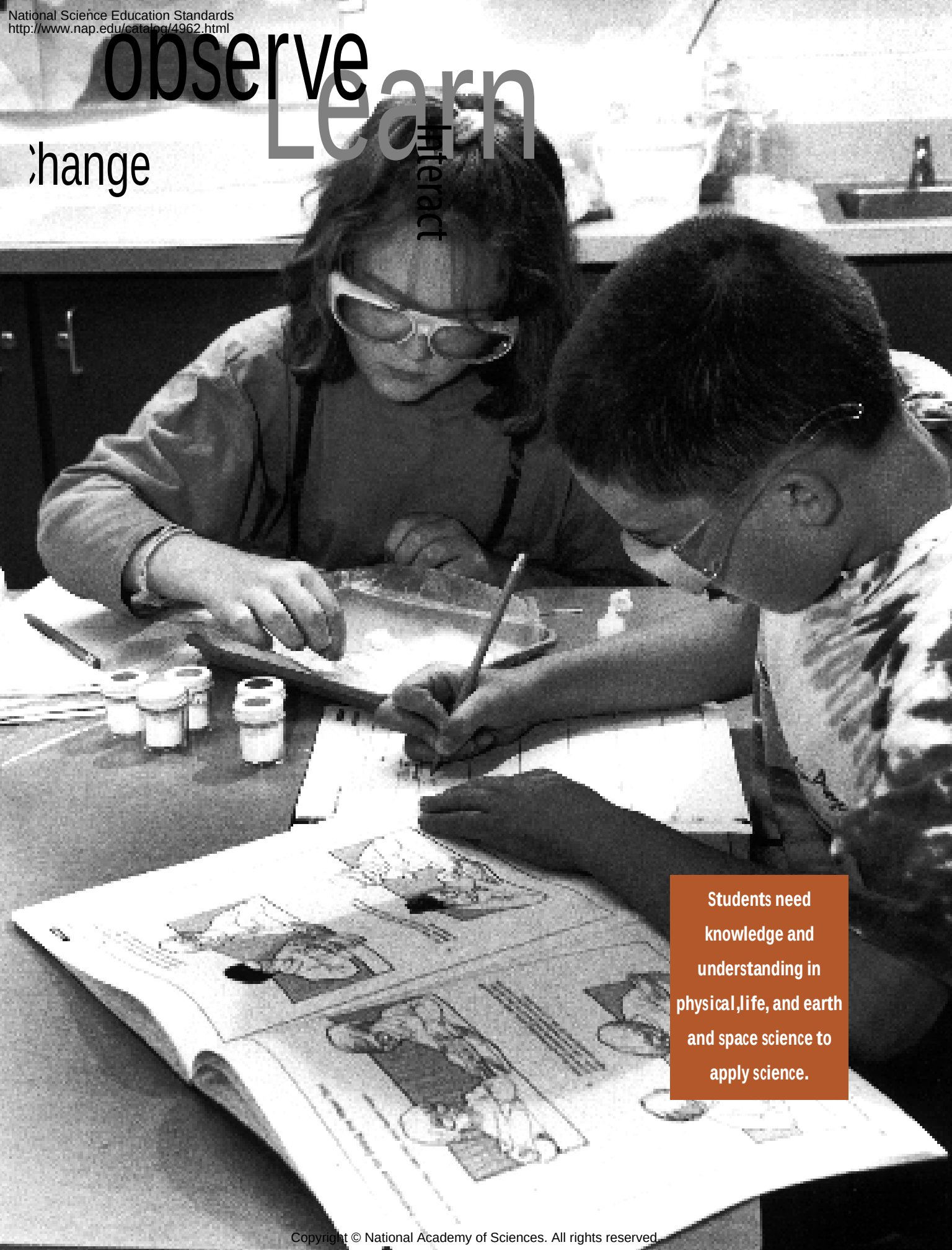


Students need knowledge and understanding in physical, life, and earth and space science to apply science.

Science Content Standards

The content standards presented in this chapter outline what students should know, understand, and be able to do in natural science. The content standards are a complete set of outcomes for students; they do not prescribe a curriculum. These standards were designed and developed as one component of the comprehensive vision of science education presented in the *National Science Education Standards* and will be most effective when used in conjunction with all of the standards described in this book. Furthermore, implementation of the content standards cannot be successful if only a subset of the content standards is used (such as implementing only the subject matter standards for physical, life, and earth science). This introduction sets the framework for the content standards by describing the categories of the content standards with a rationale for

each category, the form of the standards, the criteria used to select the standards, and some advice for using the science content standards.

Rationale

The eight categories of content standards are

- **Unifying concepts and processes in science.**
- **Science as inquiry.**
- **Physical science.**
- **Life science.**
- **Earth and space science.**
- **Science and technology.**
- **Science in personal and social perspectives.**
- **History and nature of science.**

The standard for unifying concepts and processes is presented for grades K-12, because the understanding and abilities associated with major conceptual and procedural schemes need to be developed over an entire education, and the unifying concepts and processes transcend disciplinary boundaries. The next seven categories are clustered for grades K-4, 5-8, and 9-12. Those clusters were selected based on a combination of factors, including cognitive development theory, the classroom experience of teachers, organization of schools, and the frameworks of other disciplinary-based standards. References for additional reading for all the content standards are presented at the end of Chapter 6.

The sequence of the seven grade-level content standards is not arbitrary: Each standard subsumes the knowledge and skills of other standards. Students' understandings and abilities are grounded in the experience of inquiry, and inquiry is the foundation for the development of understandings and abilities of the other content standards. The personal and social aspects of science are emphasized increasingly in the progression from science as inquiry standards to the history and nature of science standards. Students need solid knowledge and understanding in physical, life, and earth and space science if they are to apply science.

Multidisciplinary perspectives also increase from the subject-matter standards to the standard on the history and nature of science, providing many opportunities for integrated approaches to science teaching.

UNIFYING CONCEPTS AND PROCESSES STANDARD

Conceptual and procedural schemes unify science disciplines and provide students with powerful ideas to help them understand the natural world. Because of the underlying principles embodied in this standard, the understandings and abilities described here are repeated in the other content standards. Unifying concepts and processes include

- **Systems, order, and organization.**
- **Evidence, models, and explanation.**
- **Change, constancy, and measurement.**
- **Evolution and equilibrium.**
- **Form and function.**

This standard describes some of the integrative schemes that can bring together students' many experiences in science education across grades K-12. The unifying concepts and processes standard can be the focus of instruction at any grade level but should always be closely linked to outcomes aligned with other content standards. In the

early grades, instruction should establish the meaning and use of unifying concepts and processes—for example, what it means to measure and how to use measurement tools. At the upper grades, the standard should facilitate and enhance the learning of scientific concepts and principles by providing students with a big picture of scientific ideas—for example,how measurement is important in all scientific endeavors.

SCIENCE AS INQUIRY STANDARDS

In the vision presented by the *Standards*, inquiry is a step beyond "science as a process," in which students learn skills, such as observation, inference, and experimentation. The new vision includes the "processes of science" and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science. Engaging students in inquiry helps students develop

- Understanding of scientific concepts.
- An appreciation of "how we know" what we know in science.
- Understanding of the nature of science.
- Skills necessary to become independent inquirers about the natural world.
- The dispositions to use the skills,abilities, and attitudes associated with science.

Science as inquiry is basic to science education and a controlling principle in the ultimate organization and selection of students' activities. The standards on inquiry highlight the ability to conduct inquiry and develop understanding about scientific inquiry. Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions,planning and conducting investigations,using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. Table 6.1 shows the standards for inquiry. The science as inquiry standards are described in terms of activities resulting in student development of certain abilities and in terms of student understanding of inquiry.

TABLE 6.1. SCIENCE AS INQUIRY STANDARDS

LEVELS K-4	LEVELS 5-8	LEVELS 9-12
Abilities necessary to do scientific inquiry	Abilities necessary to do scientific inquiry	Abilities necessary to do scientific inquiry
Understanding about scientific inquiry	Understanding about scientific inquiry	Understanding about scientific inquiry

PHYSICAL SCIENCE, LIFE SCIENCE, AND EARTH AND SPACE SCIENCE STANDARDS

The standards for physical science, life science, and earth and space science describe the subject matter of science using three widely accepted divisions of the domain of science. Science subject matter focuses on the science facts, concepts, principles, theories, and models that are important for all students to know, understand, and use. Tables 6.2, 6.3, and 6.4 are the standards for physical science, life science, and earth and space science, respectively.

SCIENCE AND TECHNOLOGY STANDARDS

The science and technology standards in Table 6.5 establish connections between the natural and designed worlds and provide students with opportunities to develop decision-making abilities. They are not standards for technology education; rather, these standards emphasize abilities associated with the process of design and fundamental understandings about the enterprise of science and its various linkages with technology.

As a complement to the abilities developed in the science as inquiry standards,

TABLE 6.2. PHYSICAL SCIENCE STANDARDS

LEVELS K-4	LEVELS 5-8	LEVELS 9-12
Properties of objects and materials	Properties and changes of properties in matter	Structure of atoms
Position and motion of objects	Motions and forces	Structure and properties of matter
Light, heat, electricity, and magnetism	Transfer of energy	Chemical reactions
		Motions and forces
		Conservation of energy and increase in disorder
		Interactions of energy and matter

TABLE 6.3. LIFE SCIENCE STANDARDS

LEVELS K-4	LEVELS 5-8	LEVELS 9-12
Characteristics of organisms	Structure and function in living systems	The cell
Life cycles of organisms	Reproduction and heredity	Molecular basis of heredity
Organisms and environments	Regulation and behavior	Biological evolution
	Populations and ecosystems	Interdependence of organisms
	Diversity and adaptations of organisms	Matter, energy, and organization in living systems
		Behavior of organisms

these standards call for students to develop abilities to identify and state a problem, design a solution—including a cost and risk-and-benefit analysis—implement a solution,and evaluate the solution.

Science as inquiry is parallel to technology as design. Both standards emphasize student development of abilities and understanding. Connections to other domains, such as mathematics, are clarified in Chapter 7, *Program Standards*.

SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES STANDARDS

An important purpose of science education is to give students a means to understand and act on personal and social issues. The science in personal and social perspectives standards help students develop decision-making skills. Understandings associated with the concepts in Table 6.6 give students a foundation on which to base decisions they will face as citizens.

HISTORY AND NATURE OF SCIENCE STANDARDS

In learning science,students need to understand that science reflects its history and is an ongoing, changing enterprise. The standards for the history and nature of science recommend the use of history in school science programs to clarify different aspects of scientific inquiry, the human aspects of science, and the role that science has played in the development of various cultures. Table 6.7 provides an overview of this standard.

TABLE 6.4. EARTH AND SPACE SCIENCE STANDARDS

LEVELS K-4	LEVELS 5-8	LEVELS 9-12
Properties of earth materials	Structure of the earth system	Energy in the earth system
Objects in the sky	Earth's history	Geochemical cycles
Changes in earth and sky	Earth in the solar system	Origin and evolution of the earth system
		Origin and evolution of the universe

TABLE 6.5. SCIENCE AND TECHNOLOGY STANDARDS

LEVELS K-4	LEVELS 5-8	LEVELS 9-12
Abilities to distinguish between natural objects and objects made by humans	Abilities of technological design	Abilities of technological design
Abilities of technological design	Understanding about science and technology	Understanding about science and technology
Understanding about science and technology		

TABLE 6.6. SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES

LEVELS K-4	LEVELS 5-8	LEVELS 9-12
Personal health	Personal health	Personal and community health
Characteristics and changes in populations	Populations, resources, and environments	Population growth
Types of resources	Natural hazards	Natural resources
Changes in environments	Risks and benefits	Environmental quality
Science and technology in local challenges	Science and technology in society	Natural and human-induced hazards
		Science and technology in local, national, and global challenges

TABLE 6.7. HISTORY AND NATURE OF SCIENCE STANDARDS

LEVELS K-4	LEVELS 5-8	LEVELS 9-12
Science as a human endeavor	Science as a human endeavor	Science as a human endeavor
	Nature of science	Nature of scientific knowledge
	History of science	Historical perspectives

Form of the Content Standards

Below is an example of a content standard. Each content standard states that, as the result of activities provided for all students in the grade level discussed, the content of the standard is to be understood or the abilities are to be developed.

PHYSICAL SCIENCE (EXAMPLE)

CONTENT STANDARD B:
As a result of the activities in grades K-4, all students should develop an understanding of

- **Properties of objects and materials**
- **Position and motion of objects**
- **Light, heat, electricity, and magnetism**

After each content standard is a section entitled, Developing Student Understanding (or abilities and understanding, when appropriate), which elaborates upon issues associated with opportunities to learn the content. This section describes linkages among student learning, teaching, and classroom situations. This discussion on developing student understanding, including the remarks on the selection of content for grade levels, is based in part on educational research. It also incorporates the experiences of many thoughtful people, including teachers, teacher educators, curriculum developers, and educational researchers. (Some references to research on student understanding and abilities are located at the end of the chapter.)

The next section of each standard is a Guide to the Content Standard, which

describes the fundamental ideas that underlie the standard. Content is fundamental if it

- Represents a central event or phenomenon in the natural world.
- Represents a central scientific idea and organizing principle.
- Has rich explanatory power.
- Guides fruitful investigations.
- Applies to situations and contexts common to everyday experiences.
- Can be linked to meaningful learning experiences.
- Is developmentally appropriate for students at the grade level specified.

Criteria for the Content Standards

Three criteria influence the selection of science content. The first is an obligation to the domain of science. The subject matter in the physical, life, and earth and space science standards is central to science education and must be accurate. The presentation in national standards also must accommodate the needs of many individuals who will implement the standards in school science programs. The standards represent science

TABLE 6.8. CONTENT STANDARDS, GRADES K-4

UNIFYING CONCEPTS AND PROCESSES	SCIENCE AS INQUIRY	PHYSICAL SCIENCE	LIFE SCIENCE
Systems, order, and organization Evidence, models, and explanation Change, constancy, and measurement Evolution and equilibrium Form and function	Abilities necessary to do scientific inquiry Understandings about scientific inquiry	Properties of objects and materials Position and motion of objects Light, heat, electricity, and magnetism	Characteristics of organisms Life cycles of organisms Organisms and environments

EARTH AND SPACE SCIENCE	SCIENCE AND TECHNOLOGY	SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES	HISTORY AND NATURE OF SCIENCE
Properties of earth materials Objects in the sky Changes in earth and sky	Abilities of technological design Understandings about science and technology Abilities to distinguish between natural objects and objects made by humans	Personal health Characteristics and changes in populations Types of resources Changes in environments Science and technology in local challenges	Science as a human endeavor

content accurately and appropriately at all grades, with increasing precision and more scientific nomenclature from kindergarten to grade 12.

The second criterion is an obligation to develop content standards that appropriately represent the developmental and learning abilities of students. Organizing principles were selected that express meaningful links to direct student observations of the natural world. The content is aligned with students' ages and stages of development. This criterion includes increasing emphasis on abstract and conceptual understandings as students progress from kindergarten to grade 12.

Tables 6.8, 6.9, and 6.10 display the standards grouped according to grade levels K-4, 5-8, and 9-12, respectively. These tables provide an overview of the standards for elementary-, middle-, and high-school science programs.

The third criterion is an obligation to present standards in a usable form for those who must implement the standards, e.g., curriculum developers, science supervisors, teachers, and other school personnel. The standards need to provide enough breadth of content to define the domains of science, and they need to provide enough depth of content to direct the design of science curricula. The descriptions also need to be understandable by school personnel and to accommodate the structures of elementary, middle, and high schools, as well as the grade levels used in national standards for other disciplines.

TABLE 6.9. CONTENT STANDARDS, GRADES 5-8

UNIFYING CONCEPTS AND PROCESSES	SCIENCE AS INQUIRY	PHYSICAL SCIENCE	LIFE SCIENCE
Systems, order, and organization	Abilities necessary to do scientific inquiry	Properties and changes of properties in matter	Structure and function in living systems
Evidence, models, and explanation	Understandings about scientific inquiry	Motions and forces	Reproduction and heredity
Change, constancy, and measurement		Transfer of energy	Regulation and behavior
Evolution and equilibrium			Populations and ecosystems
Form and function			Diversity and adaptations of organisms

EARTH AND SPACE SCIENCE	SCIENCE AND TECHNOLOGY	SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES	HISTORY AND NATURE OF SCIENCE
Structure of the earth system	Abilities of technological design	Personal health	Science as a human endeavor
Earth's history	Understandings about science and technology	Populations, resources, and environments	Nature of science
Earth in the solar system		Natural hazards	History of science
		Risks and benefits	
		Science and technology in society	

TABLE 6.10. CONTENT STANDARDS, GRADES 9-12

UNIFYING CONCEPTS AND PROCESSES	SCIENCE AS INQUIRY	PHYSICAL SCIENCE	LIFE SCIENCE
Systems, order, and organization	Abilities necessary to do scientific inquiry	Structure of atoms	The cell
Evidence, models,and explanation	Understandings about scientific inquiry	Structure and properties of matter	Molecular basis of heredity
Change, constancy, and measurement		Chemical reactions	Biological evolution
Evolution and equilibrium		Motions and forces	Interdependence of organisms
Form and function		Conservation of energy and increase in disorder	Matter, energy, and organization in living systems
		Interactions of energy and matter	Behavior of organisms

EARTH AND SPACE SCIENCE	SCIENCE AND TECHNOLOGY	SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES	HISTORY AND NATURE OF SCIENCE
Energy in the earth system	Abilities of technological design	Personal and community health	Science as a human endeavor
Geochemical cycles	Understandings about science and techology	Population growth	Nature of scientific knowledge
Origin and evolution of the earth system		Natural resources	Historical perspectives
Origin and evolution of the universe		Environmental quality	
		Natural and human-induced hazards	
		Science and technology in local,national,and global challenges	

Use of the Content Standards

Many different individuals and groups will use the content standards for a variety of purposes. *All users and reviewers are reminded that the content described is not a science curriculum*. Content is what students should learn. Curriculum is the way content is organized and emphasized; it includes structure, organization,balance, and presentation of the content in the classroom. Although the structure for the content standards organizes the understanding and abilities to be acquired by all students K-12,that structure does not imply any particular organization for science curricula.

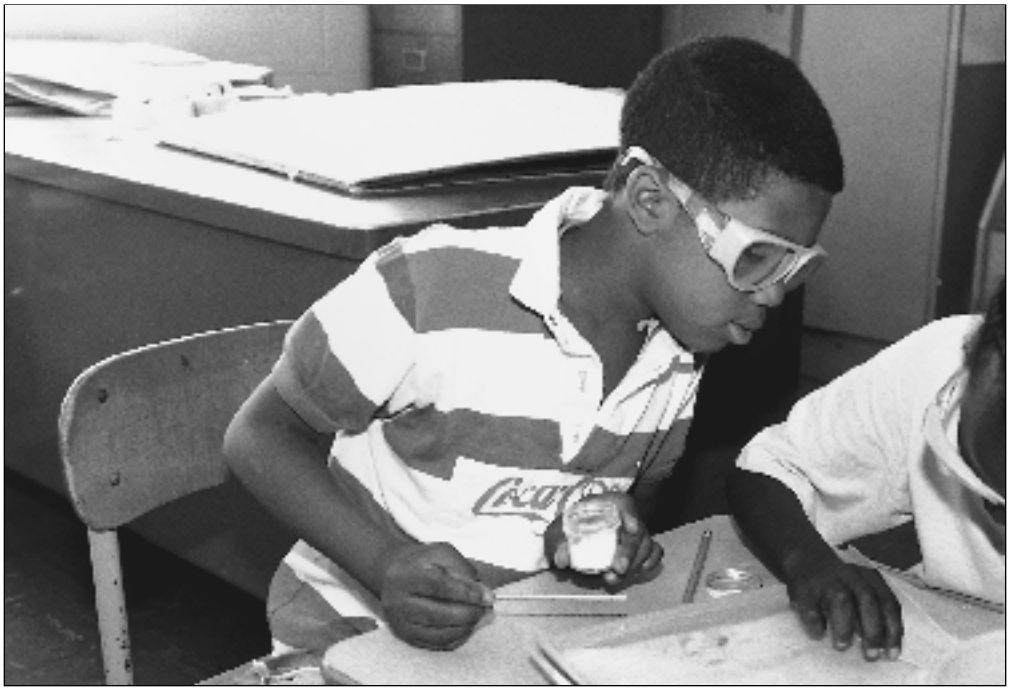
Persons responsible for science curricula, teaching, assessment and policy who use the *Standards* should note the following

- None of the eight categories of content

standards should be eliminated. For instance, students should have opportunities to learn science in personal and social perspectives and to learn about the history and nature of science, as well as to learn subject matter, in the school science program.

- No standards should be eliminated from a category. For instance, "biological evolution" cannot be eliminated from the life science standards.
- Science content can be added. The connections, depth, detail, and selection of topics can be enriched and varied as appropriate for individual students and school science programs. However, addition of content must not prevent the learning of fundamental concepts by all students.
- The content standards must be used in the context of the standards on teaching and assessment. Using the standards with traditional teaching and assessment strategies defeats the intentions of the *National Science Education Standards*.

As science advances, the content standards might change, but the conceptual organization will continue to provide students with knowledge, understanding, and abilities that will improve their scientific literacy.



CHANGING EMPHASES

The *National Science Education Standards* envision change throughout the system. The science content standards encompass the following changes in emphases:

LESS EMPHASIS ON	MORE EMPHASIS ON
Knowing scientific facts and information	Understanding scientific concepts and developing abilities of inquiry
Studying subject matter disciplines (physical, life, earth sciences) for their own sake	Learning subject matter disciplines in the context of inquiry, technology, science in personal and social perspectives, and history and nature of science
Separating science knowledge and science process	Integrating all aspects of science content
Covering many science topics	Studying a few fundamental science concepts
Implementing inquiry as a set of processes	Implementing inquiry as instructional strategies, abilities, and ideas to be learned

CHANGING EMPHASES TO PROMOTE INQUIRY

LESS EMPHASIS ON	MORE EMPHASIS ON
Activities that demonstrate and verify science content	Activities that investigate and analyze science questions
Investigations confined to one class period	Investigations over extended periods of time
Process skills out of context	Process skills in context
Emphasis on individual process skills such as observation or inference	Using multiple process skills—manipulation, cognitive, procedural
Getting an answer	Using evidence and strategies for developing or revising an explanation
Science as exploration and experiment	Science as argument and explanation
Providing answers to questions about science content	Communicating science explanations
Individuals and groups of students analyzing and synthesizing data without defending a conclusion	Groups of students often analyzing and synthesizing data after defending conclusions
Doing few investigations in order to leave time to cover large amounts of content	Doing more investigations in order to develop understanding, ability, values of inquiry and knowledge of science content
Concluding inquiries with the result of the experiment	Applying the results of experiments to scientific arguments and explanations
Management of materials and equipment	Management of ideas and information
Private communication of student ideas and conclusions to teacher	Public communication of student ideas and work to classmates