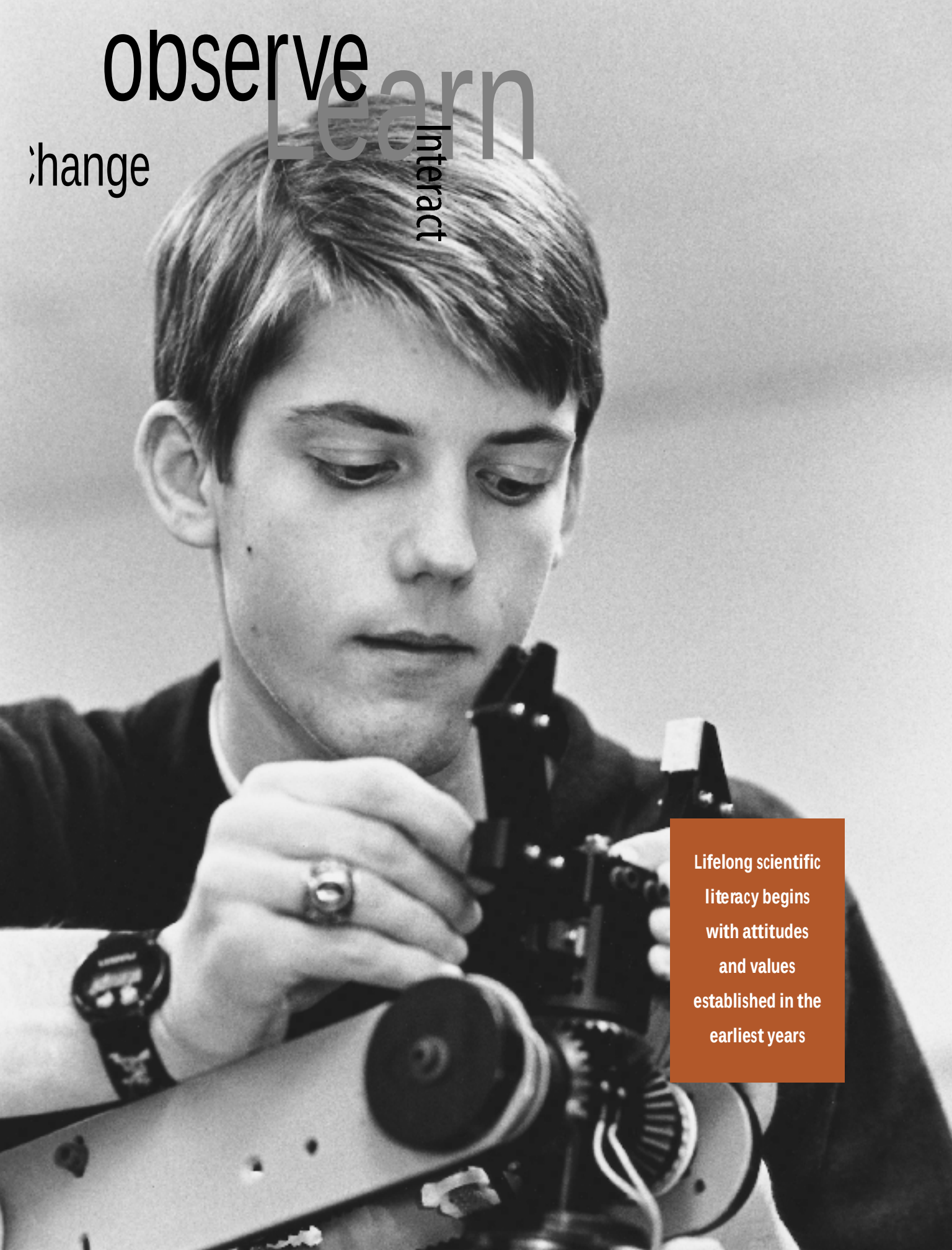
observe
Learn
Interact
:hange
Lifelong scientific literacy begins with attitudes and values established in the earliest years

Content Standard: K—12

Unifying Concepts and Processes

STANDARD: As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes:

- **Systems, order, and organization**
- **Evidence, models, and explanation**
- **Constancy, change, and measurement**
- **Evolution and equilibrium**
- **Form and function**

DEVELOPING STUDENT UNDERSTANDING

This standard presents broad unifying concepts and processes that complement the analytic, more discipline-based perspectives presented in the other content standards. The conceptual and procedural schemes in this standard provide students with productive and insightful ways of thinking about and integrating a range of basic ideas that explain the natural and designed world.

The unifying concepts and processes in this standard are a subset of the many unifying ideas in science and technology. Some of the criteria used in the selection and organization of this standard are

- The concepts and processes provide connections between and among traditional scientific disciplines.
- The concepts and processes are fundamental and comprehensive.
- The concepts and processes are understandable and usable by people who will implement science programs.
- The concepts and processes can be expressed and experienced in a developmentally appropriate manner during K-12 science education.

Each of the concepts and processes of this standard has a continuum of complexity that

lends itself to the K-4, 5-8, and 9-12 grade-level clusters used in the other content standards. In this standard, however, the boundaries of disciplines and grade-level divisions are not distinct—teachers should develop students' understandings continuously across grades K-12.

Systems and subsystems, the nature of models, and conservation are fundamental concepts and processes included in this standard. Young students tend to interpret phenomena separately rather than in terms of a system. Force, for example, is perceived as a property of an object rather than the result of interacting bodies. Students do not recognize the differences between parts and whole systems, but view them as similar. Therefore, teachers of science need to help students recognize the properties of objects, as emphasized in grade-level content standards, while helping them to understand systems.

As another example, students in middle school and high school view models as physical copies of reality and not as conceptual representations. Teachers should help students understand that models are developed and tested by comparing the model with observations of reality.

Teachers in elementary grades should recognize that students' reports of changes in such things as volume, mass, and space can represent errors common to well-recognized developmental stages of children.

GUIDE TO THE CONTENT STANDARD

Some of the fundamental concepts that underlie this standard are

SYSTEMS, ORDER, AND ORGANIZATION The natural and designed world is complex; it is too large and complicated to investigate and comprehend all at once. Scientists and students learn to define small portions for the convenience of investigation. The units of investigation can be referred to as "systems." A system is an organized group of related objects or components that form a whole. Systems can consist, for example, of organisms, machines, fundamental particles, galaxies, ideas, numbers, transportation, and education. Systems have boundaries, components, resources flow (input and output), and feedback.

The goal of this standard is to think and analyze in terms of systems. Thinking and analyzing in terms of systems will help students keep track of mass, energy, objects, organisms, and events referred to in the other content standards. The idea of simple systems encompasses subsystems as well as identifying the structure and function of systems, feedback and equilibrium, and the distinction between open and closed systems.

Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere,and that it is understandable and predictable. Students can develop an understanding of regularities in systems, and by extension, the universe; they then can develop understanding of basic laws, theories, and models that explain the world.

Newton's laws of force and motion, Kepler's laws of planetary motion, conservation laws, Darwin's laws of natural selection, and chaos theory all exemplify the idea of order and regularity. An assumption of order establishes the basis for cause-effect relationships and predictability.

Prediction is the use of knowledge to identify and explain observations, or changes,in advance. The use of mathematics, especially

See Program Standard C

probability, allows for greater or lesser certainty of predictions.

Order—the behavior of units of matter, objects, organisms, or events in the universe—can be described statistically. Probability is the relative certainty (or uncertainty) that individuals can assign to selected events happening (or not happening) in a specified space or time. In science, reduction of uncertainty occurs through such processes as the development of knowledge about factors influencing objects, organisms, systems, or events; better and more observations; and better explanatory models.

Types and levels of organization provide useful ways of thinking about the world. Types of organization include the periodic table of elements and the classification of organisms. Physical systems can be described at different levels of organization—such as fundamental particles, atoms, and molecules. Living systems also have different levels of organization—for example, cells, tissues, organs, organisms, populations, and communities. The complexity and number of fundamental units change in extended hierarchies of organization. Within these systems, interactions between components occur. Further, systems at different levels of organization can manifest different properties and functions.

EVIDENCE, MODELS, AND EXPLANATION

Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems.

See Content Standard A (all grade levels)

Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. Different terms, such as "hypothesis," "model," "law," "principle," "theory," and "paradigm" are used to describe various types of scientific explanations. As students develop and as they understand more science concepts and processes, their explanations should become more sophisticated. That is, their scientific explanations should more frequently include a rich scientific knowledge base, evidence of logic, higher levels of analysis, greater tolerance of criticism and uncertainty, and a clearer demonstration of the relationship between logic, evidence, and current knowledge.

As students develop and…understand more science concepts and processes, their explanations should become more sophisticated…frequently reflecting a rich scientific knowledge base, evidence of logic, higher levels of analysis, and greater tolerance of criticism and uncertainty.

CONSTANCY, CHANGE, AND MEASUREMENT

Although most things are in the process of becoming different—changing—some properties of objects and processes are characterized by constancy, including the speed

See Content Standard B (grades 9-12)

of light, the charge of an electron, and the total mass plus energy in the universe. Changes might occur, for example, in properties of materials, position of objects, motion, and form and function of systems. Interactions within and among systems result in change. Changes vary in rate, scale, and pattern, including trends and cycles.

Energy can be transferred and matter can be changed. Nevertheless, when measured, the sum of energy and matter in systems, and by extension in the universe, remains the same.

Changes in systems can be quantified. Evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions—measurement. Mathematics is essential for accurately measuring change.

Different systems of measurement are used for different purposes. Scientists usually use the metric system. An important part of measurement is knowing when to use which system. For example, a meteorologist might use degrees Fahrenheit when reporting the weather to the public, but in writing scientific reports, the meteorologist would use degrees Celsius.

Scale includes understanding that different characteristics, properties, or relationships within a system might change as its dimensions are increased or decreased.

Rate involves comparing one measured quantity with another measured quantity, for example, 60 meters per second. Rate is also a measure of change for a part relative to the whole, for example, change in birth rate as part of population growth.

EVOLUTION AND EQUILIBRIUM

See Content Standard C (grades 9-12)

Evolution is a series of changes, some gradual and some sporadic, that accounts for the present form and function of objects, organisms,and natural and designed systems. The general idea of evolution is that the present arises from materials and forms of the past. Although evolution is most commonly associated with the biological theory explaining the process of descent with modification of organisms from common ancestors, evolution also describes changes in the universe.

Equilibrium is a physical state in which forces and changes occur in opposite and off-setting directions: for example, opposite forces are of the same magnitude, or off-setting changes occur at equal rates. Steady state,balance, and homeostasis also describe equilibrium states. Interacting units of matter tend toward equilibrium states in which the energy is distributed as randomly and uniformly as possible.

See Content Standard C (grades 5-8)

FORM AND FUNCTION Form and function are complementary aspects of objects, organisms,and systems in the natural and designed world. The form or shape of an object or system is frequently related to use, operation, or function. Function frequently relies on form. Understanding of form and function applies to different levels of organization. Students should be able to explain function by referring to form and explain form by referring to function.