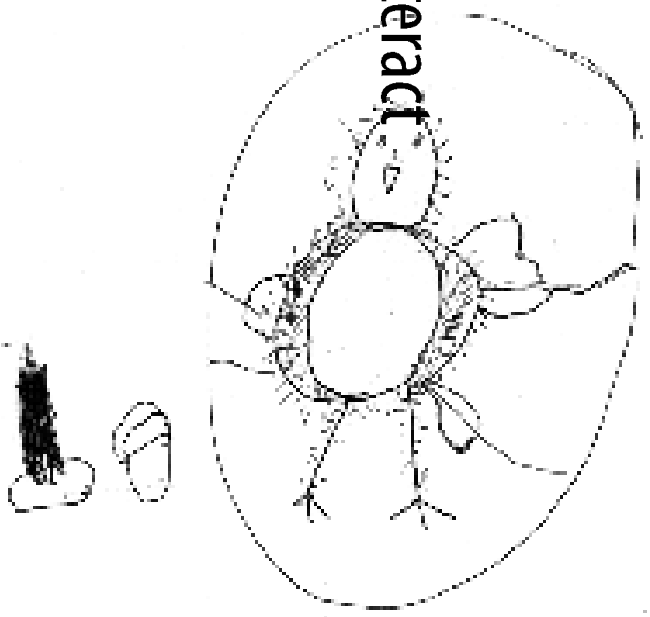
observe

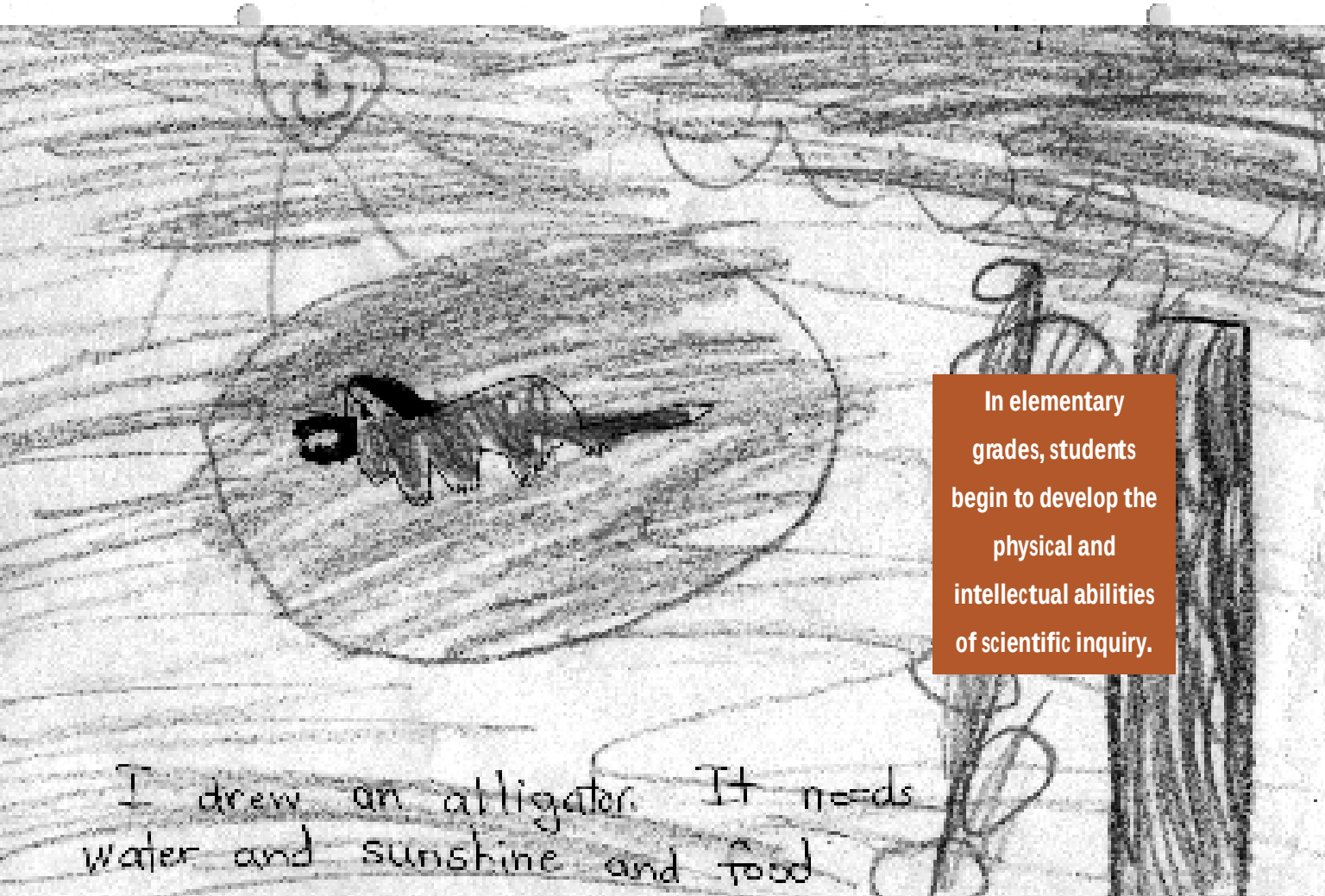
Learn

Change

Interact



I drew a chick. It needs I don't know.



In elementary grades, students begin to develop the physical and intellectual abilities of scientific inquiry.

I drew an alligator. It needs water and sunshine and food

Content Standards: K-4

Science as Inquiry

CONTENT STANDARD A:
As a result of activities in grades K-4, all students should develop

- **Abilities necessary to do scientific inquiry**
- **Understanding about scientific inquiry**

DEVELOPING STUDENT ABILITIES AND UNDERSTANDING

From the earliest grades, students should experience science in a form that engages them in the active construction of ideas and explanations and enhances their opportunities to develop the abilities of doing science. Teaching science as inquiry provides teachers with the opportunity to develop student abilities and to enrich student understanding of science. Students should do science in ways that are within their developmental capabilities. This standard sets forth some abilities of scientific inquiry appropriate for students in grades K-4.

In the early years of school, students can investigate earth materials, organisms, and properties of common objects. Although children develop concepts and vocabulary from such experiences, they also should develop inquiry skills. As students focus on the processes of doing investigations, they develop the ability to ask scientific questions, investigate aspects of the world around them, and use their observations to construct reasonable explanations for the questions posed. Guided by teachers, students continually develop their science knowledge. Students should also learn through the inquiry process how to communicate about their own and their peers' investigations and explanations.

There is logic is behind the abilities outlined in the inquiry standard, but a step-by-step sequence or scientific method is not implied. In practice, student questions might arise from previous investigations, planned classroom activities, or questions students ask each other. For instance, if children ask each other how animals are similar and different, an investigation

might arise into characteristics of organisms they can observe.

Full inquiry involves asking a simple question, completing an investigation, answering the question, and presenting the results to others. In elementary grades, students begin to develop the physical and intellectual abilities of scientific inquiry. They can design investigations to try things to see what happens—they tend to focus on concrete results of tests and will entertain the idea of a "fair" test (a test in which only one variable at a time is changed). However, children in K-4 have difficulty with experimentation as a process of testing ideas and the logic of using evidence to formulate explanations.

GUIDE TO THE CONTENT STANDARD

Fundamental abilities and concepts that underlie this standard include

ABILITIES NECESSARY TO DO SCIENTIFIC INQUIRY

ASK A QUESTION ABOUT OBJECTS, ORGANISMS, AND EVENTS IN THE ENVIRONMENT. This aspect of the standard emphasizes students asking questions that they can answer with scientific knowledge, combined with their own observations. Students should answer their questions by seeking information from reliable sources of scientific information and from their own observations and investigations.

PLAN AND CONDUCT A SIMPLE INVESTIGATION. In the earliest years, investigations are largely based on systematic observations. As students develop, they may design and conduct simple experiments to answer questions. The idea of a fair test is possible for many students to consider by fourth grade.

EMPLOY SIMPLE EQUIPMENT AND TOOLS TO GATHER DATA AND EXTEND THE SENSES. In early years, students develop simple skills, such as how to observe, measure, cut, connect, switch, turn on and off, pour, hold, tie, and hook. Beginning with simple instruments, students can use rulers to measure the length, height, and depth of objects and materials; thermometers to measure temperature; watches to measure time; beam balances and spring scales to measure weight and force; magnifiers to observe objects and organisms; and microscopes to observe the finer details of plants, animals, rocks, and other materials. Children also develop skills in the use of computers and calculators for conducting investigations.

USE DATA TO CONSTRUCT A REASONABLE EXPLANATION. This aspect of the standard emphasizes the students' thinking as they use data to formulate explanations. Even at the earliest grade levels, students should learn what constitutes evidence and judge the merits or strength of the data and information that will be used to make explanations. After students propose an explanation, they will appeal to the knowledge and evidence they obtained to support their explanations. Students should check their explanations against scientific knowledge, experiences, and observations of others.

COMMUNICATE INVESTIGATIONS AND EXPLANATIONS. Students should begin developing the abilities to communicate, critique, and analyze their work and the work of other students. This communica-

See Teaching Standard B

tion might be spoken or drawn as well as written.

UNDERSTANDINGS ABOUT SCIENTIFIC INQUIRY

See Content Standard G (grades K-4)

- Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world.
- Scientists use different kinds of investigations depending on the questions they are trying to answer. Types of investigations include describing objects, events, and organisms; classifying them; and doing a fair test (experimenting).

See Program Standard C

- Simple instruments, such as magnifiers, thermometers, and rulers, provide more information than scientists obtain using only their senses.
- Scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge). Good explanations are based on evidence from investigations.
- Scientists make the results of their investigations public; they describe the investigations in ways that enable others to repeat the investigations.
- Scientists review and ask questions about the results of other scientists' work.

Physical Science

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**

DEVELOPING STUDENT UNDERSTANDING

During their early years, children's natural curiosity leads them to explore the world by observing and manipulating common objects and materials in their environment. Children compare, describe, and sort as they begin to form explanations of the world. Developing a subject-matter knowledge base to explain and predict the world requires many experiences over a long period. Young children bring experiences, understanding, and ideas to school; teachers provide opportunities to continue children's explorations in focused settings with other children using simple tools, such as magnifiers and measuring devices.

Full inquiry involves asking a simple question, completing an investigation, answering the question, and presenting the results to others.

Physical science in grades K-4 includes topics that give students a chance to increase their understanding of the characteristics of objects and materials that they encounter daily. Through the observation, manipulation,and classification of common objects, children reflect on the similarities and differences of the objects. As a result,their initial sketches and single-word descriptions lead to increasingly more detailed drawings and richer verbal descriptions. Describing, grouping, and sorting solid objects and materials is possible early in this grade range. By grade 4, distinctions between the properties of objects and materials can be understood in specific contexts, such as a set of rocks or living materials.

Willie the Hamster

Ms. W. encourages students to engage in an investigation initiated by a question that signals student interest. The context for the investigation is one familiar to the students—a pet in the classroom. She teaches some of the important aspects of inquiry by asking the students to consider alternative explanations, to look at the evidence, and to design a simple investigation to test a hypothesis.Ms. W. has planned the science classes carefully, but changes her plans to respond to student interests, knowing the goals for the school science program and shaping the activities to be consistent with those goals. She understands what is developmentally appropriate for students of this age—she chooses not to launch into an abstract explanation of evaporation. She has a classroom with the resources she needs for the students to engage in an inquiry activity.

[This example highlights some elements of Teaching Standards A, B, D, E, and F; K-4 Content Standards A and B; Program Standards A, C, and D; and System Standard D.]

George is annoyed. There was plenty of water in the watering can when he left it on the windowsill on Friday. Now the can is almost empty, and he won't have time to go the restroom and fill it so that he can water the plants before science class starts. As soon as Ms. W. begins science class, George raises his hand to complain about the disappearance of the water. "Who used the water?" he asks. "Did someone drink it? Did someone spill it?" None of the students in the class touched the watering can, and Ms. W asks what the students think happened to the water.

Marie has an idea. If none of the children took the water, then it must be that Willie, their pet hamster, is leaving his cage at night and drinking the water. The class decides to test Marie's idea by covering the watering can so that Willie cannot drink the water. The children implement their investigation, and the next morning observe that the water level has not dropped. The children now have proof that their explanation is correct. Ms. W. asks the class to consider alternative explanations consistent with their observations. Are they sure that Willie is getting out of his cage at night? The children are quite certain that he is.

"How can you be sure?"asks Ms. W. The children devise an ingenious plan to convince her that Willie is getting out of the cage. They place his cage in the middle of the sand table and smooth the sand. After several days and nights,the children observe that no footprints have appeared in the sand, and the water level has not changed. The children now conclude that Willie is not getting out of his cage at night.

"But wait." says Kahena, "Why should Willie get out of his cage? Willie can see that the watering can is covered." So the class decides to leave the cage in the middle of the sand table and take the cover off the watering can. The water level begins to drop again, yet there are no footprints in the sand. Now the children dismiss the original idea about the disappearance of the water, and Ms. W. takes the opportunity to give the class more experiences with the disappearance of water.

At Ms. W.'s suggestion, a container of water with a wide top is placed on the windowsill and the class measures and records changes in the water level each day using strips of paper to represent the height of the

water. These strips are dated and pasted on a large sheet of paper to create a bar graph. After a few days, the students discern a pattern: The level of water fell steadily but did not decrease the same amount each day. After considerable discussion about the differences, Patrick observes that when his mother dries the family's clothes, she puts them in the dryer. Patrick notes that the clothes are heated inside the dryer and that when his mother does not set the dial on the dryer to heat, the clothes just spin around and do not dry as quickly. Patrick suggests that water might disappear faster when it is warmer.

Based on their experience using strips of paper to measure changes in the level of water and in identifying patterns of change, the students and Ms. W. plan an investigation to learn whether water disappears faster when it is warmer.

The children's experiences with the disappearance of water continue with an investigation about how the size (area) of the uncovered portion of the container influences how fast the water disappears and another where the children investigate whether using a fan to blow air over the surface of a container of water makes the water disappear faster.

Young children begin their study of matter by examining and qualitatively describing objects and their behavior. The important but abstract ideas of science, such as atomic structure of matter and the conservation of energy, all begin with observing and keeping track of the way the world behaves. When carefully observed, described, and measured, the properties of objects, changes in properties over time, and the changes that occur when materials interact provide the necessary precursors to the later introduction of more abstract ideas in the upper grade levels.

Students are familiar with the change of state between water and ice, but the idea of liquids having a set of properties is more nebulous and requires more instructional effort than working with solids. Most students will have difficulty with the generalization that many substances can exist as either a liquid or a solid. K-4 students do not understand that water exists as a gas when it boils or evaporates; they are more likely to think that water disappears or goes into the sky. Despite that limitation, students can conduct simple investigations with heating and evaporation that develop inquiry skills and familiarize them with the phenomena.

When students describe and manipulate objects by pushing, pulling, throwing, dropping, and rolling, they also begin to focus on the position and movement of objects: describing location as up, down, in front, or behind, and discovering the various kinds of motion and forces required to control it. By experimenting with light, heat, electricity, magnetism, and sound, students begin to understand that phenomena can be observed, measured, and controlled in various ways. The children cannot understand a complex concept such as energy. Nonetheless, they have intuitive notions of energy—for example, energy is needed to get things done; humans get energy from food. Teachers can build on the intuitive notions of students without requiring them to memorize technical definitions.

Sounds are not intuitively associated with the characteristics of their source by younger K-4 students, but that association can be developed by investigating a variety of concrete phenomena toward the end of the K-4 level. In most children's minds, electricity begins at a source and goes to a target. This mental model can be seen in students' first attempts to light a bulb using a battery and wire by attaching one wire to a bulb. Repeated activities will help students develop an idea of a circuit late in this grade range and begin to grasp the effect of more than one battery. Children cannot distinguish between heat and temperature at this age; therefore, investigating heat necessarily must focus on changes in temperature.

As children develop facility with language, their descriptions become richer and include more detail. Initially no tools need to be used, but children eventually learn that they can add to their descriptions by measuring objects—first with measuring devices they create and then by using conventional measuring instruments, such as rulers, balances, and thermometers. By recording data and making graphs and charts, older children can search for patterns and order in their work and that of their peers. For example, they can determine the

speed of an object as fast, faster, or fastest in the earliest grades. As students get older, they can represent motion on simple grids and graphs and describe speed as the distance traveled in a given unit of time.

GUIDE TO THE CONTENT STANDARD

Fundamental concepts and principles that underlie this standard include

PROPERTIES OF OBJECTS AND MATERIALS

- Objects have many observable properties, including size, weight, shape, color, temperature, and the ability to react with other substances. Those properties can be measured using tools, such as rulers, balances,and thermometers.
- Objects are made of one or more materials, such as paper, wood, and metal. Objects can be described by the properties of the materials from which they are made,and those properties can be used to separate or sort a group of objects or materials.
- Materials can exist in different states—solid,liquid, and gas. Some common materials, such as water, can be changed from one state to another by heating or cooling.

POSITION AND MOTION OF OBJECTS

- The position of an object can be described by locating it relative to another object or the background.
- An object's motion can be described by tracing and measuring its position over time.
- The position and motion of objects can be changed by pushing or pulling. The size of the change is related to the strength of the push or pull.
- Sound is produced by vibrating objects. The pitch of the sound can be varied by changing the rate of vibration.

LIGHT, HEAT, ELECTRICITY, AND MAGNETISM

- Light travels in a straight line until it strikes an object. Light can be reflected by a mirror, refracted by a lens, or absorbed by the object.
- Heat can be produced in many ways, such as burning, rubbing, or mixing one substance with another. Heat can move from one object to another by conduction.
- Electricity in circuits can produce light, heat, sound, and magnetic effects. Electrical circuits require a complete loop through which an electrical current can pass.
- Magnets attract and repel each other and certain kinds of other materials.

Life Science

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

- **The characteristics of organisms**
- **Life cycles of organisms**
- **Organisms and environments**

DEVELOPING STUDENT UNDERSTANDING

During the elementary grades, children build understanding of biological concepts through direct experience with living things, their life cycles,and their habitats. These experiences emerge from the sense of won-

der and natural interests of children who ask questions such as: "How do plants get food? How many different animals are there? Why do some animals eat other animals? What is the largest plant? Where did the dinosaurs go?" An understanding of the characteristics of organisms, life cycles of organisms, and of the complex interactions among all components of the natural environment begins with questions such as these and an understanding of how individual organisms maintain and continue life. Making sense of the way organisms live in their environments will develop some understanding of the diversity of life and how all living organisms depend on the living and nonliving environment for survival. Because the child's world at grades K-4 is closely associated with the home, school, and immediate environment, the study of organisms should include observations and interactions within the natural world of the child. The experiences and activities in grades K-4 provide a concrete foundation for the progressive development in the later grades of major biological concepts, such as evolution, heredity, the cell, the biosphere, interdependence, the behavior of organisms, and matter and energy in living systems.

Children's ideas about the characteristics of organisms develop from basic concepts of living and nonliving. Piaget noted, for instance, that young children give anthropomorphic explanations to organisms. In lower elementary grades, many children associate "life" with any objects that are active in any way. This view of life develops into one in which movement becomes the defining characteristic. Eventually children incorporate other concepts, such as eating, breathing, and reproducing to define life. As students have a variety of experiences with organisms, and subsequently develop a knowledge base in the life sciences, their anthropomorphic attributions should decline.

In classroom activities such as classification, younger elementary students generally use mutually exclusive rather than hierarchical categories. Young children, for example, will use two groups, but older children will use several groups at the same time. Students do not consistently use classification schemes similar to those used by biologists until the upper elementary grades.

As students investigate the life cycles of organisms, teachers might observe that young children do not understand the continuity of life from, for example, seed to seedling or larvae to pupae to adult. But teachers will notice that by second grade, most students know that children resemble their parents. Students can also differentiate learned from inherited characteristics. However, students might hold some naive thoughts about inheritance, including the belief that traits are inherited from only one parent, that certain traits are inherited exclusively from one parent or the other, or that all traits are simply a blend of characteristics from each parent.

Young children think concretely about individual organisms. For example, animals are associated with pets or with animals kept in a zoo. The idea that organisms depend on their environment (including other organisms in some cases) is not well developed in young children. In grades K-4, the focus should be on establishing the primary association of organisms with their environments and the secondary ideas of dependence on

various aspects of the environment and of behaviors that help various animals survive. Lower elementary students can understand the food link between two organisms.

GUIDE TO THE CONTENT STANDARD

Fundamental concepts and principles that underlie this standard include

THE CHARACTERISTICS OF ORGANISMS

- Organisms have basic needs. For example, animals need air, water, and food; plants require air, water, nutrients, and light. Organisms can survive only in environments in which their needs can be met. The world has many different environments, and distinct environments support the life of different types of organisms.
- Each plant or animal has different structures that serve different functions in growth, survival,and reproduction. For example, humans have distinct body structures for walking, holding, seeing, and talking.
- The behavior of individual organisms is influenced by internal cues (such as hunger) and by external cues (such as a change in the environment). Humans and other organisms have senses that help them detect internal and external cues.

LIFE CYCLES OF ORGANISMS

- Plants and animals have life cycles that include being born, developing into adults, reproducing, and eventually dying. The details of this life cycle are different for different organisms.
- Plants and animals closely resemble their parents.
- Many characteristics of an organism are inherited from the parents of the organism, but other characteristics result from an individual's interactions with the environment. Inherited characteristics include the color of flowers and the number of limbs of an animal. Other features, such as the ability to ride a bicycle, are learned through interactions with the environment and cannot be passed on to the next generation.

ORGANISMS AND THEIR ENVIRONMENTS

- All animals depend on plants. Some animals eat plants for food. Other animals eat animals that eat the plants.
- An organism's patterns of behavior are related to the nature of that organism's environment, including the kinds and numbers of other organisms present, the availability of food and resources, and the physical characteristics of the environment. When the environment changes, some plants and animals survive and reproduce, and others die or move to new locations.
- All organisms cause changes in the environment where they live. Some of these changes are detrimental to the organism or other organisms, whereas others are beneficial.
- Humans depend on their natural and constructed environments. Humans change environments in ways that can be either beneficial or detrimental for themselves and other organisms.

See Content Standard F (grades K-4)

Earth and Space Science

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

- **Properties of earth materials**
- **Objects in the sky**
- **Changes in earth and sky**

DEVELOPING STUDENT UNDERSTANDING

Young children are naturally interested in everything they see around them—soil, rocks, streams, rain, snow, clouds, rainbows, sun, moon, and stars. During the first years of school, they should be encouraged to observe closely the objects and materials in their environment, note their properties, distinguish one from another and develop their own explanations of how things become the way they are. As children become more familiar with their world,they can be guided to observe changes, including cyclic changes, such as night and day and the seasons; predictable trends, such as growth and decay, and less consistent changes, such as weather or the appearance of meteors. Children should have opportunities to observe rapid changes, such as the movement of water in a stream, as well as gradual changes, such as the erosion of soil and the change of the seasons.

Children come to school aware that earth's surface is composed of rocks, soils, water, and living organisms, but a closer look will help them identify many additional properties of earth materials. By carefully observing and describing the properties of many rocks, children will begin to see that some rocks are made of a single substance, but most are made of several substances. In later grades, the substances can be identified as minerals. Understanding rocks and minerals should not be extended to the study of the source of the rocks, such as sedimentary, igneous, and metamorphic, because the origin of rocks and minerals has little meaning to young children.

Playgrounds and nearby vacant lots and parks are convenient study sites to observe a variety of earth materials. As students collect rocks and observe vegetation, they will become aware that soil varies from place to place in its color, texture, and reaction to water. By planting seeds in a variety of soil samples, they can compare the effect of different soils on plant growth. If they revisit study sites regularly, children will develop an understanding that earth's surface is constantly changing. They also can simulate some changes, such as erosion, in a small tray of soil or a stream table and compare their observations with photographs of similar, but larger scale, changes.

By observing the day and night sky regularly, children in grades K-4 will learn to identify sequences of changes and to look for patterns in these changes. As they observe changes, such as the movement of an object's shadow during the course of a day, and the positions of the sun and the moon, they will find the patterns in these movements. They can draw the moon's shape for each evening on a calendar and then determine the pattern in the shapes over several weeks. These understandings should be confined to observations,

Weather

Mr. H. plans a year-long science activity integral to the entire school science program. The students are to observe and record information about the daily weather. Mr. H. begins the activity by assessing what students know, but realizes that students might use terms without understanding. He focuses on the aspects of weather that his teaching experience and knowledge from research on student abilities lead him to believe are developmentally appropriate, and he keeps a record of terms to help him modify his plans as the activity progresses. Students design instruments for measuring weather that are within the range of their skills and a parent provides expertise. They make measurements using their mathematical knowledge and skills; they organize data in a meaningful way and communicate the data to other students. There is an ebb and flow of teacher-directed, whole-class discussions and small-group work sessions.

[This example highlights some elements of Teaching Standards A, B, D, and E; Professional Development Standard C; the Content Standard on Unifying Concepts and Processes; K-4 Content Standards A, D, E, and F; and Program Standards A, C, and D.]

Mr. H.'s fourth grade class was in charge of the school weather station as part of the schoolwide science program. In planning for the weather station, Mr. H. reviewed the objectives he and his colleagues had defined for the activity. Because of their age, the students would not be studying the causes of weather change such as air pressure, the worldwide air currents, or the effects of land and sea masses. Rather, over the course of the year, they would identify and observe the elements of weather; devise and use measurement and data collection strategies; build measurement instruments; analyze data to find patterns and relationships within the data; and communicate their work to the entire school.

Mr. H. introduced the weather station to the students soon after school opened. After a discussion of students' experiences with and ideas about weather, Mr. H. asked the class what kinds of information they thought would be important to collect and how they might go about collecting it. The children quickly identified the need to record whether the day was sunny or cloudy, presence of precipitation, and the temperature. Mr. H. asked some questions, and the list became more complicated: What kinds of clouds were evident? How much precipitation accumulated? How did temperature change during the day? What was the wind speed and direction? One student said that he had heard on the weather report that there was a high-pressure front moving in. What is a front, he asked, and is it important? At the end of the discussion, someone mentioned humidity and recalled the muggy heat wave of the summer.

When Mr. H. thought about the lesson and reviewed what he was going to do next, he realized that much of what the students had said was predictable. He wondered about the last two items—humidity and air pressure. Those concepts were well beyond the students' ability to fully understand, yet they were familiar with the words. Mr. H. decided to continue, as he had planned, focusing on the most observable weather conditions and see whether the children's interests in humidity and air pressure were maintained.

The class spent time the next week discussing and planning how they were going

to measure weather conditions, what tools would they need, and how they would collect and organize their data. Groups worked in the classroom and in the library; each group chose one aspect of weather for its focus. Mr. H. spent some time with each group supporting their ideas, pushing them further, and providing specific guidance when needed. He encouraged the groups to get together and compare notes. Twice during the week, the whole class came together and groups shared their work while students critiqued and offered ideas.

Several weeks later, the weather station of the fourth grade was in operation. After much work, including some trial and error, library research, and the helpful input of a parent who was a skilled mechanic,the students were recording data twice a day for wind direction and speed, using a classmade anemometer and wind vane; temperature,using a commercial thermometer (the students did make a thermometer following the directions in a book but decided that they would get better data with a commercial one); precipitation,using a rain gauge; and cloud formation. Design of the anemometer was extremely difficult. It was easy to build something that would turn in the wind, but the students needed help in figuring how to measure the speed. The children were also measuring air pressure with a homemade barometer that a parent had helped one group construct. Mr. H. supported this, although the children's ability to understand the concept was limited. The interest of the student and her parent and the class' familiarity with the term seemed reason enough.

The students recorded their data on charts in the classroom for 2 months. Then it was time to analyze the data, write the

first report for the class weather book, and make a report to the school. Again, the work began with a discussion. What were some of the ideas that the students had about the weather after all this measuring and recording? Were any patterns observed? Many students thought the temperature was getting lower; several noted that if it was windy one day, it rained the next day. As ideas were presented, other students agreed or challenged what was said. Mr. H. listened and wrote the ideas on a chart as the students spoke. When the discussion quieted, he turned the students' attention to the list and asked them to think about which of the ideas on the board they might actually be able to confirm by reviewing the data. They listed several and agreed on the following list for a starting place: Is the temperature getting lower? What is the relationship between the direction of the wind and the weather the next day? What happened when the pressure went down or up? Was it colder when it was cloudy?

Mr. H. reminded the students of some ways they might represent the data to help them in the analysis; he then assigned tasks, and the students returned to their groups. Several days later, the work was well under way. One group was working on a bar graph showing the total number of sunny, cloudy, and rainy days; another had made a temperature graph that showed the daily fluctuations and showed the weather definitely was getting colder; an interesting table illustrated that when the pressure dropped the weather usually seemed to get worse. The next challenge was to prepare an interesting report for the school, highlighting all that had been learned.

The weather class continued to operate the weather station all year. The students became quite independent and efficient in collecting data. The data were analyzed approximately every 2 months. Some new questions were considered, and the basic ones continued. Midyear Mr. H. was satisfied that the students understood the use of charts and graphs, and he introduced a simple computer program that the students could use to log their data.

Not only did students learn to ask questions and collect, organize, and present data, they learned how to describe daily weather changes in terms of temperature, windspeed and direction, precipitation, and humidity.

descriptions,and finding patterns. Attempting to extend this understanding into explanations using models will be limited by the inability of young children to understand that earth is approximately spherical. They also have little understanding of gravity and usually have misconceptions about the properties of light that allow us to see objects such as the moon. (Although children will say that they live on a ball, probing questions will reveal that their thinking may be very different.)

Students can discover patterns of weather changes during the year by keeping a journal. Younger students can draw a daily weather picture based on what they see out a window or at recess; older students can make simple charts and graphs from data they collect at a simple school weather station.

Emphasis in grades K-4 should be on developing observation and description skills and the explanations based on observations. Younger children should be encouraged to talk about and draw what they see and think. Older students can keep journals, use instruments, and record their observations and measurements.

GUIDE TO THE CONTENT STANDARD

Fundamental concepts and principles that underlie this standard include

PROPERTIES OF EARTH MATERIALS

- Earth materials are solid rocks and soils, water, and the gases of the atmosphere. The varied materials have different physical and chemical properties, which make them useful in different ways, for example, as building materials, as sources of fuel, or for growing the plants we use as food. Earth materials provide many of the resources that humans use.
- Soils have properties of color and texture, capacity to retain water, and ability to support the growth of many kinds of plants,including those in our food supply.
- Fossils provide evidence about the plants and animals that lived long ago and the nature of the environment at that time.

OBJECTS IN THE SKY

- The sun, moon, stars, clouds, birds, and airplanes all have properties, locations, and movements that can be observed and described.
- The sun provides the light and heat necessary to maintain the temperature of the earth.

CHANGES IN THE EARTH AND SKY

- The surface of the earth changes. Some changes are due to slow processes, such as erosion and weathering, and some changes are due to rapid processes, such as landslides, volcanic eruptions, and earthquakes.
- Weather changes from day to day and over the seasons. Weather can be described by measurable quantities, such as temperature, wind direction and speed, and precipitation.
- Objects in the sky have patterns of movement. The sun, for example,appears to move across the sky in the same way every day, but its path changes slowly over the seasons. The moon moves across the sky on a daily basis much like the sun. The observable shape of the moon changes from day to day in a cycle that lasts about a month.

Science and Technology

CONTENT STANDARD E:
As a result of activities in grades K-4, all students should develop

- **Abilities of technological design**
- **Understanding about science and technology**
- **Abilities to distinguish between natural objects and objects made by humans**

DEVELOPING STUDENT ABILITIES AND UNDERSTANDING

The science and technology standards connect students to the designed world, offer them experience in making models of useful things, and introduce them to laws of nature through their understanding of how technological objects and systems work.

This standard emphasizes developing the ability to design a solution to a problem and understanding the relationship of science and technology and the way people are involved in both. This standard helps establish design as the technological parallel to inquiry in science. Like the science as inquiry standard, this standard begins the understanding of the design process, as well as the ability to solve simple design problems.

Children in grades K-4 understand and can carry out design activities earlier than they can inquiry activities, but they cannot easily tell the difference between the two, nor is it important whether they can. In grades K-4, children should have a variety of educational experiences that involve science and technology, sometimes in the same activity and other times separately. When the activities are informal and open, such as building a balance and comparing the weight of objects on it, it is difficult to separate inquiry from technological design. At other times, the distinction might be clear to adults but not to children.

Children's abilities in technological problem solving can be developed by firsthand experience in tackling tasks with a technological purpose. They also can study technological products and systems in their world—zippers, coat hooks, can openers, bridges, and automobiles. Children can engage in projects that are appropriately challenging for their developmental level—ones in which they must design a way to fasten, move, or communicate. They can study existing products to determine function and try to identify problems solved, materials used, and how well a product does what it is supposed to do. An old technological device, such as an apple peeler, can be used as a mystery object for students to investigate and figure out what it does, how it helps people, and what problems it might solve and cause. Such activities provide excellent opportunities to direct attention to specific technology—the tools and instruments used in science.

Suitable tasks for children at this age should have clearly defined purposes and be related with the other content standards. Tasks should be conducted within immediately familiar contexts of the home and school. They should be straightforward; there should be only one or two well-defined ways to solve the problem, and there should be a single, well-defined criterion for success. Any construction of objects should

Weather Instruments

Titles in this example emphasize some important components of the assessment process. Superficially, this assessment task is a simple matching task, but the teacher's professional judgment is still key. For example, is the term "wind gauge" most appropriate or should the more technical term "anemometer" be used? The teacher needs to decide if the use of either term places some students at a disadvantage. Teacher planning includes collecting pictures of weather instruments and ensuring that all students have equal opportunity to study them. A teacher who uses this assessment task recognizes that all assessments have strengths and weaknesses; this task is appropriate for one purpose, and other modes of assessment are appropriate for other purposes. This assessment task presupposes that students have developed some understanding of weather, technology, changing patterns in the environment, and the roles science and technology have in society. The teacher examines the patterns in the responses to evaluate the individual student responses.

[This example highlights some elements of Teaching Standards A, C, and D; Assessment Standards A, B, and D; and K-4 Content Standards D, E, and F.]

SCIENCE CONTENT: The K-4 content standard for earth science is supported by the fundamental concept that weather can be described in measurable quantities.

ASSESSMENT ACTIVITY: Students match pictures of instruments used to measure weather conditions with the condition the instrument measures.

ASSESSMENT TYPE: Individual, short-answer responses to matching item format.

DATA: Students' responses.

ASSESSMENT PURPOSE: When used in conjunction with other data,this assessment activity provides information to be used in assigning a grade.

CONTEXT: This assessment activity is appropriate at the end of a unit on the weather in grades 3 or 4.

ASSESSMENT EXERCISE:

Match pictures of the following weather instruments with the weather condition they measure:

1. Thermometers of various types, including liquid-expansion thermometers, metal-expansion thermometers and digital-electronic thermometers—used to measure temperature.
2. Barometers of various types, including aneroid and mercury types—used to measure air pressure.
3. Weather vanes—used to measure wind direction.
4. Wind gauges of various sorts—instruments to measure windspeed or velocity.
5. Hygrometers of various sorts—to measure moisture in the air.
6. Rain gauges of various sorts—used to measure depth of precipitation.

EVALUATING STUDENT PERFORMANCE:

EXEMPLARY PERFORMANCE: Student matches all instruments with their use.

AVERAGE PERFORMANCE: Student matches familiar forms of measuring instruments with their uses.A student might mistakenly say that the thermometer measures heat or might not understand the concepts of air pressure or humidity. Students at this age cannot be expected to develop sophisticated understanding of the concepts of air pressure, humidity, heat, temperature, speed, or velocity.

require developmentally appropriate manipulative skills used in elementary school and should not require time-consuming preparation and assembly.

Over the course of grades K-4, student investigations and design problems should incorporate more than one material and several contexts in science and technology. A suitable collection of tasks might include making a device to shade eyes from the sun, making yogurt and discussing how it is made, comparing two types of string to see which is best for lifting different objects, exploring how small potted plants can be made to grow as quickly as possible, designing a simple system to hold two objects together, testing the strength of different materials, using simple tools, testing different designs, and constructing a simple structure. It is important also to include design problems that require application of ideas, use of communications, and implementation of procedures—for instance, improving hall traffic at lunch and cleaning the classroom after scientific investigations.

Experiences should be complemented by study of familiar and simple objects through which students can develop observation and analysis skills. By comparing one or two obvious properties, such as cost and strength of two types of adhesive tape, for example, students can develop the abilities to judge a product's worth against its ability to solve a problem. During the K-4 years, an appropriate balance of products could come from the categories of clothing, food, and common domestic and school hardware.

A sequence of five stages—stating the problem, designing an approach, implementing a solution, evaluating the solution, and communicating the problem, design, and solution—provides a framework for planning and for specifying learning outcomes. However, not every activity will involve all of those stages, nor must any particular sequence of stages be followed. For example,some activities might begin by identifying a need and progressing through the stages; other activities might involve only evaluating existing products.

GUIDE TO THE CONTENT STANDARD

Fundamental abilities and concepts that underlie this standard include

ABILITIES OF TECHNOLOGICAL DESIGN

IDENTIFY A SIMPLE PROBLEM. In problem identification, children should develop the ability to explain a problem in their own words and identify a specific task and solution related to the problem.

See Content Standard A (grades K-4)

PROPOSE A SOLUTION. Students should make proposals to build something or get something to work better; they should be able to describe and communicate their ideas. Students should recognize that designing a solution might have constraints, such as cost, materials, time, space, or safety.

IMPLEMENTING PROPOSED SOLUTIONS. Children should develop abilities to work individually and collaboratively and to use suitable tools, techniques, and quantitative measurements when appropriate.Students should demonstrate the ability to balance simple constraints in problem solving.

EVALUATE A PRODUCT OR DESIGN. Students should evaluate their own results or solutions to problems, as well as those of

other children, by considering how well a product or design met the challenge to solve a problem. When possible, students should use measurements and include constraints and other criteria in their evaluations. They should modify designs based on the results of evaluations.

COMMUNICATE A PROBLEM, DESIGN, AND SOLUTION. Student abilities should include oral, written, and pictorial communication of the design process and product. The communication might be show and tell, group discussions, short written reports, or pictures, depending on the students' abilities and the design project.

UNDERSTANDING ABOUT SCIENCE AND TECHNOLOGY

- People have always had questions about their world. Science is one way of answering questions and explaining the natural world.
- People have always had problems and invented tools and techniques (ways of doing something) to solve problems. Trying to determine the effects of solutions helps people avoid some new problems.
- Scientists and engineers often work in teams with different individuals doing different things that contribute to the results. This understanding focuses primarily on teams working together and secondarily, on the combination of scientist and engineer teams.
- Women and men of all ages, backgrounds, and groups engage in a variety of scientific and technological work.
- Tools help scientists make better observations,measurements, and equipment for investigations. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.

ABILITIES TO DISTINGUISH BETWEEN NATURAL OBJECTS AND OBJECTS MADE BY HUMANS

- Some objects occur in nature; others have been designed and made by people to solve human problems and enhance the quality of life.
- Objects can be categorized into two groups, natural and designed.

Science in Personal and Social Perspectives

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

- **Personal health**
- **Characteristics and changes in populations**
- **Types of resources**
- **Changes in environments**
- **Science and technology in local challenges**

DEVELOPING STUDENT UNDERSTANDING

Students in elementary school should have a variety of experiences that provide initial understandings for various science-related personal and societal challenges. Central ideas related to health, populations, resources, and environments provide the foundations for students' eventual under-

standings and actions as citizens. Although the emphasis in grades K-4 should be on initial understandings, students can engage in some personal actions in local challenges related to science and technology.

Teachers should be aware of the concepts that elementary school students have about health. Most children use the word "germs" for all microbes; they do not generally use the words "virus" or "bacteria," and when they do, they do not understand the difference between the two. Children generally attribute all illnesses to germs without distinction between contagious and noncontagious diseases and without understanding of organic, functional, or dietary diseases. Teachers can expect students to exhibit little understanding of ideas, such as different origins of disease, resistance to infection, and prevention and cure of disease.

Children link eating with growth, health, strength, and energy, but they do not understand these ideas in detail. They understand connections between diet and health and that some foods are nutritionally better than others, but they do not necessarily know the reasons for these conclusions.

By grades 3 and 4, students regard pollution as something sensed by people and know that it might have bad effects on people and animals. Children at this age usually do not consider harm to plants as part of environmental problems; however, recent media attention might have increased students awareness of the importance of trees in the environment. In most cases, students recognize pollution as an environmental issue, scarcity as a resource issue, and crowded classrooms or schools as population problems. Most young students conceive of these problems as isolated issues that can be solved by dealing with them individually. For example, pollution can be solved by cleaning up the environment and producing less waste, scarcity can be solved by using less, and crowding can be solved by having fewer students in class or school. However, understanding the interrelationships is not the priority in elementary school.

Central ideas related to health, populations, resources, and environments provide the foundations for students' eventual understandings and actions as citizens.

As students expand their conceptual horizons across grades K-12, they will eventually develop a view that is not centered exclusively on humans and begin to recognize that individual actions accumulate into societal actions. Eventually, students must recognize that society cannot afford to deal only with symptoms: The causes of the problems must be the focus of personal and societal actions.

GUIDE TO THE CONTENT STANDARD

Fundamental concepts and principles that underlie this standard include

PERSONAL HEALTH

- Safety and security are basic needs of humans. Safety involves freedom from danger, risk, or injury. Security involves feelings of confidence and lack of anxiety and fear. Student understandings include following safety rules for home and school, preventing abuse and neglect, avoiding injury, knowing whom to ask for help, and when and how to say no.

See Content Standard C (grades K-4)

- Individuals have some responsibility for their own health. Students should engage in personal care—dental hygiene, cleanliness, and exercise—that will maintain and improve health. Understandings include how communicable diseases, such as colds, are transmitted and some of the body's defense mechanisms that prevent or overcome illness.
- Nutrition is essential to health. Students should understand how the body uses food and how various foods contribute to health. Recommendations for good nutrition include eating a variety of foods, eating less sugar, and eating less fat.
- Different substances can damage the body and how it functions. Such substances include tobacco, alcohol, over-the-counter medicines, and illicit drugs. Students should understand that some substances, such as prescription drugs, can be beneficial, but that any substance can be harmful if used inappropriately.

CHARACTERISTICS AND CHANGES IN POPULATIONS

- Human populations include groups of individuals living in a particular location. One important characteristic of a human population is the population density—the number of individuals of a particular population that lives in a given amount of space.
- The size of a human population can increase or decrease. Populations will increase unless other factors such as disease or famine decrease the population.

TYPES OF RESOURCES

- Resources are things that we get from the living and nonliving environment to meet the needs and wants of a population.
- Some resources are basic materials, such as air, water, and soil; some are produced from basic resources, such as food, fuel, and building materials; and some resources are nonmaterial, such as quiet places, beauty, security, and safety.
- The supply of many resources is limited. If used, resources can be extended through recycling and decreased use.

See Content Standard D (grades K-4)

CHANGES IN ENVIRONMENTS

- Environments are the space, conditions, and factors that affect an individual's and a population's ability to survive and their quality of life.
- Changes in environments can be natural or influenced by humans. Some changes are good, some are bad, and some are neither good nor bad. Pollution is a change in the environment that can influence the health, survival, or activities of organisms, including humans.
- Some environmental changes occur slowly, and others occur rapidly. Students should understand the different consequences of changing environments in small increments over long periods as compared with changing environments in large increments over short periods.

See Content Standard C (grades K-4)

SCIENCE AND TECHNOLOGY IN LOCAL CHALLENGES

- People continue inventing new ways of doing things, solving problems, and getting work done. New ideas and inventions often affect other people; sometimes the effects are good and sometimes they are bad. It is helpful to try to determine in advance how ideas and inventions will affect other people.

See Content Standard E (grades K-4)

- Science and technology have greatly improved food quality and quantity, transportation,health, sanitation, and communication. These benefits of science and technology are not available to all of the people in the world.

History and Nature of Science

CONTENT STANDARD G:
As a result of activities in grades K-4, all students should develop understanding of
- **Science as a human endeavor**

DEVELOPING STUDENT UNDERSTANDING

Beginning in grades K-4, teachers should build on students' natural inclinations to ask questions and investigate their world. Groups of students can conduct investigations that begin with a question and progress toward communicating an answer to the question. For students in the early grades, teachers should emphasize the experiences of investigating and thinking about explanations and not overemphasize memorization of scientific terms and information. Students can learn some things about scientific inquiry and significant people from history, which will provide a foundation for the development of sophisticated ideas related to the history and nature of science that will be developed in later years. Through the use of short stories, films, videos, and other examples, elementary teachers can introduce interesting historical examples of women and men (including minorities and people with disabilities) who have made contributions to science. The stories can highlight how these scientists worked—that is, the questions, procedures,and contributions of diverse individuals to science and technology. In upper elementary grades, students can read and share stories that express the theme of this standard—science is a human endeavor.

GUIDE TO THE CONTENT STANDARD

Fundamental concepts and principles that underlie this standard include

SCIENCE AS A HUMAN ENDEAVOR

- Science and technology have been practiced by people for a long time.
- Men and women have made a variety of contributions throughout the history of science and technology.
- Although men and women using scientific inquiry have learned much about the objects, events, and phenomena in nature, much more remains to be understood.Science will never be finished.
- Many people choose science as a career and devote their entire lives to studying it. Many people derive great pleasure from doing science.