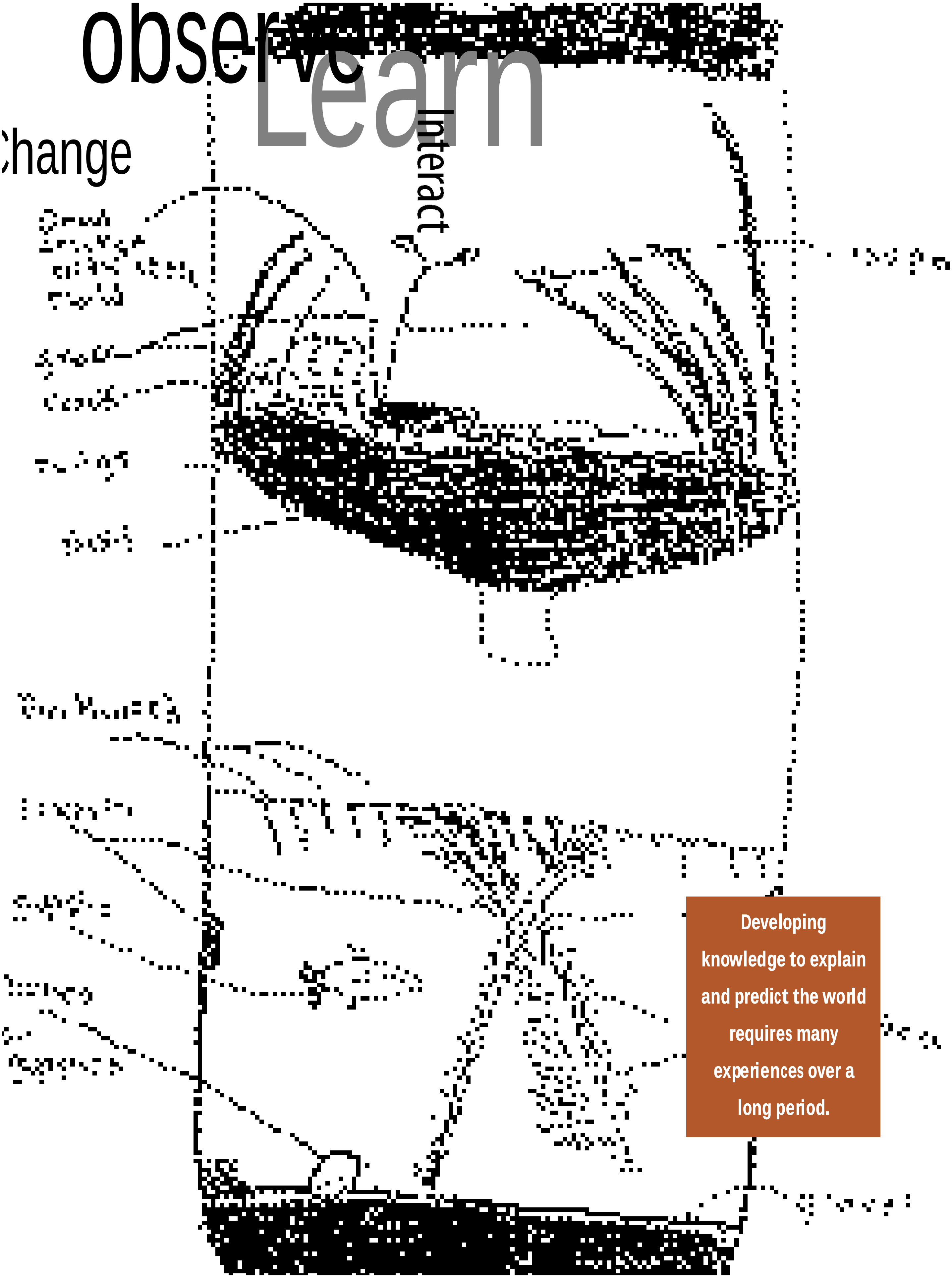
observe

Learn

Interact

Change



Developing knowledge to explain and predict the world requires many experiences over a long period.

Content Standards: 5-8

Science as Inquiry

CONTENT STANDARD A:
As a result of activities in grades 5-8, all students should develop

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

DEVELOPING STUDENT ABILITIES AND UNDERSTANDING

Students in grades 5-8 should be provided opportunities to engage in full and in partial inquiries. In a full inquiry students begin with a question, design an investigation, gather evidence, formulate an answer to the original question,and communicate the investigative process and results. In partial inquiries, they develop abilities and understanding of selected aspects of the inquiry process.Students might, for instance, describe how they would design an investigation, develop explanations based on scientific information and evidence provided through a classroom activity, or recognize and analyze several alternative explanations for a natural phenomenon presented in a teacher-led demonstration.

Students in grades 5-8 can begin to recognize the relationship between explanation and evidence. They can understand that background knowledge and theories guide the design of investigations, the types of observations made, and the interpretations of data. In turn,the experiments and investigations students conduct become experiences that shape and modify their background knowledge.

With an appropriate curriculum and adequate instruction, middle-school students can develop the skills of investigation and the understanding that scientific inquiry is guided by knowledge, observations, ideas, and questions. Middle-school students might have trouble identifying variables and controlling more than one variable in an experiment.Students also might have difficulties understanding the influence of different variables in an experiment—

for example, variables that have no effect, marginal effect, or opposite effects on an outcome.

Teachers of science for middle-school students should note that students tend to center on evidence that confirms their current beliefs and concepts (i.e., personal explanations), and ignore or fail to perceive evidence that does not agree with their current concepts. It is important for teachers of science to challenge current beliefs and concepts and provide scientific explanations as alternatives.

Several factors of this standard should be highlighted. The instructional activities of a scientific inquiry should engage students in identifying and shaping an understanding of the question under inquiry. Students should know what the question is asking, what background knowledge is being used to frame the question, and what they will have to do to answer the question. The students' questions should be relevant and meaningful for them. To help focus investigations, students should frame questions, such as "What do we want to find out about . . .?", "How can we make the most accurate observations?", "Is this the best way to answer our questions?"and "If we do this, then what do we expect will happen?"

Students in grades 5-8 can begin to recognize the relationship between explanation and evidence.

The instructional activities of a scientific inquiry should involve students in establishing and refining the methods, materials, and data they will collect. As students conduct investigations and make observations,they should consider questions such as "What data will answer the question?"and "What are the best observations or measurements to make?" Students should be encouraged to repeat data-collection procedures and to share data among groups.

In middle schools, students produce oral or written reports that present the results of their inquiries. Such reports and discussions should be a frequent occurrence in science programs. Students' discussions should center on questions, such as "How should we organize the data to present the clearest answer to our question?" or "How should we organize the evidence to present the strongest explanation?"Out of the discussions about the range of ideas, the background knowledge claims, and the data, the opportunity arises for learners to shape their experiences about the practice of science and the rules of scientific thinking and knowing.

The language and practices evident in the classroom are an important element of doing inquiries.Students need opportunities to present their abilities and understanding and to use the knowledge and language of science to communicate scientific explanations and ideas. Writing, labeling drawings, completing concept maps, developing spreadsheets, and designing computer graphics should be a part of the science education. These should be presented in a way that allows students to receive constructive feedback on the quality of thought and expression and the accuracy of scientific explanations.

This standard should not be interpreted as advocating a "scientific method." The conceptual and procedural abilities suggest a logical progression, but they do not imply a rigid approach to scientific inquiry. On the contrary, they imply codevelopment of the skills of students in acquiring science knowledge, in using high-level reasoning, in applying their existing understanding of scientific ideas, and in communicating scientific information. This standard cannot be met by having the students memorize the abilities and understandings. It can be met only when students frequently engage in active inquiries.

GUIDE TO THE CONTENT STANDARD

Fundamental abilities and concepts that underlie this standard include

ABILITIES NECESSARY TO DO SCIENTIFIC INQUIRY

IDENTIFY QUESTIONS THAT CAN BE ANSWERED THROUGH SCIENTIFIC INVESTIGATIONS. Students should develop the ability to refine and refocus broad and ill-defined questions. An important aspect of this ability consists of students' ability to clarify questions and inquiries and direct them toward objects and phenomena that can be described, explained, or predicted by scientific investigations. Students should develop the ability to identify their questions with scientific ideas, concepts, and quantitative relationships that guide investigation.

DESIGN AND CONDUCT A SCIENTIFIC INVESTIGATION. Students should develop general abilities, such as systematic observation, making accurate measurements, and identifying and controlling variables. They should also develop the ability to clarify their ideas that are influencing and guiding the inquiry, and to understand how those ideas compare with current scientific knowledge. Students can learn to formulate questions, design investigations, execute investigations, interpret data, use evidence to generate explanations, propose alternative explanations, and critique explanations and procedures.

USE APPROPRIATE TOOLS AND TECHNIQUES TO GATHER, ANALYZE, AND INTERPRET DATA. The use of tools and techniques, including mathematics, will be guided by the question asked and the investigations students design. The use of computers for the collection, summary, and display of evidence is part of this standard. Students should be able to access, gather, store, retrieve, and organize data, using hardware and software designed for these purposes.

DEVELOP DESCRIPTIONS, EXPLANATIONS, PREDICTIONS, AND MODELS USING EVIDENCE. Students should base their explanation on what they observed, and as they develop cognitive skills, they should be able to differentiate explanation from description—providing causes for effects and establishing relationships based on evidence and logical argument. This standard requires a subject matter knowledge base so the students can effectively conduct investigations, because developing explanations establishes connections between the content of science and the contexts within which students develop new knowledge.

THINK CRITICALLY AND LOGICALLY TO MAKE THE RELATIONSHIPS BETWEEN EVIDENCE AND EXPLANATIONS. Thinking critically about evidence includes deciding what evidence should be used and accounting for anomalous data. Specifically, students should be able to review data from a simple experiment, summarize the data, and form a logical argument about the cause-and-effect relationships in the experiment.

Pendulums

Ms. D. wants to focus on inquiry. She wants students to develop an understanding of variables in inquiry and how and why to change one variable at a time. This inquiry process skill is imparted in the context of physical science subject matter. The activity is purposeful, planned, and requires teacher guidance. Ms. D. does not tell students that the number of swings depends on the length of the pendulum, but creates an activity that awakens students' interest and encourages them to ask questions and seek answers. Ms. D. encourages students to look for applications of the science knowledge beyond the classroom. Students keep records of the science activities, and Ms. D. helps them understand that there are different ways to keep records of events. The activity requires mathematical knowledge and skills.. The assessment, constructing a pendulum that swings at six swings per second, is embedded in the activity.

[This example highlights some elements of Teaching Standards B, C, and D; Assessment Standard B; 5-8 Content Standards A and B; and Program Standard C.]

The students in Ms. D.'s fifth grade class are studying motion,direction,and speed. One experiment in this study is designed to enable the students to understand how and why to change one variable at a time. Ms. D. has the students form groups of four; each student has an assigned role. One student—the materials manager—goes to the supply table to pick up a length of string, scissors, tape, and washers of various sizes and weights.Each group is directed to use these materials to 1) construct a pendulum, 2) hang the pendulum so that it swings freely from a pencil taped to the surface of the desk, and 3) count the number of swings of the pendulum in 15 seconds.

The notetaker in each group records the result in a class chart. Ms. D. asks the students to examine the class data. Because the number of swings recorded by each group is different, a lively discussion begins about why this happened. The students decide to repeat the experiment to make sure that they have measured the time and counted the swings correctly. When the second set of

data are entered on the class data table, the results make it clear that the differences are not because students did not count swings or measure time correctly. Again the class discusses why the results are different. Some of the suggestions include the length of the string, the weight of the washer, the diameter of the washer, and how high the student starting the pendulum held the washer to begin the swing.

As each suggestion is made, Ms. D. writes it on the board. The class is then asked to design experiments that could determine which suggestion is correct. Each group chooses to do an experiment to test one of the suggestions, but before the group work continues, Ms. D. collects the pendulums that were used to generate the first and second sets of data. As the groups resume work, one group keeps the string the same length but attaches washers of different diameters and tries to start the swing at exactly the same place. Another group uses one piece of string and one washer, but starts the swing at higher and higher places on an arc. A third group cuts pieces of string of different lengths, but uses one washer and starts the swing at the same place each time. Discussion is animated as students set up their pendulums and the class quiets as they count the swings. Finally, each group shares with the rest of the class what they did and the data they collected. The class concludes that the difference in the number of swings that the pendulum makes is due to the different lengths of string.

The next day, students notice that Ms. D. has constructed a board for the pendulums at the front of the room. Across the top are pegs from which to hang pendulums, and across the bottom are consecutive numbers. The notetaker from each group is directed to hang the group's original pendulum on the peg corresponding to its number of swings in a fixed time. When all of the pendulums are hung on the peg board, the class is asked to interpret the results. After considerable discussion, the students conclude that the number of swings in a fixed time increases in a regular manner as the length of the string gets shorter.

Ms. D. notes that pendulums were constructed with five and seven swings per 15 seconds on the peg board, but no pendulum with six; she asks each group to construct a pendulum with six swings per 15 seconds. After much measuring and counting and measuring again, and serious discussion on what counts as a "swing," every group declares success. Ms. D. then asks how they can keep the information on the relationship between the length of the string and the number of swings in a form that is more convenient than the peg board and directs the students to make a drawing in their science journals to keep that data. Most students draw the pegboard with the pendulums of different lengths, but some students draw charts and a few make graphs. Ms. D. challenges students to find examples of pendulums at home and in their neighborhoods.

The next science class is spent discussing graphing as students move from their pictures of the string lengths, to lines, to points on a graph, and to a complete graph. Finally, each student is asked to use his or her graph to make a pendulum that will swing an exact number of times.

Students have described, explained, and predicted a natural phenomenon and learned about position and motion and about gathering, analyzing, and presenting data.

Students should begin to state some explanations in terms of the relationship between two or more variables.

RECOGNIZE AND ANALYZE ALTERNATIVE EXPLANATIONS AND PREDICTIONS. Students should develop the ability to listen to and respect the explanations proposed by other students. They should remain open to and acknowledge different ideas and explanations, be able to accept the skepticism of others, and consider alternative explanations.

See Teaching Standard B

COMMUNICATE SCIENTIFIC PROCEDURES AND EXPLANATIONS. With practice, students should become competent at communicating experimental methods, following instructions, describing observations, summarizing the results of other groups, and telling other students about investigations and explanations.

See Program Standard C

USE MATHEMATICS IN ALL ASPECTS OF SCIENTIFIC INQUIRY. Mathematics is essential to asking and answering questions about the natural world. Mathematics can be used to ask questions; to gather, organize, and present data; and to structure convincing explanations.

UNDERSTANDINGS ABOUT SCIENTIFIC INQUIRY

- Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models.
- Current scientific knowledge and understanding guide scientific investigations. Different scientific domains employ different methods, core theories, and standards to advance scientific knowledge and understanding.
- Mathematics is important in all aspects of scientific inquiry.
- Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.
- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models,and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.
- Science advances through legitimate skepticism. Asking questions and querying other scientists' explanations is part of scientific inquiry. Scientists evaluate the explanations proposed by other scientists by examining evidence, comparing evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations.
- Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. All of these results can lead to new investigations.

Physical Science

CONTENT STANDARD B:
As a result of their activities in grades 5-8, all students should develop an understanding of

- **Properties and changes of properties in matter**
- **Motions and forces**
- **Transfer of energy**

DEVELOPING STUDENT UNDERSTANDING

In grades 5-8, the focus on student understanding shifts from properties of objects and materials to the characteristic properties of the substances from which the materials are made. In the K-4 years, students learned that objects and materials can be sorted and ordered in terms of their properties. During that process, they learned that some properties, such as size, weight, and shape, can be assigned only to the object while other properties, such as color, texture, and hardness, describe the materials from which objects are made. In grades 5-8, students observe and measure characteristic properties, such as boiling points, melting points,solubility, and simple chemical changes of pure substances and use those properties to distinguish and separate one substance from another.

Students usually bring some vocabulary and primitive notions of atomicity to the science class but often lack understanding of the evidence and the logical arguments that support the particulate model of matter. Their early ideas are that the particles have the same properties as the parent material; that is, they are a tiny piece of the substance. It can be tempting to introduce atoms and molecules or improve students' understanding of them so that particles can be used as an explanation for the properties of elements and compounds. However, use of such terminology is premature for these students and can distract from the understanding that can be gained from focusing on the observation and description of macroscopic features of substances and of physical and chemical reactions. At this level, elements and compounds can be defined operationally from their chemical characteristics, but few students can comprehend the idea of atomic and molecular particles.

In grades 5-8, students observe and measure characteristic properties, such as boiling and melting points, solubility, and simple chemical changes of pure substances, and use those properties to distinguish and separate one substance from another.

The study of motions and the forces causing motion provide concrete experiences on which a more comprehensive understanding of force can be based in grades 9-12. By using simple objects, such as rolling balls and mechanical toys, students can move from qualitative to quantitative descriptions of moving objects and begin to describe the forces acting on the objects. Students' everyday experience is that friction causes all moving objects to slow down and stop. Through experiences in which friction is

Funny Water

In this example, Mr. B makes his plans using his knowledge and understanding of science, students, teaching, and the district science program. His understanding and ability are the results of years of studying and reflection on his own teaching. He usually introduces new topics with a demonstration to catch the students' attention. He asks questions that encourage students to develop understanding and designs activities that require students to confirm their ideas and extend them to situations within and beyond the science classroom. Mr. B encourages students to observe, test, discuss, and write by promoting individual effort as well as by forming different-sized groups of students for various activities. Immense understanding, skill, creativity, and energy are required to organize and orchestrate ideas, students, materials, and events the way Mr. B. does with apparent ease. And Mr. B. might repeat an activity five times a day, adapting it to the needs of different classes of students, or he might teach four other school subjects.

[This example highlights some components of Teaching Standards A ,B , D, and E; Professional Development Standard C; 5-8 Content Standard A and B; Program Standards A, B, and D; and System Standards D.]

Mr. B. was beginning a unit that would include the development of students' understanding of the characteristic properties of substances such as boiling points, melting points,solubility, and density. He wanted students to consolidate their experiences and think about the properties of substances as a foundation for the atomic theories they would gradually come to understand in high school. He knew that the students had some vocabulary and some notions of atomicity but were likely not to have any understanding of the evidence of the particulate nature of matter or arguments that support that understanding. Mr. B. started the unit with a study of density because the concept is important and because this study allowed him to gather data on the students' current understandings about matter.

As he had done the year before, he began the study with the density of liquids. He knew that the students who had been in the district elementary schools had already done some work with liquids and that all students brought experience and knowledge from their daily lives. To clarify the knowledge, understanding, and confusion students might have, Mr. B. prepared a set of short exercises for the opening week of the unit of study.

For the first day, he prepared two density columns: using two 1-foot-high, clear plastic cylinders, he poured in layers of corn syrup, liquid detergent, colored water, vegetable oil, baby oil, and methanol. As the students arrived,they were directed into two groups to examine the columns and discuss what they saw. After 10 minutes of conversation,Mr. B. asked the students to take out their notebooks and jot down observations and thoughts about why the different liquids separated.

When the writing ceased,Mr. B. asked, "What did you observe? Do you have any explanations for what you see? What do you think is happening?" He took care to explain, "There are no right answers, and silence is OK. You need to think." Silence was followed by a few comments, and finally, a lively discussion ensued.

It's pretty

How do you get the colors to stay apart?

Like the ones on top are lighter or something like that.

The top looks like water.

I think the bottom liquids are heavier; they sink to the bottom .

It separated into different layers because each has different densities and they sit on top of each other.

"What do you mean by density?" asked Mr. B.

It's how packed the particles are.

This one is thick so it's on the bottom. This one is thinnest.

Doesn't oil have lighter density than water?

If we put a thicker liquid in, it would go to the bottom.

There's more of this one that's on the bottom.

The atoms in some are heavier than the ones in others.

Mr. B. realized how many different ways the students explained what they saw, for example,thickness and thinness, heaviness and lightness,more and less, different densities and atoms. The discussion gave him a sense for what the students were thinking. It was clear to him that the investigations he had planned for the following weeks to focus more closely on density would be worthwhile.

Mr. B. divided the class into seven groups of four the next day. On each of the group's tables were small cylinders. Mr B warned the students not to drink the liquid. Each group was to choose one person to be the materials manager and one to be the recorder as they proceeded to find out what they could about the same liquids used the day before (all of which were available on the supply table). Only the materials manager was to come to the supply table for the liquids, and the recorders kept track of what they did. Forty minutes later, Mr. B. asked students to clean up and gather to share their observations.

Every group identified some of the liquids. The water was easy, as was the vegetable oil. Some students knew corn syrup, others recognized the detergent. Several groups combined two and three liquids and found that some of them mixed together, and others stayed separate. Some disagreements arose about which liquid floated on which. Mr. B. suggested that interested students come back during their lunch time to try to resolve these disagreements. One group replicated the large cylinder, shook it vigorously, and was waiting to see whether the liquids would separate. Mr. B. asked that group to draw what the cylinder contents looked like now, put it on the windowsill, and check it the next day.

Mr. B. began the third day with a large density column again. This time he gave a small object to each of four students—a piece of wood,aluminum, plastic, or iron. He asked the class to predict what would happen when each of the four objects was released into the column. The students predicted and watched as some objects sank to the bottom, and others stopped somewhere in the columns.

"What do you think is going on?"asked Mr. B. "How can you explain the way these objects behaved? I don't want answers now," he went on,"I want you to try out some more things yourselves and then we'll talk." He then divided the class into four groups and gave each a large density column with the liquid layers. The students worked in their groups for 30 minutes. The discussion was animated as different objects were tried: rubber bands, a penny, a nickel, a pencil, and paper clips. Mr. B. circulated from group to group taking note of many interesting comments. With 10 minutes left in the class, he gathered the groups together and asked for some of their observations.

When we dropped something lighter in, it stopped near the top.

The rubber band is lighter than the paper clip. The paper clip is heavy so it drops down.

The rubber band has buoyancy, if you know what that means.

The nickel went all the way to the bottom because it's heavier, but the pencil wouldn't go into the last layer because it was too thick. The pencil is wood and it's lighter; the nickel is silver and it's heavier.

The nickel is denser than the pencil.

Mr. B. listened to these observations and encouraged the students to respond to one another. Occasionally he asked for a clarification—"What do you mean by that?" "How did you do that?" His primary purpose was to hear the students' ideas and encourage them to explain them to one another.

The next day he began the last of the introductory experiences. When the students came in,Mr. B. asked them to divide into their four groups and go to the tables with the density columns. Beside each column were several pieces of wood of different sizes. Students were to think and talk about what the pieces might do in the column, try them out, have more discussion, and write down some of their ideas in their science notebooks.

When enough time had passed, Mr. B. called the groups together and asked for some volunteers to read from their notebooks. Some students were struggling with what they had seen:

They stuck in the middle of the column.

The pieces are not the same weight. The bigger ones are heavier. I don't know why they all stopped in the middle.

Others seemed to understand. One student read,

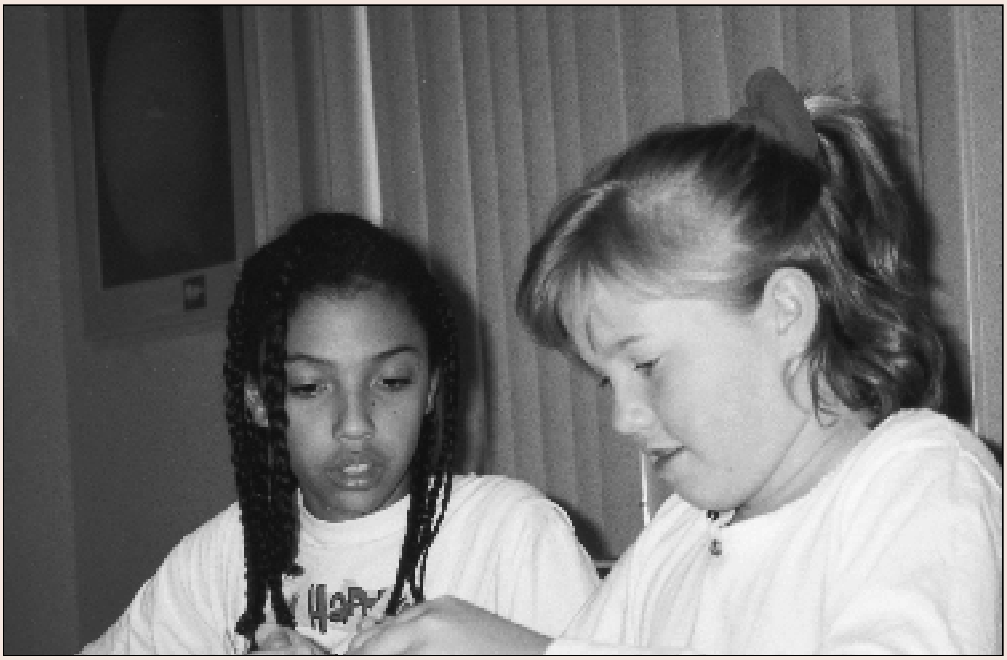
If you have a block of wood and cut it into millions of pieces, each piece would have the density of the original block. If that block of wood weighed one gram and you cut it into a million pieces the weight would change. But no matter how many times you cut something, the density will not change.

When this statement was read Mr. B. asked how many people agreed with it. Most students quickly asserted "yes." But how sure were they? Mr. B. pulled out a piece of wood larger than any of those that the students had tried. "What would happen if this piece of wood were dropped into the column?" Some students said immediately that it would stop where the smaller pieces had. Others were not quite so sure. This piece was quite a bit bigger. One student asked for a show of hands. Twelve students thought this big piece of wood would sink farther and 16 thought it would sink to the same level as the others. Mr. B. dropped it in. It stopped sinking where the others had. There were a few "yeahs," a few "what's," and some puzzled looks.

As a final teaser and check on students' understanding, Mr. B. brought out two transparent containers of colorless liquids. He asked the class to gather around, took a candle and cut two quite different-sized pieces from it. The students were asked to predict what would happen when the candle pieces were put in the liquids. Mr. B. dropped the pieces into the columns: In one container the big piece sank to the bottom; in the other, the small one floated on the top. Some students had predicted this result, saying that the bigger one was heavier and therefore would sink. Others were perplexed. The two pieces were made of the same wax so they shouldn't be different. Something was wrong. Were the two liquids really the same? Mr. B. removed the pieces of wax from the containers and reversed them. This time the little one sank and the big one floated. "Unfair," came a chorus of voices. "The liquids aren't the same."

Mr. B. had used water and isopropyl alcohol. But he noticed several students were willing to explain the sinking of the larger piece of candle and not the smaller by the difference in the size of the piece.

Mr. B. closed the lesson by summing up. They had seen the density column and worked with the liquids themselves; they had tried floating objects in liquids; they had seen the pieces of wax in the liquids. What was the explanation for all these phenomena? For homework that night he asked them to do two things. They were to think about and write down any ideas they had about what was happening in all these experiences. He also asked them to think about and write about examples of these phenomena in their daily lives. After the students shared some of their observations from outside the classroom, Mr. B. would have the students observe as he boiled water to initiate discussion of boiling points.



reduced,students can begin to see that a moving object with no friction would continue to move indefinitely, but most students believe that the force is still acting if the object is moving or that it is “used up” if the motion stops. Students also think that friction,not inertia, is the principle reason objects remain at rest or require a force to move.Students in grades 5-8 associate force with motion and have difficulty understanding balanced forces in equilibrium, especially if the force is associated with static, inanimate objects, such as a book resting on the desk.

The understanding of energy in grades 5-8 will build on the K-4 experiences with light,heat, sound, electricity, magnetism, and the motion of objects. In 5-8, students begin to see the connections among those phenomena and to become familiar with the idea that energy is an important property of substances and that most change involves energy transfer. Students might have some of the same views of energy as they do of force—that it is associated with animate objects and is linked to motion. In addition, students view energy as a fuel or something that is stored, ready to use, and gets used up. The intent at this level is for students to improve their understanding of energy by experiencing many kinds of energy transfer.

GUIDE TO THE CONTENT STANDARD

Fundamental concepts and principles that underlie this standard include

PROPERTIES AND CHANGES OF PROPERTIES IN MATTER

- A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample. A mixture of substances often can be separated into the original substances using one or more of the characteristic properties.
- Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions, the total mass is conserved. Substances often are placed in categories or groups if they react in similar ways; metals is an example of such a group.
- Chemical elements do not break down during normal laboratory reactions involving such treatments as heating, exposure to electric current, or reaction with acids. There are more than 100 known elements that combine in a multitude of ways to produce compounds, which account for the living and nonliving substances that we encounter.

MOTIONS AND FORCES

- The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.
- An object that is not being subjected to a force will continue to move at a constant speed and in a straight line.
- If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object’s motion.

See Content Standard D (grades 5-8)

TRANSFER OF ENERGY

- Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.
- Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.
- Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object—emitted by or scattered from it—must enter the eye.
- Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.
- In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light, mechanical motion, or electricity might all be involved in such transfers.
- The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

See Unifying Concepts and Processes

Life Science

CONTENT STANDARD C:
As a result of their activities in grades 5-8, all students should develop understanding of

- **Structure and function in living systems**
- **Reproduction and heredity**
- **Regulation and behavior**
- **Populations and ecosystems**
- **Diversity and adaptations of organisms**

DEVELOPING STUDENT UNDERSTANDING

In the middle-school years, students should progress from studying life science from the point of view of individual organisms to recognizing patterns in ecosystems and developing understandings about the cellular dimensions of living systems. For example, students should broaden their understanding from the way one species lives in its environment to populations and communities of species and the ways they interact with each other and with their environment. Students also should expand their investigations of living systems to include the study of cells. Observations and investigations should become increasingly quantitative, incorporating the use of computers and conceptual and mathematical models. Students in grades 5-8 also have the fine-motor skills to work with a light microscope and can interpret accurately what they see, enhancing their introduction to cells and microorganisms and establishing a foundation for developing understanding of molecular biology at the high school level.

Some aspects of middle-school student understanding should be noted. This period of development in youth lends itself to human biology. Middle-school students can develop the understanding that the body has organs that function together to maintain life. Teachers should introduce the general idea of structure-function in the context of human organ systems working together. Other, more specific and concrete examples, such as the hand, can be used to develop a specific understanding of structure-function in living systems. By middle-school, most students know about the basic process of sexual reproduction in humans. However, the student might have misconceptions about the role of sperm and eggs and about the sexual reproduction of flowering plants. Concerning heredity, younger middle-school students tend to focus on observable traits, and older students have some understanding that genetic material carries information.

Students understand ecosystems and the interactions between organisms and environments well enough by this stage to introduce ideas about nutrition and energy flow, although some students might be confused by charts and flow diag rams. If asked about common ecological concepts, such as community and competition between organisms, teachers are likely to hear responses based on everyday experiences rather than scientific explanations. Teachers should use the students' understanding as a basis to develop the scientific understanding.

Understanding adaptation can be par ticularly troublesome at this level. Many students think adaptation means that individuals change in major ways in response to environmental changes (that is, if the environment changes, individual organisms deliberately adapt).

GUIDE TO THE CONTENT STANDARD

Fundamental concepts and principles that underlie this standard include

STRUCTURE AND FUNCTION IN LIVING SYSTEMS

See Unifying Concepts and Processes

- Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms, and ecosystems.
- All organisms are composed of cells—the fundamental unit of life. Most organisms are single cells; other organisms, including humans,are multicellular.
- Cells carry on the many functions needed to sustain life. They grow and divide, thereby producing more cells. This requires that they take in nutrients, which they use to provide energy for the work that cells do and to make the materials that a cell or an organism needs.
- Specialized cells perform specialized functions in multicellular organisms. Groups of specialized cells cooperate to form a tissue, such as a muscle. Different tissues are in turn grouped together to form larger functional units, called organs.Each type of cell, tissue, and organ has a distinct structure and set of functions that serve the organism as a whole.
- The human organism has systems for digestion, respiration, reproduction, circulation, excretion,movement, control, and coordination,and for protection

from disease. These systems interact with one another.

- Disease is a breakdown in structures or functions of an organism. Some diseases are the result of intrinsic failures of the system. Others are the result of damage by infection by other organisms.

REPRODUCTION AND HEREDITY

- Reproduction is a characteristic of all living systems; because no individual organism lives forever, reproduction is essential to the continuation of every species. Some organisms reproduce asexually. Other organisms reproduce sexually.
- In many species, including humans, females produce eggs and males produce sperm. Plants also reproduce sexually—the egg and sperm are produced in the flowers of flowering plants. An egg and sperm unite to begin development of a new individual. That new individual receives genetic information from its mother (via the egg) and its father (via the sperm). Sexually produced offspring never are identical to either of their parents.
- Every organism requires a set of instructions for specifying its traits. Heredity is the passage of these instructions from one generation to another.
- Hereditary information is contained in genes, located in the chromosomes of each cell. Each gene carries a single unit of information. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait. A human cell contains many thousands of different genes.
- The characteristics of an organism can be described in terms of a combination of traits. Some traits are inherited and others result from interactions with the environment.

REGULATION AND BEHAVIOR

- All organisms must be able to obtain and use resources, grow, reproduce, and maintain stable internal conditions while living in a constantly changing external environment.
- Regulation of an organism's internal environment involves sensing the internal environment and changing physiological activities to keep conditions within the range required to survive.
- Behavior is one kind of response an organism can make to an internal or environmental stimulus. A behavioral response requires coordination and communication at many levels, including cells, organ systems, and whole organisms. Behavioral response is a set of actions determined in part by heredity and in part from experience.
- An organism's behavior evolves through adaptation to its environment. How a species moves, obtains food, reproduces, and responds to danger are based in the species' evolutionary history.

POPULATIONS AND ECOSYSTEMS

- A population consists of all individuals of a species that occur together at a given place and time. All populations living together and the physical factors with which they interact compose an ecosystem.
- Populations of organisms can be categorized by the function they serve in an ecosystem. Plants and some microorganisms are producers—they make

their own food. All animals, including humans, are consumers, which obtain food by eating other organisms. Decomposers, primarily bacteria and fungi, are consumers that use waste materials and dead organisms for food. Food webs identify the relationships among producers, consumers, and decomposers in an ecosystem.

- For ecosystems, the major source of energy is sunlight.Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis. That energy then passes from organism to organism in food webs.
- The number of organisms an ecosystem can support depends on the resources available and abiotic factors, such as quantity of light and water, range of temperatures,and soil composition. Given adequate biotic and abiotic resources and no disease or predators, populations (including humans) increase at rapid rates. Lack of resources and other factors, such as predation and climate,limit the growth of populations in specific niches in the ecosystem.

DIVERSITY AND ADAPTATIONS OF ORGANISMS

- Millions of species of animals, plants, and microorganisms are alive today. Although different species might look dissimilar, the unity among organisms becomes apparent from an analysis of internal structures, the similarity of their chemical processes, and the evidence of common ancestry.
- Biological evolution accounts for the diversity of species developed through gradual processes over many generations. Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations in populations. Biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment.
- Extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient to allow its survival. Fossils indicate that many organisms that lived long ago are extinct. Extinction of species is common; most of the species that have lived on the earth no longer exist.

Earth and Space Science

CONTENT STANDARD D:
As a result of their activities in grades 5-8, all students should develop an understanding of

- **Structure of the earth system**
- **Earth's history**
- **Earth in the solar system**

DEVELOPING STUDENT UNDERSTANDING

A major goal of science in the middle grades is for students to develop an understanding of earth and the solar system as a set of closely coupled systems. The idea of systems provides a framework in which students can investigate the four major interacting components of the earth system—

geosphere (crust, mantle, and core), hydrosphere (water), atmosphere (air), and the biosphere (the realm of all living things). In this holistic approach to studying the planet, physical, chemical, and biological processes act within and among the four components on a wide range of time scales to change continuously earth's crust, oceans, atmosphere, and living organisms.Students can investigate the water and rock cycles as introductory examples of geophysical and geochemical cycles. Their study of earth's history provides some evidence about coevolution of the planet's main features—the distribution of land and sea, features of the crust,the composition of the atmosphere, global climate, and populations of living organisms in the biosphere.

By plotting the locations of volcanoes and earthquakes,students can see a pattern of geological activity. Earth has an outermost rigid shell called the lithosphere. It is made up of the crust and part of the upper mantle. It is broken into about a dozen rigid plates that move without deforming, except at boundaries where they collide. Those plates range in thickness from a few to more than 100 kilometers.Ocean floors are the tops of thin oceanic plates that spread outward from midocean rift zones; land surfaces are the tops of thicker, less-dense continental plates.

Because students do not have direct contact with most of these phenomena and the long-term nature of the processes,some explanations of moving plates and the evolution of life must be reserved for late in grades 5-8. As students mature, the concept of evaporation can be reasonably well understood as the conservation of matter combined with a primitive idea of particles and the idea that air is real. Condensation is less well understood and requires extensive observation and instruction to complete an understanding of the water cycle.

The understanding that students gain from their observations in grades K-4 provides the motivation and the basis from which they can begin to construct a model that explains the visual and physical relationships among earth, sun, moon, and the solar system. Direct observation and satellite data allow students to conclude that earth is a moving, spherical planet, having unique features that distinguish it from other planets in the solar system. From activities with trajectories and orbits and using the earth-sun-moon system as an example, students can develop the understanding that gravity is a ubiquitous force that holds all parts of the solar system together. Energy from the sun transferred by light and other radiation is the primary energy source for processes on earth's surface and in its hydrosphere, atmosphere,and biosphere.

By grades 5-8, students have a clear notion about gravity, the shape of the earth, and the relative positions of the earth, sun, and moon. Nevertheless, more than half of the students will not be able to use these models to explain the phases of the moon, and correct explanations for the seasons will be even more difficult to achieve.

GUIDE TO THE CONTENT STANDARD

Fundamental concepts and principles that underlie this standard include

STRUCTURE OF THE EARTH SYSTEM

- The solid earth is layered with a lithosphere; hot, convecting mantle; and dense, metallic core.

See Content Standard F (grades 5-8)

- Lithospheric plates on the scales of continents and oceans constantly move at rates of centimeters per year in response to movements in the mantle. Major geological events, such as earthquakes, volcanic eruptions, and mountain building, result from these plate motions.
- Land forms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruption, and deposition of sediment, while destructive forces include weathering and erosion.
- Some changes in the solid earth can be described as the "rock cycle." Old rocks at the earth's surface weather, forming sediments that are buried, then compacted, heated, and often recrystallized into new rock. Eventually, those new rocks may be brought to the surface by the forces that drive plate motions, and the rock cycle continues.
- Soil consists of weathered rocks and decomposed organic material from dead plants,animals, and bacteria. Soils are often found in layers, with each having a different chemical composition and texture.
- Water, which covers the majority of the earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the "water cycle." Water evaporates from the earth's surface, rises and cools as it moves to higher elevations, condenses as rain or snow, and falls to the surface where it collects in lakes, oceans, soil, and in rocks underground.
- Water is a solvent. As it passes through the water cycle it dissolves minerals and gases and carries them to the oceans.
- The atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor. The atmosphere has different properties at different elevations.
- Clouds, formed by the condensation of water vapor, affect weather and climate.
- Global patterns of atmospheric movement influence local weather. Oceans have a major effect on climate, because water in the oceans holds a large amount of heat.
- Living organisms have played many roles in the earth system, including affecting the composition of the atmosphere, producing some types of rocks, and contributing to the weathering of rocks.

EARTH'S HISTORY

- The earth processes we see today, including erosion,movement of lithospheric plates, and changes in atmospheric composition,are similar to those that occurred in the past. earth history is also influenced by occasional catastrophes, such as the impact of an asteroid or comet.
- Fossils provide important evidence of how life and environmental conditions have changed.

See Content Standard C (grades 5-8)

EARTH IN THE SOLAR SYSTEM

See Unifying Concepts and Processes

- The earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The sun, an average star, is the central and largest body in the solar system.
- Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the moon, and eclipses.

- Gravity is the force that keeps planets in orbit around the sun and governs the rest of the motion in the solar system. Gravity alone holds us to the earth's surface and explains the phenomena of the tides.
- The sun is the major source of energy for phenomena on the earth's surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of the sun's energy hitting the surface, due to the tilt of the earth's rotation on its axis and the length of the day.

Science and Technology

CONTENT STANDARD E:
As a result of activities in grades 5-8, all students should develop
- **Abilities of technological design**
- **Understandings about science and technology**

DEVELOPING STUDENT ABILITIES AND UNDERSTANDING

Students in grades 5-8 can begin to differentiate between science and technology, although the distinction is not easy to make early in this level.One basis for understanding the similarities,differences, and relationships between science and technology should be experiences with design and problem solving in which students can further develop some of the abilities introduced in grades K-4. The understanding of technology can be developed by tasks in which students have to design something and also by studying technological products and systems.

In the middle-school years, students' work with scientific investigations can be complemented by activities in which the purpose is to meet a human need, solve a human problem, or develop a product rather than to explore ideas about the natural world. The tasks chosen should involve the use of science concepts already familiar to students or should motivate them to learn new concepts needed to use or understand the technology. Students should also, through the experience of trying to meet a need in the best possible way, begin to appreciate that technological design and problem solving involve many other factors besides the scientific issues.

In the middle-school years, students' work with scientific investigations can be complemented by activities that are meant to meet a human need, solve a human problem, or develop a product . . .

Suitable design tasks for students at these grades should be well-defined,so that the purposes of the tasks are not confusing. Tasks should be based on contexts that are immediately familiar in the homes, school, and immediate community of the students. The activities should be straightforward with only a few well-defined ways to solve the problems involved. The criteria for success and the constraints for design should be limited. Only one or two science ideas should be involved in any particular task. Any construction involved should be readily

The Egg Drop

This rich example includes both a description of teaching and an assessment task. Mr. S. has students engage in a full design activity, designing and testing a container that can prevent an egg from breaking when dropped. The technology activity was preceded by a science unit on force and motion so that students were able to use their understanding of science in the design process. He has carefully considered commercially prepared versions of this activity but modified them to create one based on his experiences and the needs of the students. He has considered the safety of the students. The use of the videotape of former students not only provides a local context for the activity, but provides students with ideas about the designs that work and do not work. After the enjoyable day, Mr. S. requires students to reflect on what they have learned and apply it to a new, but similar problem.

[This example highlights some elements of all of the Teaching Standards; Assessment Standard A; 5-8 Content Standards B and E; Program Standard D; and System Standard D.]

As Mr. S. reviewed his syllabus for the year, he saw the next unit and smiled. On Monday they would begin the "Egg Drop"—the students, working in teams, would design a container for an uncooked egg. The time was right. During the period between the winter break and the new semester, the students had focused on the similarities and differences between science and technology. At the beginning of the second semester the students had completed activities and engaged in discussions until they demonstrated an adequate understanding of force, motion, gravity and acceleration. Now it was time to bring the knowledge of science principles to a design problem. The problem was to design a container that could be dropped from the second floor balcony without breaking the egg.

Some variation of the egg drop activity was found in just about every middle school science book that Mr. S. had ever seen. But over the years he had come to know what worked and what didn't, where to anticipate the students would have difficulties, and just how to phrase questions and challenges the students could respond to without being overwhelmed. He had developed some aspects of the unit that were special to him and to the students in Belle Vue Middle School. He knew when he introduced the idea that at least one student would have a tale to tell about dropping a carton of eggs when carrying groceries home from the store or when removing the carton from the refrigerator. While dropping eggs from the balcony was not part of the every day experience of the students, dropping things and having them break was.

On Monday, he would set the challenge, the constraints, and the schedule. They would begin with a whole class review of what the students knew about force, acceleration, and gravity and the design principles. He would have someone write these on a chart that they could hang on the wall during the unit. Next they would identify things they had seen fall gently without breaking and about the size, shape, material, and construction of these items. Finally he would tell the students the constraints: teams would be made up of three students each; materials would be limited to the 'stuff' available on the work table; teams would have to show him a sketch before they began building their container; they would have to conduct at least two trials with their container—one with a plastic egg and one with a hard-cooked egg. For years, he had collected odds and ends—string and plastic, paper towel rolls end egg cartons, Styrofoam peanuts, cotton and other packing material. In the world outside of school, limited availability of materials was a real constraint. He was grateful that he taught in Florida where he could open the door and watch the students outside as they climbed to the second floor balcony to conduct their trial runs. He knew that if he taught up North, where they would have to do this activity from the gym balcony, he would have to plan differently as the class would have to move to and from the gym.

On Tuesday, he would have a few raw eggs for each class. He would have several students try to crush them by exerting force with their hands. He would need lab aprons, goggles, and plastic gloves for that. Then he would show the egg drop video. After the first few years, he learned to videotape the class on the day of the egg drop. He had edited a short video of some of the more spectacular egg drops—both successful and unsuccessful. The students enjoyed watching older brothers and sisters, and famous and infamous students. The students would then get into their groups and discuss the features of the containers in which the eggs broke and those in which the eggs did not break. He would challenge them to consider how they might improve the successful egg drop containers. Toward the end of the period, each group would have someone report to the class one thing the group had learned from the video and discussion.

Wednesday would be an intense day as students argued and sketched, sketched and argued, had plans approved, collected materials, bartered with other teams for materials, and tried to build a prototype of their container.

Thursday they would begin class with a discussion of why they needed to build a prototype and why they needed to do some trial runs with plastic and hard cooked eggs. He would ask them the advantages and disadvantages of using the plastic and hard cooked eggs in the trial runs. This would give them an opportunity to consider cost and the characteristics of models. There would be time in class to work and some groups would be ready to begin the field trials. He would need a supply of trash bags to use as drop cloths.

Friday's class would begin by reminding the students that the assessment for the egg drop would not be whether the egg broke, but rather how they would be able to share what they considered as they tried to solve the problem of designing a container for an egg so that the egg would drop 15 feet and not break. He would also remind them that the egg drop was scheduled for Wednesday, ready or not.

Monday would be an uninterrupted work day. On Tuesday they would by work in their groups to determine what would be needed to make their egg drop event a success. In his plans Mr. S. noted that he would need a set-up team that would cover the ground below the balcony with trash bags. A clean up crew, again wearing plastic gloves, would gather the bags and get them into the disposal. He anticipated that they would want two class mates to have stopwatches to measure the time it took for the egg to drop. The students would want to determine where the egg should be held for the start of the egg drop. There were always heated arguments about whether the starting line was from the arm of the dropper or from some point on the container. They would need someone to call "Drop!"

Wednesday would be the day of the egg drop. Thursday, the class would begin by meeting in their small groups to discuss what worked, what didn't, why, and what they would do differently if they were to do the egg drop design experiment again. Then they would discuss these same ideas as a whole class.

Friday, the students would fill the board with characteristics of good design procedures. Then they would write and sketch in their notebooks these characteristics and what each had learned from the egg drop activity. He knew from experience that the egg drop would be an engaging activity.

The "header titles" emphasize some important components of the assessment process.

SCIENCE CONTENT: The Content Standards for Science and Technology for students in Grades 5-8 call for them to understand and be able to solve a problem by using design principles. These include the ability to design a product; evaluate technological products; and communicate the process of technological design.

ASSESSMENT ACTIVITY: Following the egg drop activity, students each prepare a report on one thing they propose in order to improve their team's container and how they would test the effectiveness of their improvement.

ASSESSMENT TYPE: Individual. embedded in teaching.

ASSESSMENT PURPOSE: The teacher will use the information to assess student understanding of the process of design and for assigning a grade.

DATA: A report, written, sketched, or both, in which students describe an improvement to the container, the anticipated gains and losses from the improvement, and how they would propose to test the new container.

CONTEXT: The egg drop activity allows students the opportunity to bring scientific principles and creativity to a problem, while developing the skills of technology and having a good time. However, the excitement of the activity can overshadow the intended outcome of developing understanding and abilities of technological design. This assessment activity provides the opportunity for students to reflect on what they have experienced and articulate what they have come to understand. The activity comes after the design of an original container, the testing of that container, a class discussion on what worked and why, what didn't work and why, what they would do differently next time, and an opportunity to make notes in a personal journal for science class.

EVALUATING STUDENT PERFORMANCE: Student progress in understanding and doing design can be evaluated by comparing the student responses in the reports with the list generated by previous classes. The astute teacher will have made sure that the list included constraints such as cost, time, materials, and trade-offs. Criteria for a quality report might also include how well the student has differentiated between the design and its evaluation. The teacher might also consider the clarity of expression, as well as alternate ways used to present the information, such as drawings.

accomplished by the students and should not involve lengthy learning of new physical skills or time-consuming preparation and assembly operations.

During the middle-school years, the design tasks should cover a range of needs, materials, and aspects of science. Suitable experiences could include making electrical circuits for a warning device, designing a meal to meet nutritional criteria, choosing a material to combine strength with insulation, selecting plants for an area of a school, or designing a system to move dishes in a restaurant or in a production line.

Such work should be complemented by the study of technology in the students' everyday world. This could be achieved by investigating simple, familiar objects through which students can develop powers of observation and analysis—for example, by comparing the various characteristics of competing consumer products, including cost, convenience, durability, and suitability for different modes of use. Regardless of the product used, students need to understand the science behind it. There should be a balance over the years, with the products studied coming from the areas of clothing, food, structures, and simple mechanical and electrical devices. The inclusion of some non-product-oriented problems is important to help students understand that technological solutions include the design of systems and can involve communication, ideas, and rules.

The principles of design for grades 5-8 do not change from grades K-4. But the complexity of the problems addressed and the extended ways the principles are applied do change.

GUIDE TO THE CONTENT STANDARD

Fundamental abilities and concepts that underlie this standard include

ABILITIES OF TECHNOLOGICAL DESIGN

See Content Standard A (grades 5-8)

IDENTIFY APPROPRIATE PROBLEMS FOR TECHNOLOGICAL DESIGN. Students should develop their abilities by identifying a specified need, considering its various aspects, and talking to different potential users or beneficiaries. They should appreciate that for some needs, the cultural backgrounds and beliefs of different groups can affect the criteria for a suitable product.

DESIGN A SOLUTION OR PRODUCT. Students should make and compare different proposals in the light of the criteria they have selected. They must consider constraints—such as cost, time, trade-offs, and materials needed—and communicate ideas with drawings and simple models.

IMPLEMENT A PROPOSED DESIGN. Students should organize materials and other resources, plan their work, make good use of group collaboration where appropriate, choose suitable tools and techniques, and work with appropriate measurement methods to ensure adequate accuracy.

EVALUATE COMPLETED TECHNOLOGICAL DESIGNS OR PRODUCTS. Students should use criteria relevant to the original purpose or need, consider a variety of factors that might affect acceptability and suitability for intended users or beneficiaries, and develop measures of quality with respect to such criteria and factors; they should also suggest improvements and, for their own products, try proposed modifications.

See Teaching Standard B

COMMUNICATE THE PROCESS OF TECHNOLOGICAL DESIGN. Students should review and describe any completed piece of work and identify the stages of problem identification,solution design, implementation, and evaluation.

UNDERSTANDINGS ABOUT SCIENCE AND TECHNOLOGY

See Content Standards A, F, & G (grades 5-8)

- Scientific inquiry and technological design have similarities and differences. Scientists propose explanations for questions about the natural world, and engineers propose solutions relating to human problems, needs, and aspirations. Technological solutions are temporary; technologies exist within nature and so they cannot contravene physical or biological principles; technological solutions have side effects; and technologies cost, carry risks, and provide benefits.
- Many different people in different cultures have made and continue to make contributions to science and technology.
- Science and technology are reciprocal. Science helps drive technology, as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and technique. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis.
- Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Engineers often build in back-up systems to provide safety. Risk is part of living in a highly technological world. Reducing risk often results in new technology.
- Technological designs have constraints. Some constraints are unavoidable, for example, properties of materials, or effects of weather and friction; other constraints limit choices in the design, for example, environmental protection, human safety, and aesthetics.
- Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.

Science in Personal and Social Perspectives

CONTENT STANDARD F:
As a result of activities in grades 5-8, all students should develop understanding of

- **Personal health**
- **Populations, resources, and environments**
- **Natural hazards**
- **Risks and benefits**
- **Science and technology in society**

DEVELOPING STUDENT UNDERSTANDING

Due to their developmental levels and expanded understanding, students in grades 5-8 can undertake sophisticated study of personal and societal challenges. Building on the foundation established in grades K-4, students can expand their study of health and establish linkages among populations, resources, and environments; they can develop an understanding of natural hazards, the role of technology in relation to personal and societal issues, and learn about risks and personal decisions. Challenges emerge from the knowledge that the products, processes, technologies and inventions of a society can result in pollution and environmental degradation and can involve some level of risk to human health or to the survival of other species.

The study of science-related personal and societal challenges is an important endeavor for science education at the middle level. By middle school, students begin to realize that illness can be caused by various factors, such as microorganisms, genetic predispositions, malfunctioning of organs and organ-systems, health habits, and environmental conditions. Students in grades 5-8 tend to focus on physical more than mental health. They associate health with food and fitness more than with other factors such as safety and substance use. One very important issue for teachers in grades 5-8 is overcoming students' perceptions that most factors related to health are beyond their control.

Students often have the vocabulary for many aspects of health, but they often do not understand the science related to the terminology. Developing a scientific understanding of health is a focus of this standard. Healthy behaviors and other aspects of health education are introduced in other parts of school programs.

By grades 5-8, students begin to develop a more conceptual understanding of ecological crises. For example, they begin to realize the cumulative ecological effects of pollution. By this age, students can study environmental issues of a large and abstract nature, for example, acid rain or global ozone depletion. However, teachers should challenge several important misconceptions, such as anything natural is not a pollutant, oceans are limitless resources, and humans are indestructible as a species.

Although students in grades 5-8 have some awareness of global issues, teachers should challenge misconceptions, such as anything natural is not a pollutant, oceans are limitless resources, and humans are indestructible as a species.

Little research is available on students' perceptions of risk and benefit in the context of science and technology. Students sometimes view social harm from technological failure as unacceptable. On the other hand, some believe if the risk is personal and voluntary, then it is part of life and should not be the concern of others (or society). Helping students develop an understanding of risks and benefits in the areas of health, natural hazards—and science and technology in general—presents a challenge to middle-school teachers.

Middle-school students are generally aware of science-technology-society issues from the media, but their awareness is fraught with misunderstandings. Teachers should begin developing student understanding with concrete and personal examples that avoid an exclusive focus on problems.

GUIDE TO THE CONTENT STANDARD

Fundamental concepts and principles that underlie this standard include

PERSONAL HEALTH

- Regular exercise is important to the maintenance and improvement of health. The benefits of physical fitness include maintaining healthy weight, having energy and strength for routine activities, good muscle tone, bone strength, strong heart/lung systems, and improved mental health. Personal exercise, especially developing cardiovascular endurance, is the foundation of physical fitness.
- The potential for accidents and the existence of hazards imposes the need for injury prevention. Safe living involves the development and use of safety precautions and the recognition of risk in personal decisions. Injury prevention has personal and social dimensions.
- The use of tobacco increases the risk of illness. Students should understand the influence of short-term social and psychological factors that lead to tobacco use, and the possible long-term detrimental effects of smoking and chewing tobacco.
- Alcohol and other drugs are often abused substances. Such drugs change how the body functions and can lead to addiction.
- Food provides energy and nutrients for growth and development. Nutrition requirements vary with body weight, age, sex, activity, and body functioning.
- Sex drive is a natural human function that requires understanding. Sex is also a prominent means of transmitting diseases. The diseases can be prevented through a variety of precautions.
- Natural environments may contain substances (for example, radon and lead) that are harmful to human beings. Maintaining environmental health involves establishing or monitoring quality standards related to use of soil, water, and air.

POPULATIONS, RESOURCES, AND ENVIRONMENTS

- When an area becomes overpopulated, the environment will become degraded due to the increased use of resources.
- Causes of environmental degradation and resource depletion vary from region to region and from country to country.

NATURAL HAZARDS

See Content Standard D (grades 5-8)

- Internal and external processes of the earth system cause natural hazards, events that change or destroy human and wildlife habitats, damage property, and harm or kill humans. Natural hazards include earthquakes, landslides, wildfires, volcanic eruptions, floods, storms, and even possible impacts of asteroids.
- Human activities also can induce hazards through resource acquisition, urban growth, land-use decisions, and waste disposal. Such activities can accelerate many natural changes.
- Natural hazards can present personal and societal challenges because misidentifying the change or incorrectly estimating the rate and scale of change may result in either too little attention and significant

human costs or too much cost for unneeded preventive measures.

RISKS AND BENEFITS

- Risk analysis considers the type of hazard and estimates the number of people that might be exposed and the number likely to suffer consequences. The results are used to determine the options for reducing or eliminating risks.
- Students should understand the risks associated with natural hazards (fires, floods, tornadoes, hurricanes,earthquakes, and volcanic eruptions), with chemical hazards (pollutants in air, water, soil, and food), with biological hazards (pollen, viruses, bacterial, and parasites), social hazards (occupational safety and transportation), and with personal hazards (smoking, dieting, and drinking).
- Individuals can use a systematic approach to thinking critically about risks and benefits. Examples include applying probability estimates to risks and comparing them to estimated personal and social benefits.
- Important personal and social decisions are made based on perceptions of benefits and risks.

See Content Standard E (grades 5-8)

SCIENCE AND TECHNOLOGY IN SOCIETY

- Science influences society through its knowledge and world view. Scientific knowledge and the procedures used by scientists influence the way many individuals in society think about themselves, others, and the environment. The effect of science on society is neither entirely beneficial nor entirely detrimental.
- Societal challenges often inspire questions for scientific research, and social priorities often influence research priorities through the availability of funding for research.
- Technology influences society through its products and processes. Technology influences the quality of life and the ways people act and interact. Technological changes are often accompanied by social, political, and economic changes that can be beneficial or detrimental to individuals and to society. Social needs,attitudes, and values influence the direction of technological development.
- Science and technology have advanced through contributions of many different people,in different cultures, at different times in history. Science and technology have contributed enormously to economic growth and productivity among societies and groups within societies.
- Scientists and engineers work in many different settings, including colleges and universities, businesses and industries, specific research institutes,and government agencies.
- Scientists and engineers have ethical codes requiring that human subjects involved with research be fully informed about risks and benefits associated with the research before the individuals choose to participate. This ethic extends to potential risks to communities and property. In short, prior knowledge and consent are required for research involving human subjects or potential damage to property.
- Science cannot answer all questions and technology cannot solve all human problems or meet all human needs. Students

should understand the difference between scientific and other questions. They should appreciate what science and technology can reasonably contribute to society and what they cannot do. For example, new technologies often will decrease some risks and increase others.

Science and technology have advanced through the contributions of many different people in different cultures at different times in history.

History and Nature of Science

CONTENT STANDARD G:
As a result of activities in grades 5-8, all students should develop understanding of

- **Science as a human endeavor**
- **Nature of science**
- **History of science**

DEVELOPING STUDENT UNDERSTANDING

Experiences in which students actually engage in scientific investigations provide the background for developing an understanding of the nature of scientific inquiry, and will also provide a foundation for appreciating the history of science described in this standard.

The introduction of historical examples will help students see the scientific enterprise as more philosophical,social, and human. Middle-school students can thereby develop a better understanding of scientific inquiry and the interactions between science and society. In general, teachers of science should not assume that students have an accurate conception of the nature of science in either contemporary or historical contexts.

To develop understanding of the history and nature of science, teachers of science can use the actual experiences of student investigations, case studies, and historical vignettes. The intention of this standard is not to develop an overview of the complete history of science. Rather, historical examples are used to help students understand scientific inquiry, the nature of scientific knowledge, and the interactions between science and society.

GUIDE TO THE CONTENT STANDARD

Fundamental concepts and principles that underlie this standard include

SCIENCE AS A HUMAN ENDEAVOR

- Women and men of various social and ethnic backgrounds—and with diverse interests, talents, qualities, and motivations—engage in the activities of science, engineering, and related fields such as the health professions. Some scientists work in teams, and some work alone, but all communicate extensively with others.
- Science requires different abilities, depending on such factors as the field of study and type of inquiry. Science is very much a human endeavor, and the work of science relies on basic human qualities, such as reasoning, insight, energy, skill, and creativity—as well as on scientific habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas.

NATURE OF SCIENCE

- Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models. Although all scientific ideas are tentative and subject to change and improvement in principle, for most major ideas in science,there is much experimental and observational confirmation. Those ideas are not likely to change greatly in the future.Scientists do and have changed their ideas about nature when they encounter new experimental evidence that does not match their existing explanations.
- In areas where active research is being pursued and in which there is not a great deal of experimental or observational evidence and understanding, it is normal for scientists to differ with one another about the interpretation of the evidence or theory being considered. Different scientists might publish conflicting experimental results or might draw different conclusions from the same data. Ideally, scientists acknowledge such conflict and work towards finding evidence that will resolve their disagreement.
- It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists. Evaluation includes reviewing the experimental procedures, examining the evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations. Although scientists may disagree about explanations of phenomena, about interpretations of data, or about the value of rival theories, they do agree that questioning, response to criticism, and open communication are integral to the process of science. As scientific knowledge evolves, major disagreements are eventually resolved through such interactions between scientists.

Students should understand the difference between scientific and other questions and what science and technology can and cannot reasonably contribute to society.

HISTORY OF SCIENCE

- Many individuals have contributed to the traditions of science.Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.
- In historical perspective,science has been practiced by different individuals in different cultures. In looking at the history of many peoples, one finds that scientists and engineers of high achievement are considered to be among the most valued contributors to their culture.
- Tracing the history of science can show how difficult it was for scientific innovators to break through the accepted ideas of their time to reach the conclusions that we currently take for granted.