Chapter 1

Introduction to Physical Science

The BIG Idea

Nature of Science and Inquiry

How do scientists investigate the natural world?

Chapter Preview

1 What Is Physical Science?

Discover How Does a Ball Bounce?

At-Home Activity Quantitative or Qualitative?

2 Scientific Inquiry

Discover Can You Make a Shadow Disappear?

Skills Activity Classifying

Analyzing Data Car Travel

Active Art The Nature of Inquiry

At-Home Activity Which Falls Fastest?

3 Science Laboratory Safety

Discover Where Is the Safety Equipment in Your School?

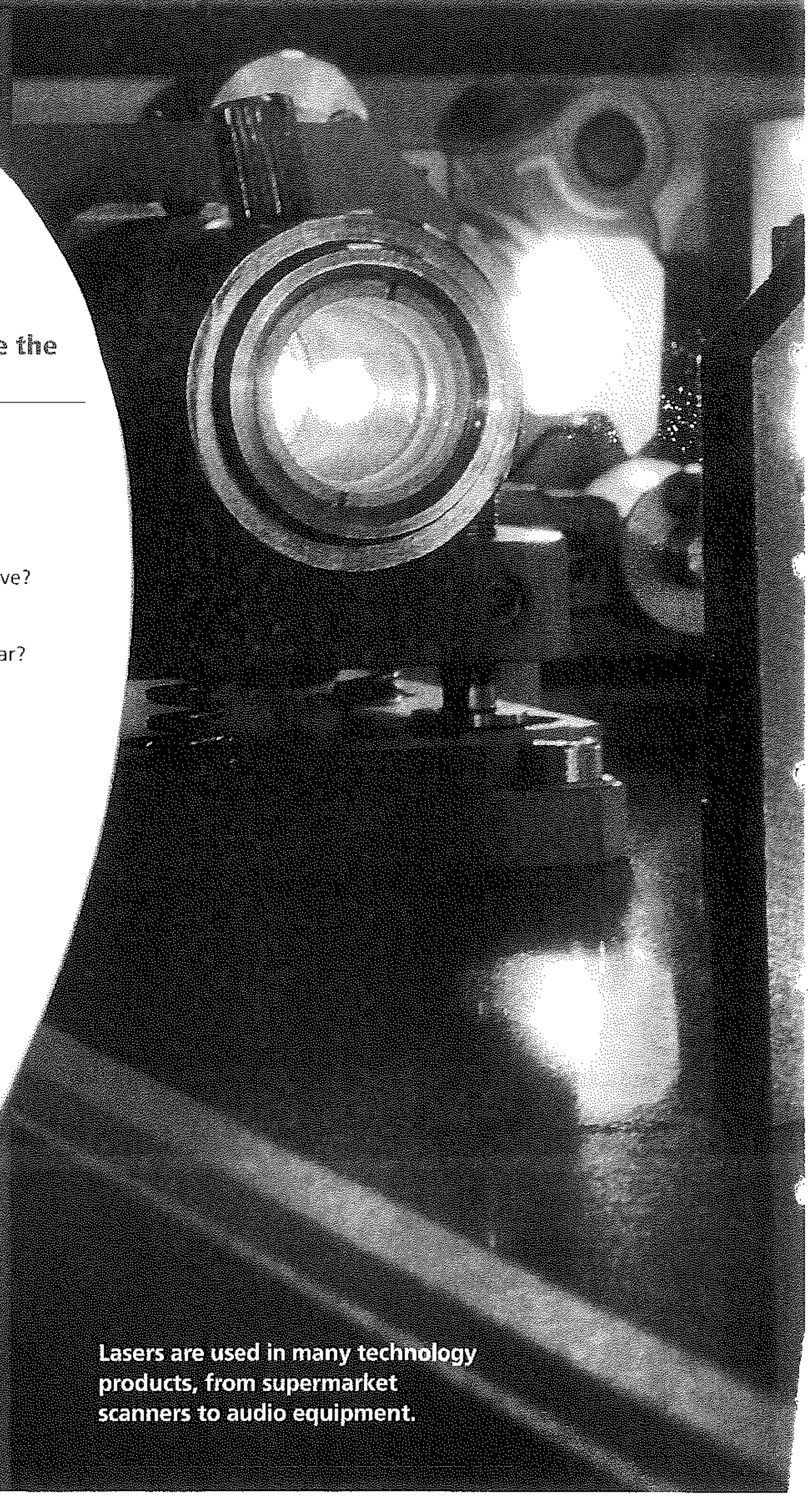
Skills Lab Swing Time

4 What Is Technology?

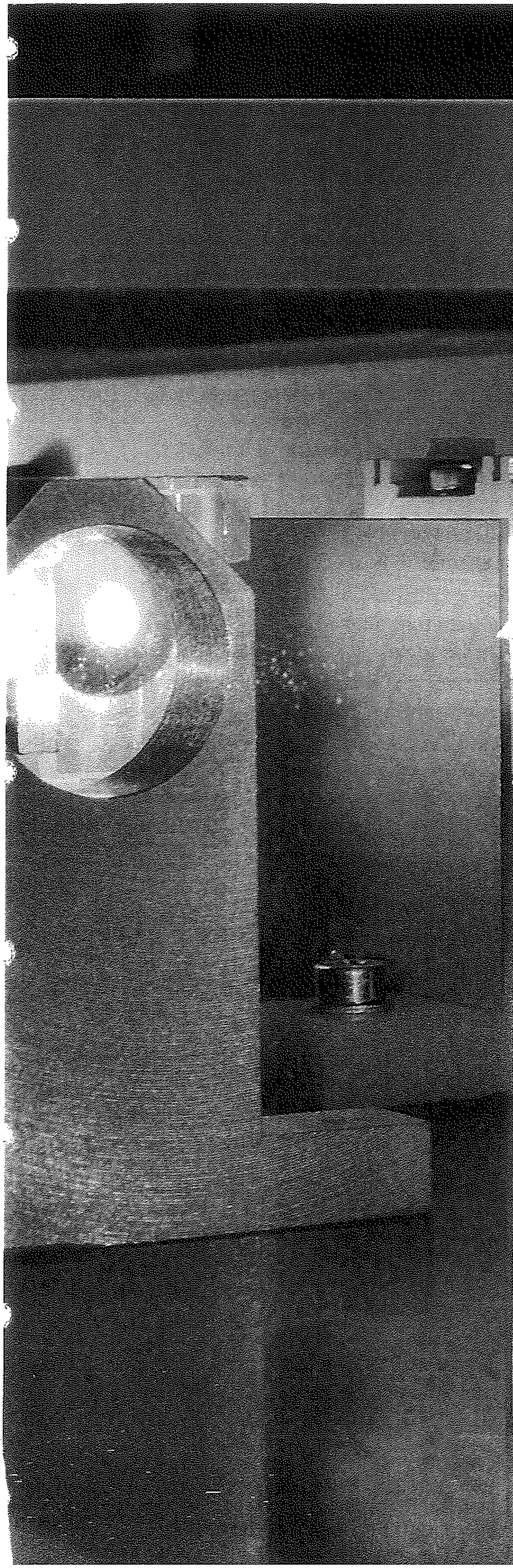
Discover Why Redesign?

Active Art Technology Design Process

Try This Watch Ideas Take Off



Lasers are used in many technology products, from supermarket scanners to audio equipment.



Lab zone™ Chapter **Project**

Design and Build a Chair

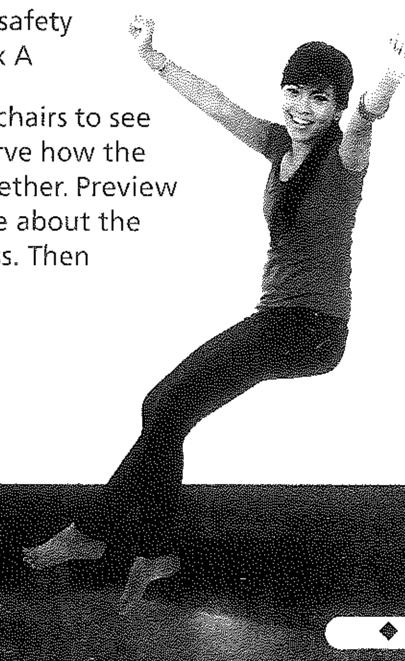
Do you have a favorite chair? If so, what makes it more comfortable than the desk chairs at school? The answer lies in its design. In this chapter project, you will explore the process by which a chair is designed and built.

Your Goal To design and build a chair made of cardboard

The chair you build must

- be constructed from no more than 4 square meters of cardboard
- have a seat and a sturdy back
- support at least 20 kilograms of books
- be built following the safety guidelines in Appendix A

Plan It! Examine several chairs to see how they are built. Observe how the chair parts are joined together. Preview the chapter to learn more about the technology design process. Then sketch your chair design. When your teacher has approved your design, start to build your chair.



Section 1

What Is Physical Science?

Reading Preview

Key Concepts

- What skills do scientists use to learn about the world?
- What do physical scientists study?

Key Terms

- science
- observing
- qualitative observation
- quantitative observation
- inferring
- predicting
- chemistry
- physics

Target Reading Skill

Using Prior Knowledge Before you read, look at the section headings to see what this section is about. Then write what you know about physical science in a graphic organizer like the one below. As you read, write what you learn.

What You Know
1. Physical science includes the study of motion. 2.

What You Learned
1. 2.

Lab zone Discover Activity

How Does a Ball Bounce?

1. Your teacher will give you three balls and a meter stick. Hold the meter stick with the zero end touching the floor.
2. Hold one ball beside the top of the meter stick so it doesn't touch. Drop the ball. Have a partner record the height of the first bounce.
3. Repeat Step 2 twice using the same ball.
4. Repeat Steps 2 and 3 for each of the other balls.

Think It Over

Predicting Can you use your data to predict accurately how each ball will bounce in the future? Explain.

As you walk around an amusement park, you may wonder how the rides work. How does a ferris wheel spin? How do the bumper cars work? What makes the neon lights so colorful? Why don't people fall out of the roller coaster as it completes a loop? These are all questions that physical science can help to answer. The designers of amusement parks must know a great deal about physical science to make sure that visitors experience fun and thrills while staying safe.

An amusement park is a great place to observe physical science in action. ▶

How Scientists Think

Physical science is one type of science. **Science** is a way of learning about the natural world by gathering information. Science includes all of the knowledge gained by exploring nature. To think and work like a scientist, you need to use the same skills that they do. **Scientists use the skills of observing, inferring, and predicting to learn more about the natural world.**

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Observing Like everyone else, scientists observe things. **Observing** means using one or more senses to gather information. Your senses include sight, hearing, touch, taste, and smell. Each day of your life, you observe things that help you decide what to eat, what to wear, and whether to stay inside or go out.

Scientists usually make observations in a careful, orderly way. They make both qualitative and quantitative observations. **Qualitative observations** are descriptions that don't involve numbers or measurements. Noticing that a ball is round, that milk smells sour, that honey tastes sweet, or that a car is moving is a qualitative observation. **Quantitative observations** are measurements. You make a quantitative observation when you measure your height or weight. In science, observations may also be called evidence, or data.

Inferring Have you ever bumped into a bumper car that wasn't moving? What happened? If your bumper car was moving fast enough, it made the other bumper car move when they bumped. You might then say that if an object is standing still, one way to make it move is to hit it with another moving object.

When you explain your observations, you are **inferring,** or making an inference. Inferences are based on reasoning from what you already know. You make inferences all the time without thinking about it. For example, your teacher gives lots of surprise quizzes. So if your teacher walks into the room carrying a stack of paper, you may infer that the pages contain a quiz. But inferences are not always correct. The papers could be announcements to be taken home.

Reading Checkpoint What are inferences based on?

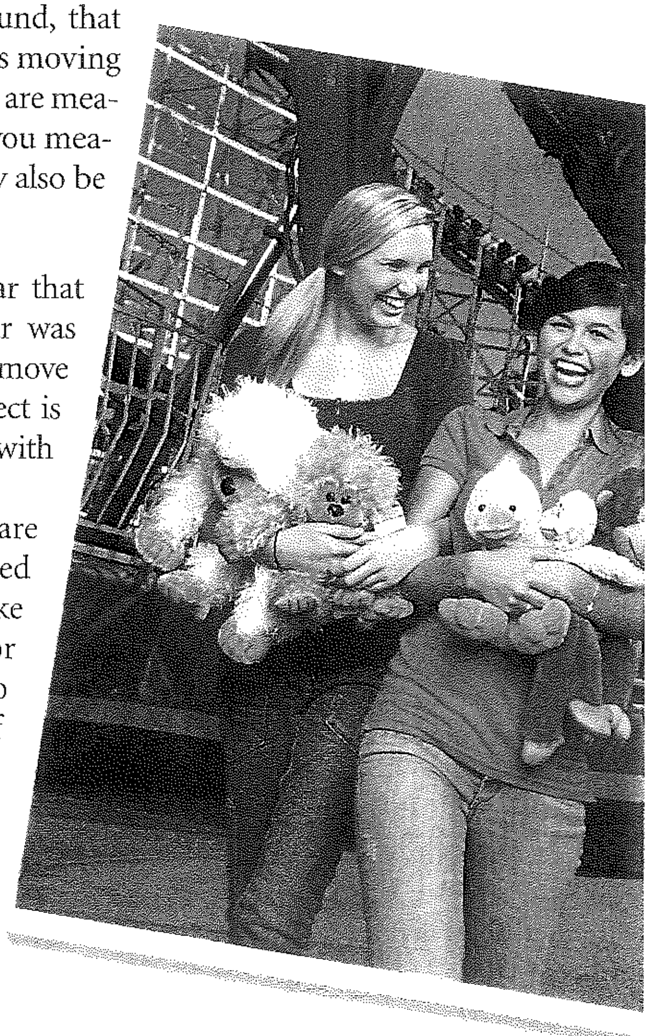
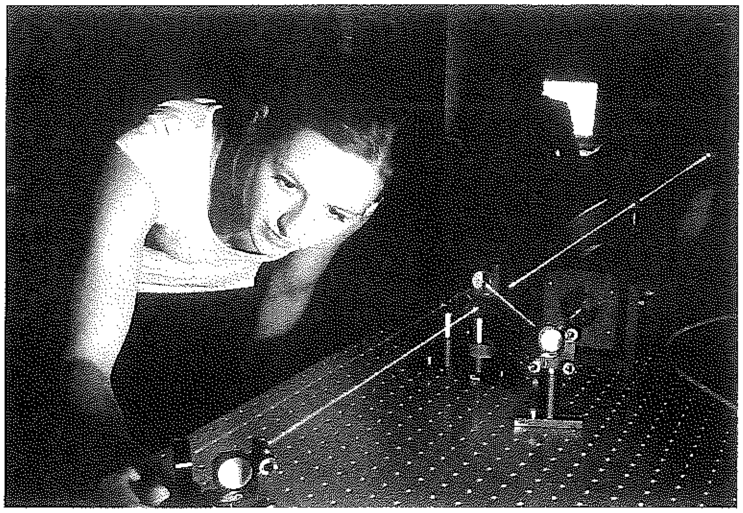


FIGURE 1 **Inferring**
When you explain or interpret your observations, you are making an inference. Inferring *How do you think these young women obtained the stuffed toys? Explain your reasoning.*



▲ This physicist is experimenting with lasers.

▲ A chemist is removing a liquid from a flask.

FIGURE 2
Careers in Physical Science
People who work in physical science study changes in matter and energy. Physicists, chemists, and engineers are examples of people who work in physical science.

Predicting Every day, people make statements about the future. Before a soccer game, for example, you might predict, "We're going to win big!" **Predicting** means making a forecast of what will happen in the future based on past experience or evidence. Saying your team will win is a prediction if it is based on the records of the two teams. It is a guess if it is not based on any data.

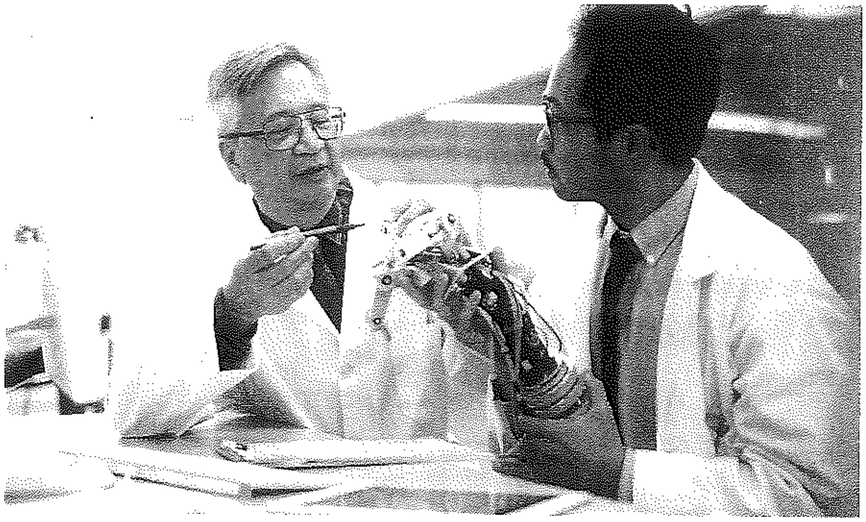
Predicting is important in science, too. For example, some scientists predict the weather based on past experience and current information.

The Study of Matter and Energy

Physical science is the study of matter, energy, and the changes they undergo. Matter is all around you. It is anything that has mass and occupies space. Energy is the ability to do work or cause change. An amusement park ride uses energy as it moves. Physical science is divided into two main areas: chemistry and physics.

Chemistry is the study of the properties of matter and how matter changes. When you study chemistry, you will learn about the particles that make up matter and why different forms of matter have different properties. You will find out how matter can change and why. For example, you'll learn why some materials burn while others do not.

Physics is the study of matter and energy and how they interact. When you study physics, you will learn about motion and forces and how they are related. You will also learn about the different forms of energy and the physical laws that govern energy. Other topics you will study in physics include sound, light, electricity, and magnetism.



▲ Two engineers are building a robot.

All of the people shown in Figure 2 work in some area of physical science. Some careers involve scientific research. Other careers, such as photographer, piano tuner, or firefighter, require that you understand physical science.

You may be thinking that physical science is important only if you work in careers like these. But you use physical science all the time. For example, when you put on sunglasses to protect your eyes from bright sunlight, or you blow on a spoonful of soup to cool it down, you are using physical science. In this book, you will find out about many more everyday events that involve physical science.

Reading Checkpoint **What is physics?**

Section 1 Assessment

Target Reading Skill Using Prior Knowledge Review your graphic organizer and revise it based on what you just learned in the section.

Reviewing Key Concepts

1. a. Listing Name three skills that scientists use to learn more about the natural world.
   b. Comparing and Contrasting How do observing and inferring differ?
   c. Classifying Is this statement an observation or an inference? *It must be raining outside.* Explain.
2. a. Defining What is physical science?
   b. Identifying What are the two main areas of physical science?
   c. Inferring How would a knowledge of physical science be useful to a musician? To a photographer?

Lab zone At-Home Activity

Quantitative or Qualitative? Look around your room at home. Write down three qualitative and three quantitative observations. How do these two types of observations differ from one another?

Section 2

Scientific Inquiry

Reading Preview

Key Concepts

- How do scientists investigate the natural world?
- What role do models, laws, and theories play in science?

Key Terms

- scientific inquiry
- hypothesis
- variable
- manipulated variable
- responding variable
- controlled experiment
- data
- communicating
- scientific law
- scientific theory

Target Reading Skill

Building Vocabulary After you read this section, reread the paragraphs that contain definitions of Key Terms. Use all the information you have learned to write a definition of each Key Term in your own words.

Lab zone **Discover Activity**

Can You Make a Shadow Disappear?

1. Using a piece of clay as a base, set up a straw so that it stands up straight.
2. Shine a flashlight on the straw from as many directions as you can. Observe the different shadows you create. Record your observations.
3. Determine whether you can make the shadow disappear while using the light. If you can, describe how you did it.

Think It Over

Posing Questions If you had a meter stick among your materials, what are two other questions you could investigate?

Have you ever made shadow puppets on a wall? Shadows are produced when something blocks light from shining on a surface. Making shadow puppets might make you wonder about light and shadows. Your curiosity can be the first step in scientific inquiry. **Scientific inquiry** refers to the different ways scientists study the natural world. It is the ongoing process of discovery in science.

Just like you, scientists often find that being curious is the first step in scientific inquiry. Scientists have other habits of mind as well: honesty, open-mindedness, skepticism, and creativity. Honesty means reporting observations truthfully. Open-mindedness is accepting new and different ideas. Skepticism is being doubtful about information presented without evidence. Creativity involves coming up with new ways to solve problems.

A shadow puppet ▼

The Process of Inquiry

Scientific inquiry does not always occur in the same way. But, certain processes are often involved. **The processes that scientists use in inquiry include posing questions, developing hypotheses, designing experiments, collecting and interpreting data, drawing conclusions, and communicating ideas and results.**

Posing Questions Suppose you want to learn more about light and shadows. You might ask, Does the size of a shadow depend on the distance between the light and the object? How is a shadow affected by the light's position? Will you get shadows if you have several light sources?

All those questions about light and shadows are scientific questions because you can answer them by making observations. Not all questions are scientific, however. For example, suppose you ask, "Which is the most interesting photo in a photography contest?" The answer to that question is based on personal opinion, not on evidence. Scientific inquiry cannot answer questions based on opinions, values, or judgments.

Developing Hypotheses Scientific inquiry moves forward when ideas can be tested. For example, suppose you want to find out how the distance between the object and the light affects the size of a shadow. Your first step might be to develop a hypothesis (plural: *hypotheses*). A **hypothesis** is a possible answer to a scientific question or explanation for a set of observations. For example, you may say: *Changing the distance between an object and a light source changes the size of the object's shadow.*

It is important to realize that your hypothesis is not a fact. It is only one possible way to answer a question. But in science, a hypothesis must be testable by observation or experiment. In that way, information can be collected that may or may not support the hypothesis. Many trials are needed before a hypothesis can be accepted as true.

Reading Checkpoint **What is a hypothesis?**

Lab zone **Skills Activity**

Classifying

Which of the following questions can be answered by scientific inquiry?

- Is running a better sport than swimming?
- Does running make your muscles stronger than swimming does?
- Which brand of running shoes looks best?

How did you make your decision in each case?

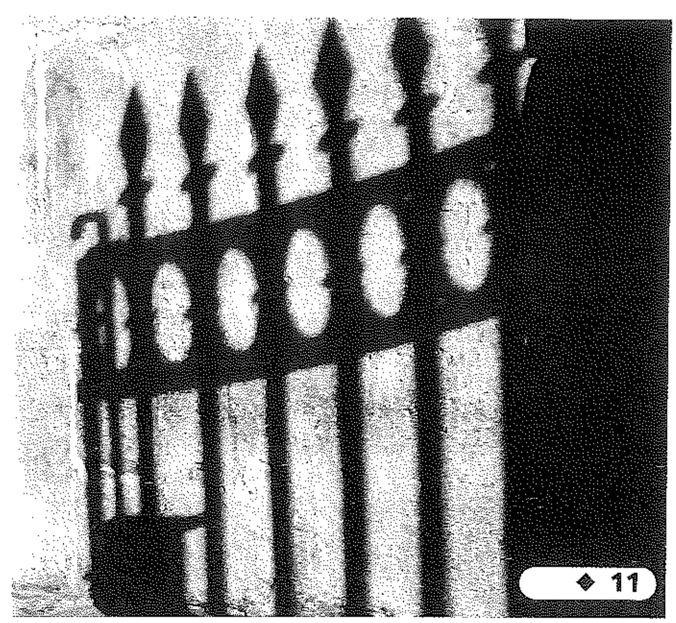


FIGURE 3
Photographing Shadows
Photographers make use of shadows to create artistic works.
Posing Questions *What are some questions about light and shadows that a photographer would want to investigate to take photographs like these?*

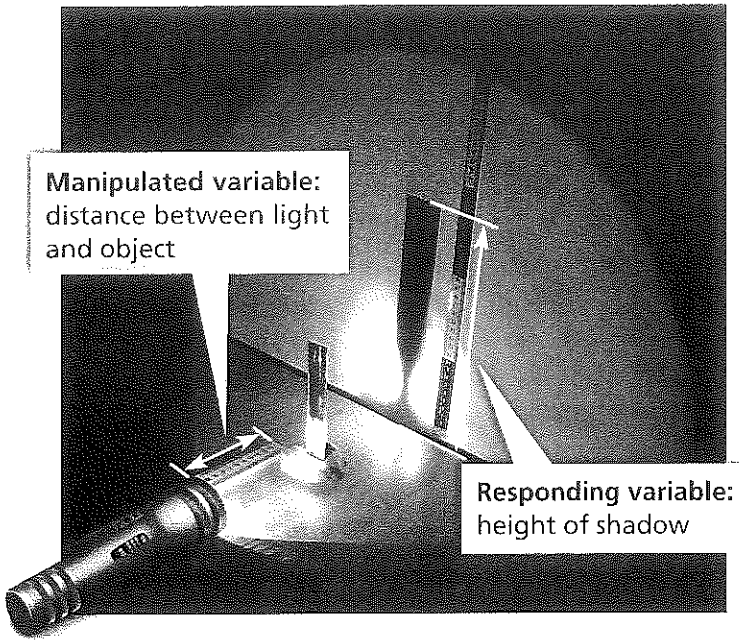


FIGURE 4
Investigating Shadows
This photo shows the setup for an experiment to test how the distance between an object and a light source affects the size of the object's shadow. What is the manipulated variable in the experiment?

Designing an Experiment Scientists can test a hypothesis by designing an experiment. They begin to plan their experiment by first examining all the variables. **Variables** are factors that can change in an experiment. In a well-designed experiment, only one variable is purposely changed. The variable that is changed is the **manipulated variable** (or independent variable). The variable that is expected to change because of the manipulated variable is the **responding variable** (or dependent variable).

Look at Figure 4. For your hypothesis about shadows, the manipulated variable is the distance between the light source and the object. The responding variable is the height of the shadow.

To be sure that changes in the manipulated variable are causing the changes in the responding variable, scientists change only one variable at a time. All the other variables must be controlled—that is, kept constant. Figure 4 shows some variables that need to be controlled in your shadow experiment: the type of light, the height and angle of the light, and the distance between the object and the wall. An investigation in which all variables except one remain the same is called a **controlled experiment.**

Shadow Experiment

Distance Between Object and Light (cm)	Height of Shadow (cm)
10	32
15	27
20	25
25	23
30	22
35	21
40	20

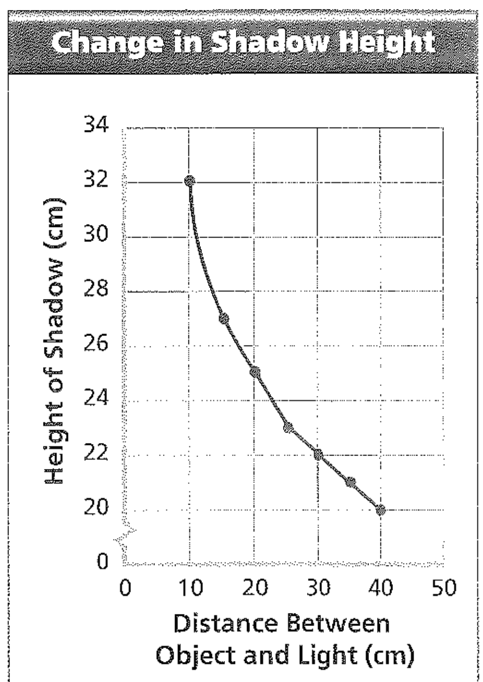


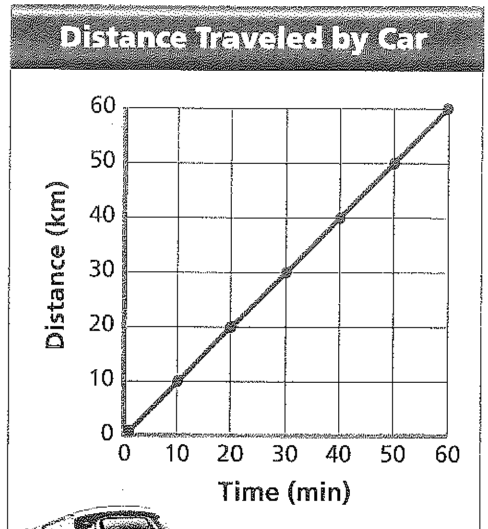
FIGURE 5 Showing Experimental Results
The results of the shadow experiment are shown here as a data table and as a graph. **Interpreting Graphs** *What relationship do the data show?*

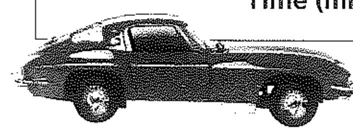
Math Analyzing Data

Car Travel

The graph shows the distance a car travels in a one-hour period. Use the graph to answer the questions below.

1. Reading Graphs What variable is plotted on the horizontal axis? What variable is plotted on the vertical axis?
2. Interpreting Data How far does the car travel in the first 10 minutes? In the first 40 minutes?
3. Interpreting Data How long does it take the car to travel 30 km? 60 km?
4. Predicting Use the graph to predict how far the car would travel in 120 minutes. Assume the car continues to travel at the same speed.
5. Graphing Draw a graph of a car moving at a steady speed of 30 kilometers per hour for a one-hour period. What is the relationship between the steepness of the graph lines and the speed of the cars?





Collecting and Interpreting Data Before scientists begin an experiment, they usually create a data table for recording their data. **Data** are the facts, figures, and other evidence gathered through observations. A data table provides an organized way to collect and record observations. Figure 5 shows a data table that you might have made during your shadow experiment.

Recall that observations can be qualitative or quantitative. Data can also be qualitative or quantitative. Qualitative data can be recorded as notes in a journal or log. Scientists make it easier to share quantitative data by using the same system of measurement, called the International System of Units (SI). Notice that the data table uses centimeters (cm), an SI unit of length. You can learn more about measuring with SI in the Skills Handbook at the end of this book.

After the data are collected, they need to be interpreted, or explained. Graphs are a useful way to view quantitative data because they can reveal trends or patterns in the data. Look at the graph in Figure 5. It shows that as the distance between the object and the light increased, the height of the shadow decreased in a regular way. You can learn more about using data tables and graphs in the Skills Handbook.

Reading Checkpoint **Why do scientists use the SI system?**

Drawing Conclusions After scientists interpret their data, they draw a conclusion about their hypothesis. A conclusion states whether or not the data support the hypothesis. For the data in the shadow experiment, you would conclude that the height of a shadow decreases as the light is moved farther away from an object.

Communicating An important part of scientific inquiry is communicating. **Communicating** is sharing ideas and conclusions with others through writing and speaking. It is also sharing the process you used in your inquiry. When a scientist shares the design of an experiment, others can repeat that experiment to check the results. Scientists often communicate by giving talks at scientific meetings, exchanging information on the Internet, or publishing articles in scientific journals.

Communicating information about scientific discoveries often leads to new questions, new hypotheses, and new investigations, as you can see in Figure 6. Scientific inquiry is a process with many paths. Work may go forward or even backward when testing out new ideas.

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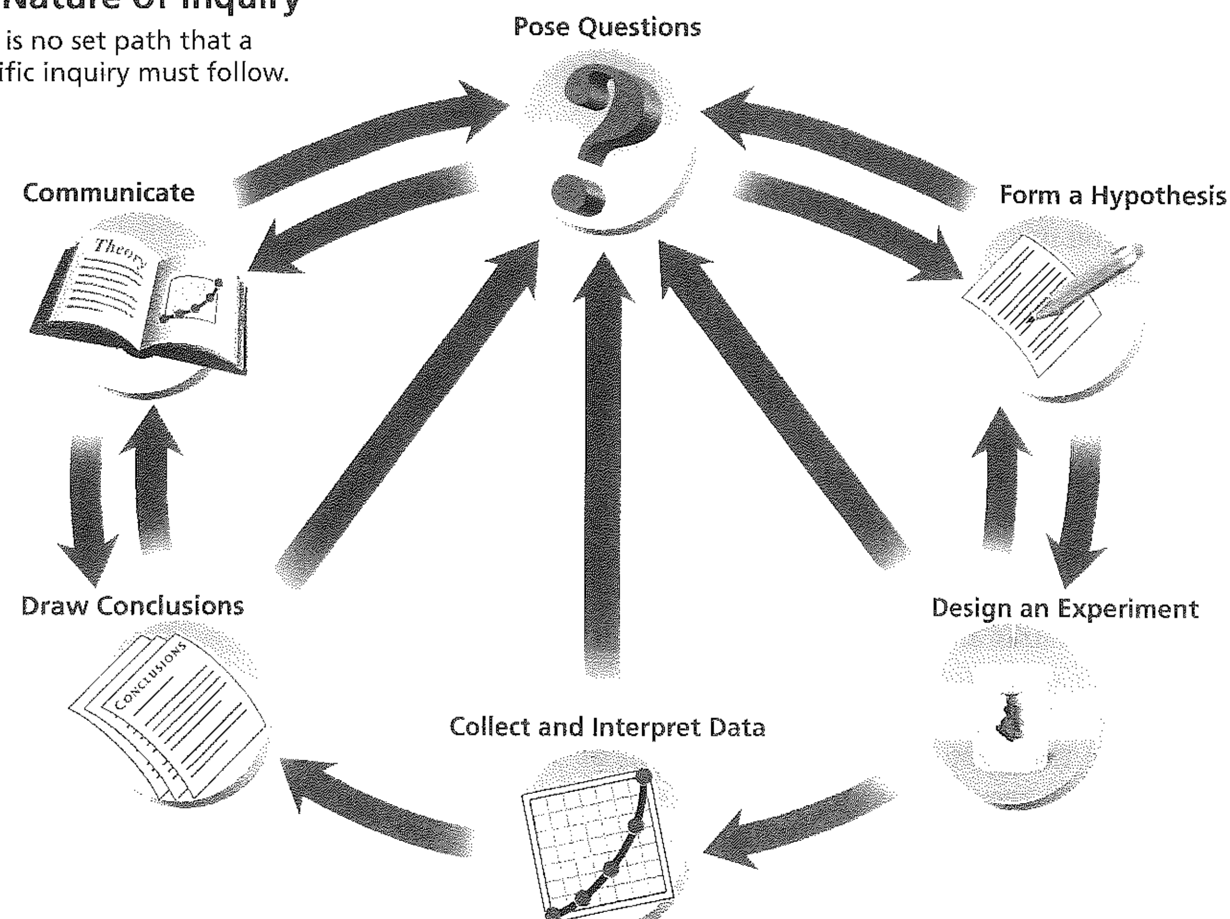
FIGURE 6
The Nature of Inquiry
There is no set path that a scientific inquiry must follow.



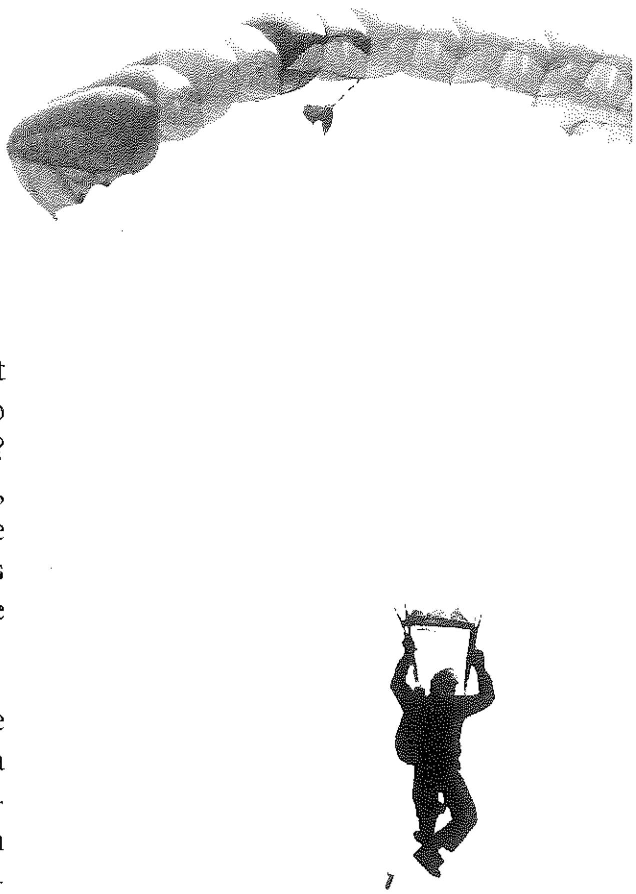


FIGURE 7
A Scientific Law
According to the law of gravity, this sky diver will eventually land back on Earth.

How Science Develops

Today, the amount of scientific knowledge is huge. It covers topics ranging from matter's smallest particles to the whole universe. How did that knowledge develop? Over the years, as scientists studied the natural world, they did more than collect facts. They developed more complete explanations for their observations. **Scientists use models and develop laws and theories to increase people's understanding of the natural world.**

Scientific Models Sometimes, it may be impossible to observe certain objects and scientific processes. So a scientist will make a model. A model is a picture, diagram, computer image, or other representation of an object or process. Physical models, such as a representation of the solar system, may look like the real thing. Other models can be generated by computers, such as the flight plan of a space vehicle. Still others can be mathematical equations or words that describe how something works. Certain models, such as models of atoms (the particles that make up matter), have been especially important in building up our understanding of science.

Scientific Laws Have you ever heard someone say "What goes up must come down"? When scientists repeatedly observe the same result in specific circumstances, they may develop a scientific law. A **scientific law** is a statement that describes what scientists expect to happen every time under a particular set of conditions.

A scientific law describes an observed pattern in nature without attempting to explain it. You can think of a scientific law as a rule of nature. For example, the law of gravity states that all objects in the universe attract each other. This law has been verified over and over again.

Reading Checkpoint **What is a scientific law?**

Scientific Theories In some cases, many observations can be connected by one explanation. This can lead to the development of a scientific theory. A **scientific theory** is a well-tested explanation for a wide range of observations or experimental results. For example, according to the atomic theory, all substances are composed of tiny particles called atoms. The atomic theory helps explain many observations, such as why water freezes or boils at certain temperatures, and why it can dissolve many other materials.

Scientists accept a theory only when there is a large body of evidence that supports it. However, future evidence may not suport the theory. If that happens, scientists may modify the theory or discard it altogether. This illustrates the ever-growing and exciting nature of scientific knowledge.

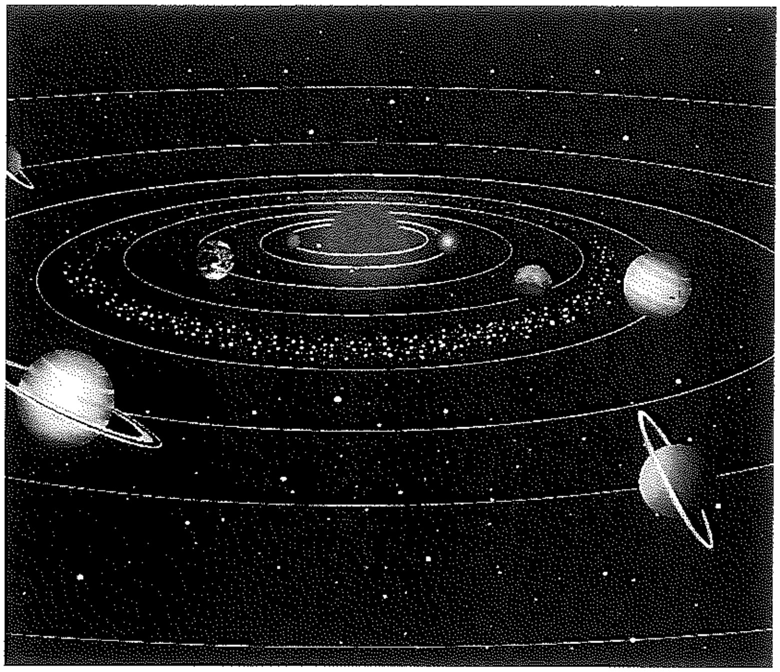


FIGURE 8
A Scientific Theory
Based on observations of sunsets and sunrises, ancient people theorized that the sun revolved around Earth. New evidence led scientists to abandon that ancient theory. Today, scientists know that Earth, along with the other planets in the solar system, revolves around the sun.

Section 2 Assessment

Target Reading Skill Building Vocabulary Use your definitions to help you answer the questions below.

1. a. Defining What is scientific inquiry?
   b. Listing Name six processes that are often involved in scientific inquiry.
   c. Inferring How can an experiment that disproves a hypothesis be useful?
2. a. Defining What is a scientific theory? A scientific law?
   b. Comparing and Contrasting How do scientific theories differ from scientific laws?
   c. Classifying The students who conducted the shadow length experiment concluded that their results supported their hypothesis. Can their supported hypothesis be called a scientific theory? Why or why not?

Lab zone At-Home Activity

Which Falls Fastest? Design an experiment to determine which falls fastest—an unfolded sheet of paper, a sheet of paper folded in fourths, or a crumpled sheet of paper. Be sure to develop a hypothesis, design a controlled experiment, and collect data. Do your data support your hypothesis? Discuss your results with a family member.

Section 3

Science Laboratory Safety

Reading Preview

Key Concepts

- Why is preparation important when carrying out scientific investigations?
- What should you do if a lab accident occurs?

Target Reading Skill

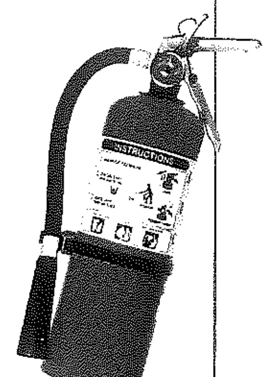
Previewing Visuals Before you read, preview Figure 10. Then write two questions that you have about the figure in a graphic organizer like the one below. As you read, answer your questions.

Safety in the Lab

Q. Why are safety goggles necessary in the lab?
A.
Q.

Lab zone Discover Activity

Where Is the Safety Equipment in Your School?



1. Look around your classroom or school for any safety-related equipment.
2. Draw a floor plan of the room or building and clearly label where each item is located.

Think It Over

Predicting Why is it important to know where safety equipment is located?

Suppose you and your family decide to go rock climbing. What plans should you make? You'll need to bring rope, some snacks to eat, and water to drink. But you'll also need to plan for everyone's safety.

For the climb to go smoothly, you'll want to make sure that everyone has the proper clothing and safety gear, such as helmets, harnesses, and climbing shoes. You'll check to see whether the equipment is in good condition. You'll also want to make sure that everyone follows proper procedures and knows their role as others take their turn climbing.

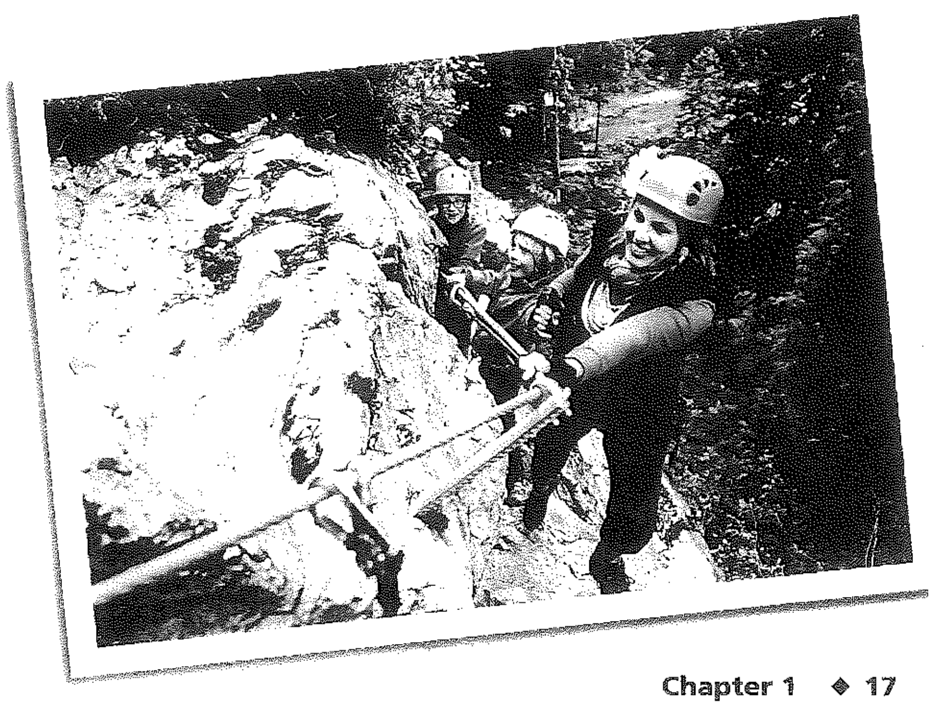


FIGURE 9
Climbing Safely
Climbing rocks safely requires careful preparation and the use of proper equipment.

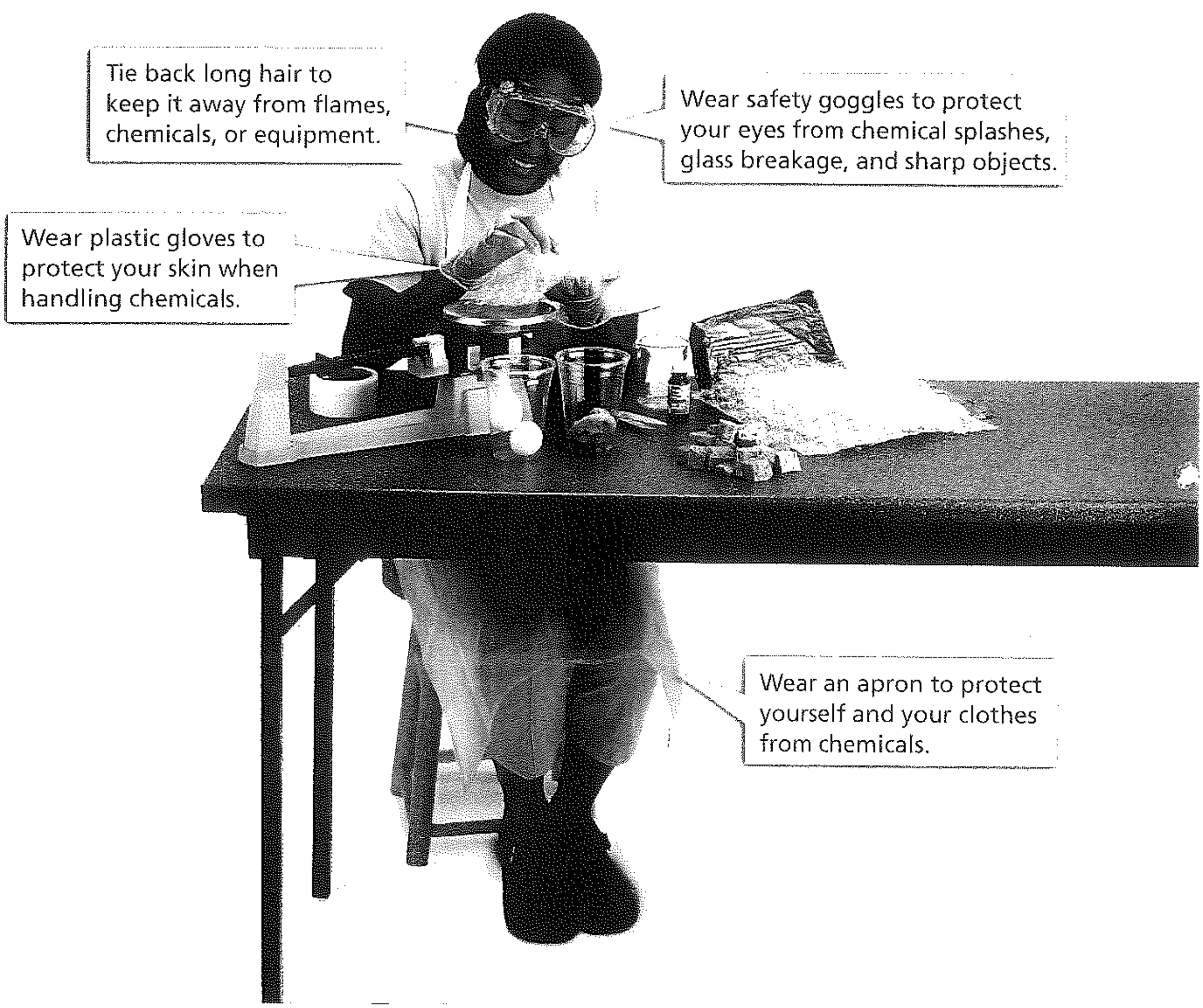
Safety in the Lab

Good preparation is as important to a scientific investigation as it is to rock climbing. **Good preparation helps you stay safe when doing science activities in the laboratory.**

Thermometers, balances, and glassware are some of the equipment you will use in science labs. Do you know how to use these items? What should you do if something goes wrong? Thinking about these questions ahead of time is an important part of being prepared.

Preparing for the Lab Preparing for a lab should begin the day before you will perform the lab. It is important to read through the procedure carefully and make sure you understand all the directions. Also, review the general safety guidelines in Appendix A, including those related to the specific equipment you will use. If anything is unclear, be prepared to ask your teacher about it before you begin the lab.

FIGURE 10
Safety in the Lab
Good preparation for an experiment helps you stay safe in the laboratory. Observing *List three precautions each student is taking while performing the labs.*

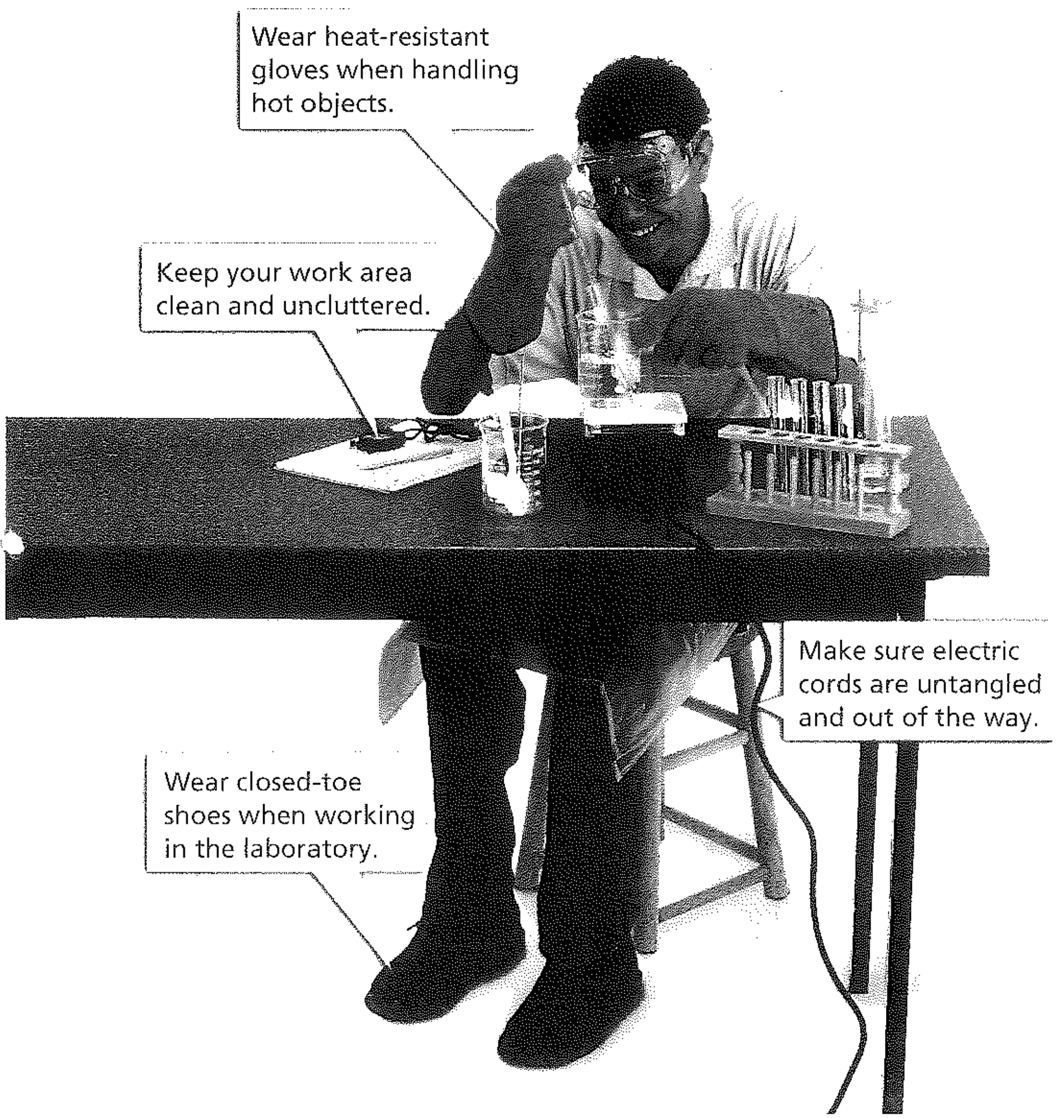


Performing the Lab Whenever you perform a science lab, your chief concern must be the safety of yourself, your classmates, and your teacher. The most important safety rule is simple: Always follow your teacher's instructions and the textbook directions exactly. You should never try anything on your own without asking your teacher first.

Labs and activities in this textbook series include safety symbols like those at the right. These symbols alert you to possible dangers in performing the lab and remind you to work carefully. They also identify any safety equipment that you should use to protect yourself from potential hazards. The symbols are explained in detail in Appendix A. Make sure you are familiar with each safety symbol and what it means.

Another thing you can do to make your lab experience safe and successful is to keep your work area clean and organized. Also, do not rush through any of the steps. Finally, always show respect and courtesy to your teacher and classmates.

Reading Checkpoint What is the most important safety rule?



Safety Symbols

- Safety Goggles
- Lab Apron
- Breakage
- Heat-Resistant Gloves
- Plastic Gloves
- Heating
- Flames
- No Flames
- Corrosive Chemical
- Poison
- Fumes
- Sharp Object
- Animal Safety
- Plant Safety
- Electric Shock
- Physical Safety
- Disposal
- Hand Washing
- General Safety Awareness

In Case of Emergency

ALWAYS NOTIFY YOUR TEACHER IMMEDIATELY

Injury	What to Do
Burns	Immerse burns in cold water.
Cuts	Cover cuts with a clean dressing. Apply direct pressure to the wound to stop bleeding.
Spills on Skin	Flush the skin with large amounts of water.
Foreign Object in Eye	Flush the eye with large amounts of water. Seek medical attention.

FIGURE 11
In Case of Emergency
These first-aid tips can help guide your actions during emergency situations. Remember, always notify your teacher immediately if an accident occurs.

End-of-Lab Procedures Your lab work does not end when you reach the last step in the procedure. There are important things you need to do at the end of every lab.

When you have completed a lab, be sure to clean up your work area. Turn off and unplug any equipment and return it to its proper place. It is very important that you dispose of any waste materials properly. Some wastes should not be thrown in the trash or poured down the drain. Follow your teacher's instructions about proper disposal. Finally, be sure to wash your hands thoroughly after working in the laboratory.

In Case of an Accident

Good preparation and careful work habits can go a long way toward making your lab experiences safe ones. But, at some point, an accident may occur. A classmate might accidentally knock over a beaker or a chemical might spill on your sleeve. Would you know what to do?

When any accident occurs, no matter how minor, notify your teacher immediately. Then, listen to your teacher's directions and carry them out quickly. Make sure you know the location and proper use of all the emergency equipment in your lab room. Knowing safety and first-aid procedures beforehand will prepare you to handle accidents properly. Figure 11 lists some first-aid procedures you should know.

Section 3 Assessment

Target Reading Skill Previewing Visuals
Refer to your questions and answers about Figure 10 to help you answer Question 1 below.

Reviewing Key Concepts

1. a. Listing List two things you should do ahead of time to prepare for a lab.
   b. Interpreting Diagrams Suppose a lab included the safety symbols below. What do these symbols mean? What precautions should you take?

   c. Making Judgments Should everyone take time to prepare for a lab when several students work together in a group? Explain.

2. a. Reviewing During a lab activity you get a cut and start to bleed. What is the first thing you should do?
   b. Sequencing List in order the next steps you would take to deal with your injury.
   c. Making Judgments Some people feel that most accidents can be prevented with careful preparation and safe behavior. Do you agree or disagree with this viewpoint? Explain your reasoning.

Writing in Science

Safety Poster Make a poster of one of the safety rules in Appendix A to post in your lab. Be sure to include the safety symbol, clear directions, and additional illustrations.

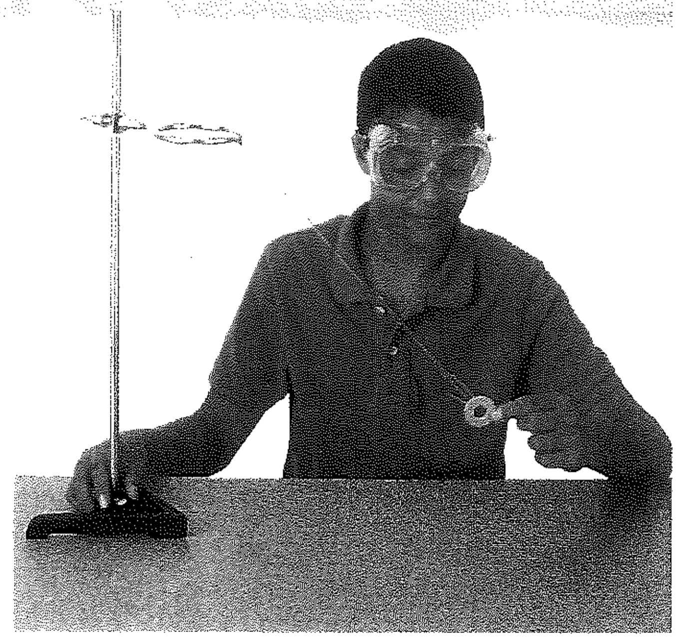
Lab zone **Skills Lab**

Swing Time

Problem
Does the swing of a pendulum take longer for an object of greater mass?

Skills Focus
graphing, interpreting data

Materials
• stand with clamp • large paper clip
• ruler • string, 50 cm in length • stopwatch
• 5 metal washers • safety goggles



Procedure

1. Read the whole procedure. Write a hypothesis describing how the mass of washers attached to a pendulum will affect the time of its swing. Then create a data table like the one below.
2. Put on your safety goggles. Tie one end of a string to a clamp on a stand. Tie the other end to a large paper clip. Pull out one side of the paper clip to serve as a hook.
3. Place a metal washer on the hook and let it hang down. If necessary, raise the clamp so that the washer swings freely.
4. Pull the washer back so that the string makes an angle of about 45° with the stand. Have your partner measure the height of the washer above the table top. Record this height as the starting position of the washer.
5. Release the washer gently, without pushing it. During a complete swing, the washer will move from its starting position and return back again.

Data Table

Number of washers	Time for 10 swings (s)	Average time per swing (s)
1		
2		

6. Record the time for 10 swings to the nearest tenth of a second. Then divide that time by 10 to find the average time for one swing.
7. Repeats Steps 5 and 6, increasing the mass each time by adding a washer. Make sure that you always start the swing at the same height.

Analyze and Conclude

1. Graphing Graph your results. (*Hint:* Place the number of washers on the horizontal axis and the average time per swing on the vertical axis.)
2. Interpreting Data Use the graph to decide if your data support your hypothesis.
3. Drawing Conclusions What conclusion can you draw from this experiment?
4. Communicating In a paragraph, explain how this experiment enabled you to test your hypothesis.

Design an Experiment
Design an experiment to test how the average time for a pendulum swing changes when the mass of the washers is constant but the length of the string changes. *Obtain your teacher's approval before carrying out this experiment.*

Section 4

• Tech & Design •

What Is Technology?

Reading Preview

Key Concepts

- What are the steps in the technology design process, and what is involved in each step?
- What are the parts of a technological system?
- How do society and technology impact each other?

Key Terms

- technology
- engineer
- brainstorming
- constraint
- trade-off
- prototype
- troubleshooting
- system

Target Reading Skill

Sequencing As you read, make a flowchart that shows the steps in the technology design process. Put each step of the process in a separate box in the flowchart in the order in which it occurs.

The Technology Design Process

Identify the need.

↓

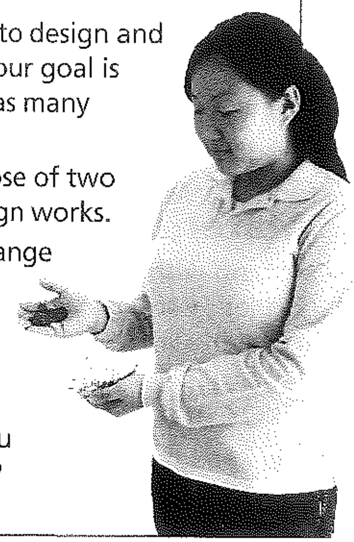
Research the problem.

↓

Lab zone Discover Activity

Why Redesign?

1. Use the materials your teacher gives you to design and construct a boat out of aluminum foil. Your goal is to make a boat that will float and carry as many pennies as possible.
2. Test your aluminum-foil boat against those of two other students to see how well your design works.
3. Based on your observations in Step 2, change the design of your boat, if necessary. Build a new boat and test it again.



Think It Over

Problem Solving What problems did you identify by testing your boat? How did you improve upon your original boat's design?

What comes to mind when you hear the word "mouse"? Perhaps you imagine a tiny furry animal? Or perhaps you might think of the device that sends signals from your hand to a computer. Where did this modern mouse come from?

The computer mouse is the result of technology. Technology is closely related to science, but the two activities have different goals. **Technology** is a way of changing the natural world to meet human needs or solve problems. By contrast, the goal of science is a study of the natural world in order to understand it.

People who work in a field in technology are called engineers. An **engineer** is someone who is trained to use both technological and scientific knowledge to solve practical problems. Engineers often follow a set of steps called the technology design process.

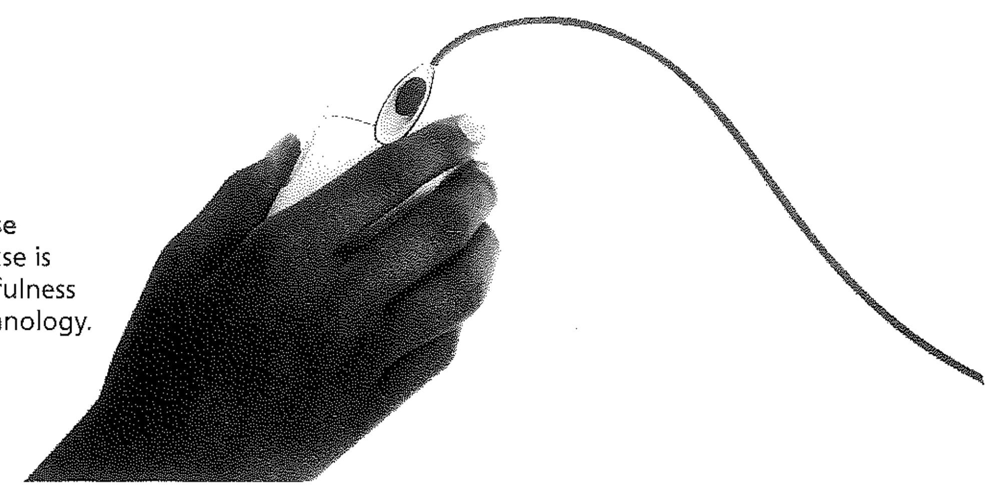


FIGURE 12
The Computer Mouse
The design of a mouse is important to its usefulness and success as a technology.

Technology Design Process

The technology design process, like scientific inquiry, does not always follow rigid steps. **Often, engineers follow a common process: They identify a need, research the problem, design a solution, build and evaluate a prototype, troubleshoot and redesign, and communicate the solution.** Figures 13 and 14 show some of the steps in this process.

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Identifying a Need Engineers designed the first mouse for use with large, complex computers. Early versions had several problems. They were expensive. Dirt easily became trapped in the mechanism, preventing the mouse from working. Also, the mouse often "slipped," meaning that the cursor didn't move when the mouse moved.

Imagine that you are an engineer on the team that is redesigning the original mouse. As your first step, you must decide exactly what need you are trying to fulfill. When engineers identify a need, they clearly define the problem they are trying to solve.

Researching the Problem What is the next stage? After defining a problem, engineers need to research it fully. That may include performing experiments related to the technology they are designing.

In gathering information about the mouse, the engineers discovered that the ball inside the mouse was held in place by a complex system of sensitive, costly parts. Too much pressure on the ball made it slip frequently. Any bit of dirt or dust would jam up the system. To fix it, the entire mouse had to be taken apart, and each part had to be cleaned separately.

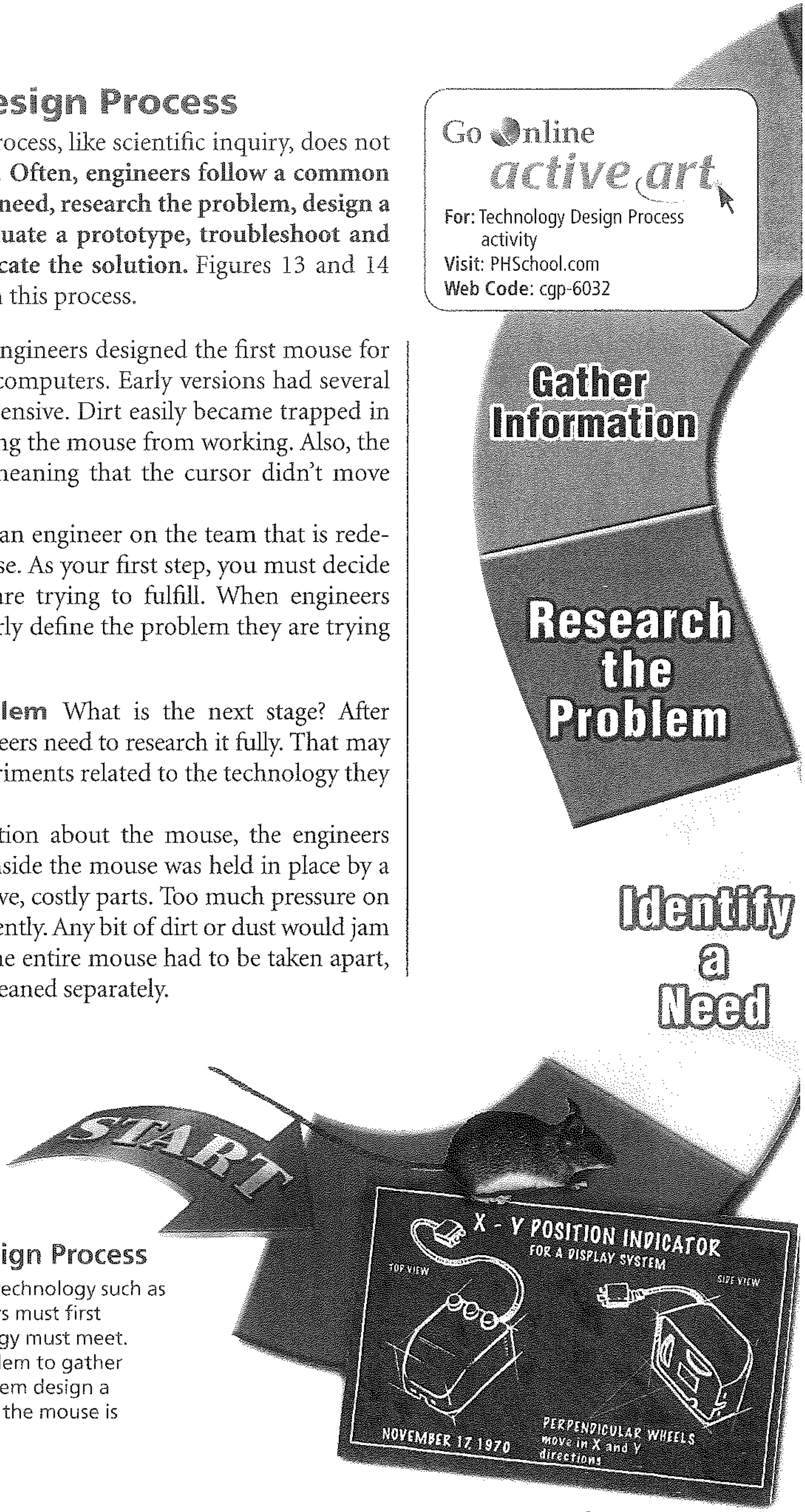


FIGURE 13
The Technology Design Process
In designing a new piece of technology such as a computer mouse, engineers must first identify needs that technology must meet. They then research the problem to gather infomation that may help them design a solution. An early design for the mouse is shown at right.

Designing a Solution Once a team has a clear understanding of the problem, it is time to think about solutions. Designing a solution involves thinking about different ways to solve the problem. Engineers consider many possible solutions and choose the best one. The best design is the one that meets the needs and has the fewest negative characteristics.

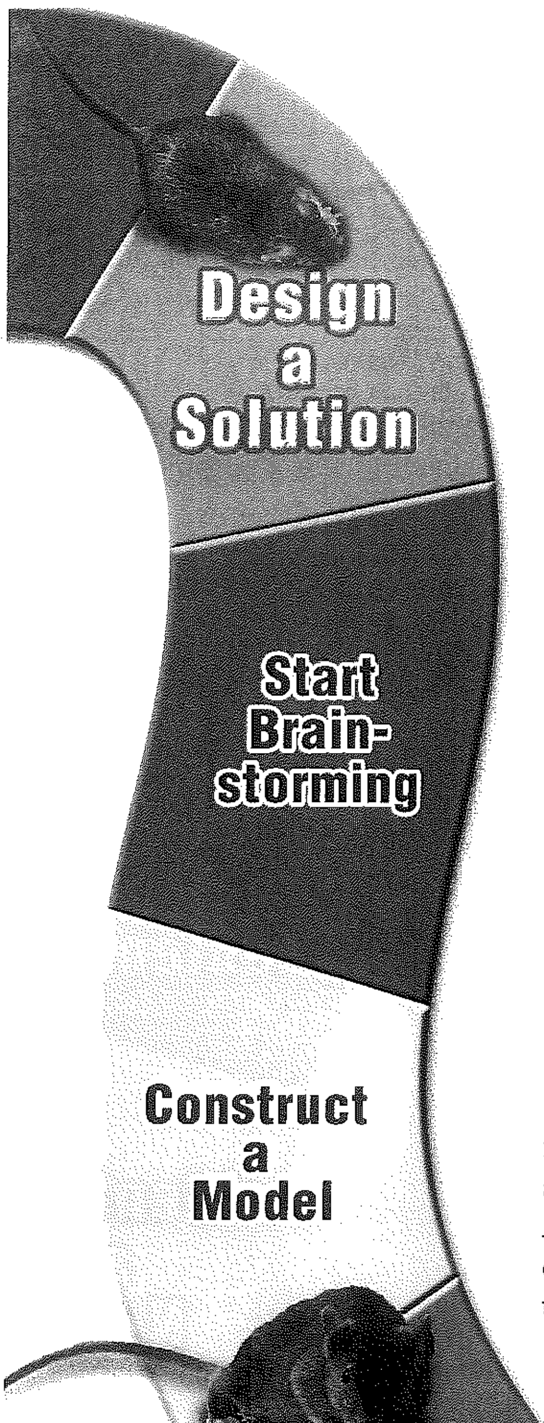
An important activity that helps generate ideas is called brainstorming. **Brainstorming** is a process in which group members freely suggest any creative solutions that come to mind. When the mouse engineers brainstormed, they proposed solutions that involved magnets, lights, and other creative ideas. Engineers may refine their ideas by making sketches or constructing models.

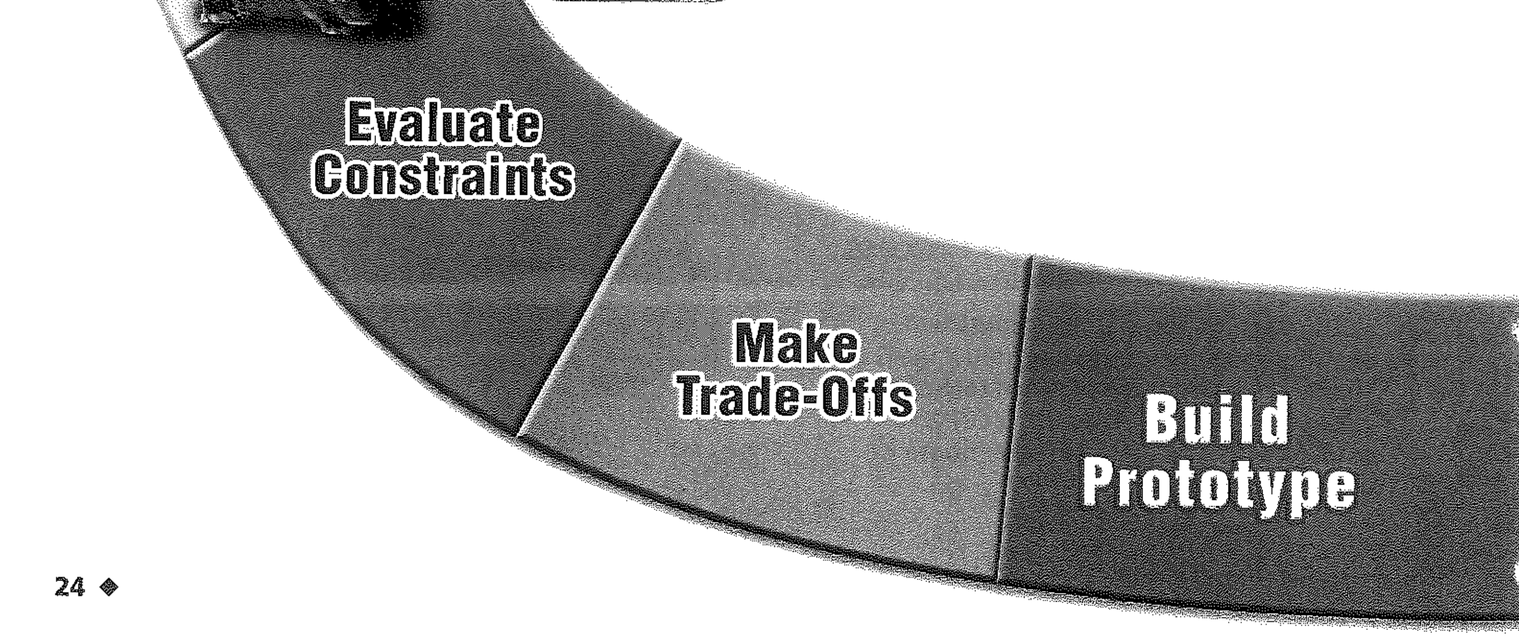
Will a design idea actually work? If so, how well? To answer the questions, engineers must evaluate the constraints of each possible design. A **constraint** is any factor that limits or restricts a design. For example, one physical constraint that engineers must consider is the strength of the materials they use. They must think about the following questions.

- How well will the parts stand up to repeated use?
- Will the product be likely to break or cause injuries?
- How much money can the finished product cost?
- What should be the overall size of the product?
- How should the product look?

A design team must sometimes make trade-offs. A **trade-off** is an exchange in which one benefit is given up in order to obtain another. For example, one material may be sturdy but ugly. Another may be more attractive but weaker. The team may decide to use the more attractive material to appeal to customers, trading off strength for appearance.

Reading Checkpoint What is a constraint?





Building a Prototype The next phase of the process is to build and test a prototype. A **prototype** is a working model used to test a design. Some prototypes are full size and made of the materials proposed for the final product. Today, many prototypes are completely "virtual," or computer generated.

The engineers designed many tests to study the new mouse. They designed a machine that kept the mouse working all day. They found that after the equivalent of three years of use, the mouse showed only minor problems in performance.

Troubleshooting and Redesigning The next stage in the design process is to identify the causes of any problems and to redesign the product to address the problems. The process of analyzing a design problem and finding a way to fix it is called **troubleshooting.** Figure 14 shows some problems the mouse team discovered.

Communicating the Solution The team will want to share its accomplishments! In the last stage of the technology design process, engineers must communicate to consumers how a product meets their needs. They must also communicate with those involved in bringing the product to consumers.

Through effective communication, information about the mouse reached the public, and the mouse became increasingly popular over the next few years. Decades later, the mouse is still the most popular method of moving a cursor around a computer screen.

Lab zone Try This Activity

Watch Ideas Take Off

In this activity, you will model some stages of the design process.

1. With a team of three or four classmates, brainstorm some ideas for a new product that would keep shoelaces from constantly untying.
2. Evaluate each idea, and discuss the constraints and trade-offs you might have to make.
3. Sketch the design solution the team has agreed on.

Predicting After selecting a design solution, what do you think is the next step your team should take?

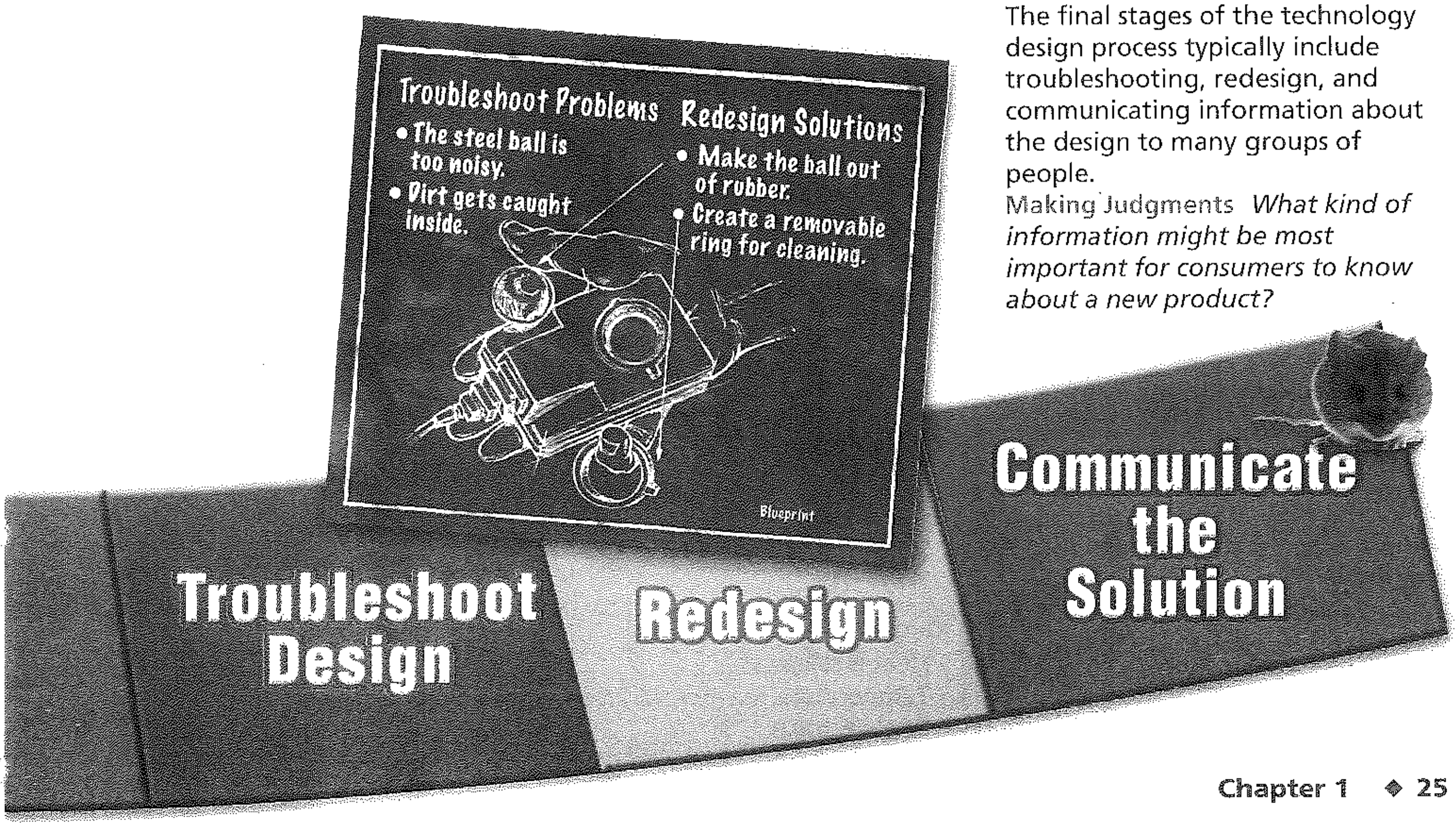


FIGURE 14
Final Design Stages
The final stages of the technology design process typically include troubleshooting, redesign, and communicating information about the design to many groups of people.
Making Judgments *What kind of information might be most important for consumers to know about a new product?*

Technology as a System

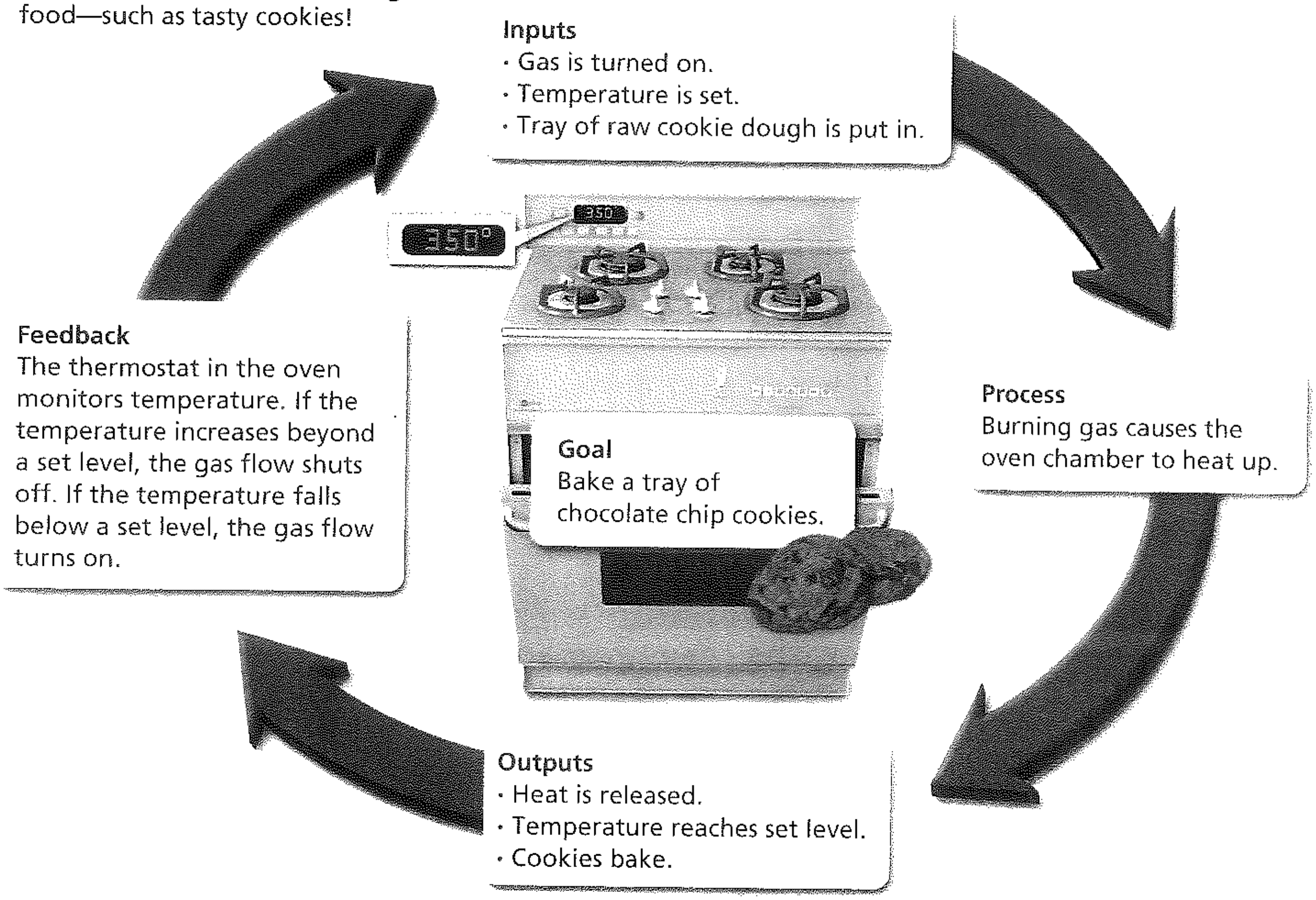
When you hear the word *system*, what comes to mind? Maybe you think of your school system or the circulatory system in your body. All **systems** have one thing in common: They are made of parts that work together.

Technology products can be thought of as systems, too. A **technological system includes a goal, inputs, processes, outputs, and, in some cases, feedback.** Figure 15 describes these in one familiar technological system—an oven.

Technological systems are designed to achieve a particular goal, or purpose. An input is something that is put into a system in order to reach that goal. The process is a sequence of actions that the system undergoes. An output is a result or product. If the system works correctly, the output should match the goal. Some technological systems have an additional component, called feedback. Feedback is information a system uses to monitor the input, process, and output so that the system can adjust itself to meet the goal.

Reading Checkpoint **What do all systems have in common?**

FIGURE 15
The Oven as a System
An oven is a technological system. Input, process, output, and feedback are all involved in achieving the goal of cooking food—such as tasty cookies!



Technology and Society

Technology has always been a part of human history. During the Stone Age, people used stones to make tools. Spears, axes, and spades enabled them to hunt animals and grow crops. The food supply became more stable. People no longer needed to wander in search of food. They began to settle in one place.

The situation in the Stone Age is one example of how technology can affect society. The term *society* refers to any group of people who live together in an area, large or small, and have certain things in common, such as a form of government. **Throughout history, from the Stone Age to the Information Age today, technology has had a large impact on society.** Today cellular phones, satellites, and high-speed Internet connections allow people to share information quickly around the world.

Technological advances have done much to move societies forward through the centuries. However, technology has both good and bad impacts. Often, the negative effects are unintentional. They may not be recognized until long after the technology has been put to use.

In deciding whether to use a particular technology, people must analyze its possible risks and benefits. Analyzing risks involves evaluating the possible problems of a technology. These risks are compared to the expected advantages, or benefits, of the technology.

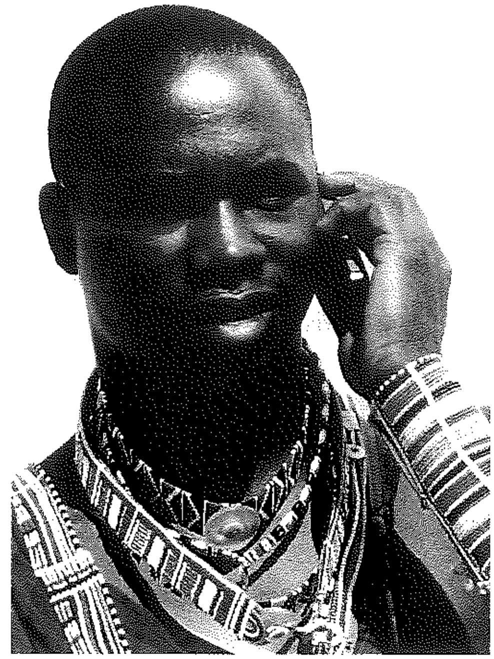


FIGURE 16
Spreading Technology
This Kenyan tribesman uses a cellular phone to communicate with friends and family.

Section 4 Assessment

Target Reading Skill Sequencing Refer to your flowchart about the technology design process as you answer Question 1.

Reviewing Key Concepts

1. a. Describing List the stages in the technology design process. Briefly describe each stage.
   b. Explaining What are design constraints? Give two examples of constraints that should be considered when designing a cellular phone.
   c. Making Judgments A team working on a new bicycle seat design must choose between a comfortable but costly material and a less expensive but uncomfortable material. Which trade-off would you make? Explain.
2. a. Reviewing What four components do all technological systems include? What fifth component do some systems have?
   b. Applying Concepts An alarm clock is a technological system. Identify each major component of this system.
3. a. Listing List five examples of common technologies that influence society today.
   b. Drawing Conclusions Do you think that technology had a greater impact on society in the past than it has today? Explain.

Writing in Science

How-To Paragraph Think about the computer mouse you use most often. Suppose your team has just finished designing this mouse model. Write step-by-step instructions explaining how to use the mouse to move a cursor on a computer screen. Include a sketch.

Chapter 1 Study Guide

The BIG Idea **Nature of Science and Inquiry** Scientists investigate the natural world by posing questions, developing hypotheses, designing experiments, analyzing data, drawing conclusions, and communicating results.

1 What Is Physical Science?

Key Concepts

- Scientists use the skills of observing, inferring, and predicting to learn more about the natural world.
- Physical science is the study of matter, energy, and the changes that matter and energy undergo.

Key Terms

science
observing
qualitative observations
quantitative observations
inferring
predicting
chemistry
physics

2 Scientific Inquiry

Key Concepts

- The processes that scientists use in inquiry include posing questions, developing hypotheses, designing experiments, collecting and interpreting data, drawing conclusions, and communicating ideas and results.
- Scientists use models and develop laws and theories to increase people's understanding of the natural world.

Key Terms

scientific inquiry
hypothesis
variable
manipulated variable
responding variable
controlled experiment
data
communicating
scientific law
scientific theory

3 Science Laboratory Safety

Key Concepts

- Good preparation helps you stay safe when doing science activities in the laboratory.
- When any accident occurs, no matter how minor, notify your teacher immediately. Then, listen to your teacher's directions and carry them out quickly.

4 What Is Technology?

Key Concepts

- Often engineers follow a common process: They identify a need, research the problem, design a solution, build and evaluate a prototype, troubleshoot and redesign, and communicate the solution.
- A technological system includes a goal, inputs, processes, outputs, and, in some cases, feedback.
- Throughout history, from the Stone Age to the Information Age today, technology has had a large impact on society.

Key Terms

• technology • engineer • brainstorming
• constraint • trade-off • prototype
• troubleshooting • system

Review and Assessment

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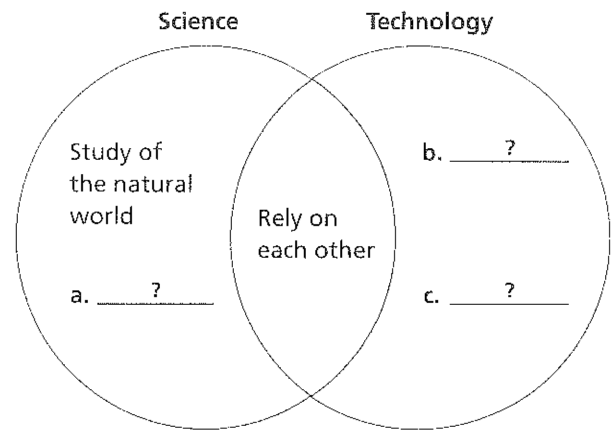
Organizing Information

Comparing and Contrasting Copy the Venn diagram comparing science and technology onto a separate sheet of paper. Then complete it and add a title. (For more on Comparing and Contrasting, see the Skills Handbook.)



Reviewing Key Terms

Choose the letter of the best answer.

1. A logical interpretation based on reasoning from prior experience is called
   a. scientific inquiry.
   b. a prediction.
   c. an inference.
   d. an observation.
2. Scientific inquiry often begins with
   a. collecting data.
   b. designing an experiment.
   c. posing questions.
   d. communicating results.
3. In an experiment where you change only the temperature, temperature is the
   a. responding variable.
   b. manipulated variable.
   c. hypothesis.
   d. controlled variable.
4. In the event that a glass beaker breaks during a lab, the first thing you should do is
   a. wash your hands.
   b. clean up the broken glass.
   c. alert your teacher.
   d. obtain another beaker.
5. Any factor that limits or restricts a design is called a
   a. trade-off. b. system.
   c. prototype. d. constraint.

If the statement is true, write *true*. If it is false, change the underlined word or words to make the statement true.

6. A <u>quantitative</u> observation doesn't involve numbers or measurements.
7. A <u>scientific law</u> is a well-tested explanation for a wide range of observations or experimental results.
8. <u>Data</u> are the facts, figures, and other evidence gathered through observations.
9. <u>Science</u> is a way of changing the natural world to meet human needs or solve problems.
10. <u>Brainstorming</u> is the process of analyzing a design problem and finding a way to fix it.

Writing in Science

News Report Choose a technology product with which you are familiar. Imagine that you are a news reporter covering the product's first introduction to the public. Write a 30-second informative report to be broadcast on the news.

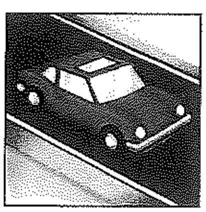
Review and Assessment

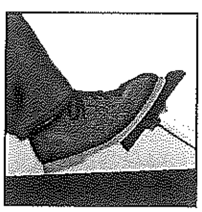
Checking Concepts

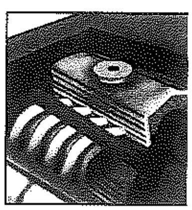
11. In your own words, briefly explain what physical science is.
12. Why must a scientific hypothesis be testable?
13. Why is it important to report experimental results honestly even when the results go against your hypothesis?
14. In a controlled experiment, why is it important to change just one variable at a time?
15. What role do graphs play in the analysis of scientific data?
16. What are three things you should do when preparing for a lab?
17. Why is building a prototype an important part of the technology design process?
18. What is the role of feedback in a technological system?

Thinking Critically

19. Making Judgments Why do you think that, as a general precaution, you should never bring food or drink into the laboratory?
20. Classifying For the system shown below, identify the input, process, and output.


Car moves forward


Driver steps on gas pedal


Gas makes engine run

21. Problem Solving Your team is designing a new computer keyboard. From prototype tests, you learn that the keyboard successfully reduces hand strain, but that it breaks easily. Users also complained about the keyboard's appearance. How would you proceed?

22. Relating Cause and Effect How might a scientist who tracks hurricanes depend on satellite technology? How might satellite engineers depend on the work of scientists?

Applying Skills

Use the table to answer Questions 23–26.

This table provides data on the types of trains in the United States in 1900 and 1960.

Number of Trains in Use in the United States, 1900 and 1960

Type	1900	1960
Steam trains	37,463	374
Electric trains	200	498
Diesel trains	0	30,240

23. Interpreting Data What kinds of trains existed in the United States in 1900? In 1960?
24. Calculating How did the number of steam trains change between 1900 and 1960? How did the number of electric and diesel trains change over that period?
25. Inferring Which type of train met people's needs best in 1960? What is your evidence?
26. Drawing Conclusions Based on this table, what can you conclude about the progress of train technology between 1900 and 1960?

Lab zone Chapter Project

Performance Assessment Before testing your chair, explain to your classmates why you designed your chair the way you did. How did you join the pieces of cardboard together? How did you address the design constraints? When you test your model, examine how steady your chair is while supporting 20 kilograms of books. How could you improve your chair's design?

Standardized Test Prep

Test-Taking Tip

Eliminating Incorrect Answers

When answering a multiple-choice question, you can often eliminate some answer choices because they are clearly incorrect. By doing this, you increase your odds of choosing the correct answer.

Sample Question

Which of the following is usually the first stage in the technology design process?

A communicate about the design solution
B identify a need
C redesign the product to address any problems
D build a prototype

Answer

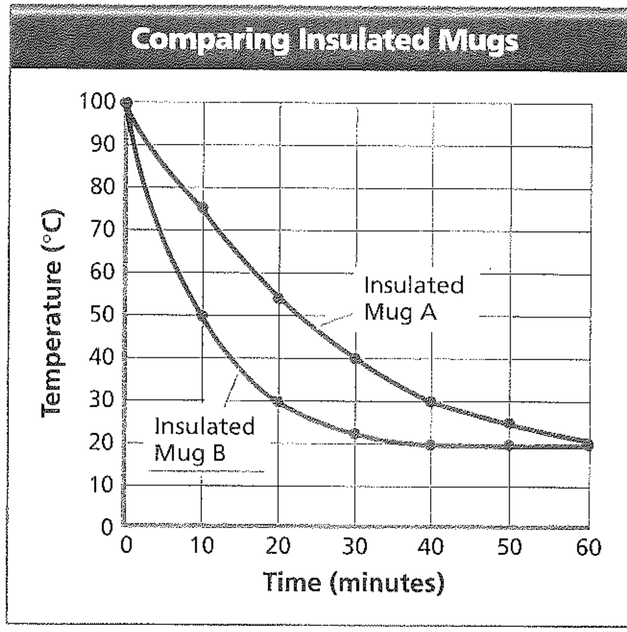
The correct answer is **B**. You can eliminate **A** and **C** because these steps typically occur near the end of the technology design process. Of the remaining choices, **B** occurs first.

Choose the letter of the best answer.

1. What would be the best way to tell which brand of paper towels is the "strongest when wet"?
   A Compare television commercials that demonstrate the strength of paper towels.
   B Tear different brands of towels when they are wet to feel which seems strongest.
   C Compare how much weight each brand of towel can hold when wet before it breaks.
   D Conduct a survey of consumers, professional cooks, and restaurant staff.

2. Engineers have designed a car with a new engine and body design. Which of the following trade-offs would have a negative effect on public safety?
   F choosing lower-cost materials over good results in crash tests
   G choosing the appearance of the car seats over their comfort
   H choosing to install a more powerful music system over a better air-conditioning system
   J choosing a more powerful engine over better gas mileage

The graph below compares how well two different brands of insulated mugs retain heat. Use the graph and your knowledge of science to answer Questions 3–4.



3. What was the manipulated variable in this experiment?
   A the temperature of the water
   B the location of the insulated mug
   C the brand of insulated mug
   D the length of time the water was allowed to cool

4. What conclusion can you draw from this experiment?
   F There is no difference between Brand A and Brand B.
   G Brand A keeps water warmer than Brand B.
   H Brand B keeps water warmer than Brand A.
   J Brand B seems to add heat to the water.

Constructed Response

5. Suppose that a newly designed robot automatically scans products at checkout lines in supermarkets. The cost to install a robot at a cash register is less than the cost of hiring a cashier. Describe some of the risks and benefits that this new technology might have on society.