# Design and Problem Solving

What You'll Learn

- **Explain** how creativity influences design.
- **Explain** the importance of engineering and appearance in design.
- **Discuss** ways to evaluate designs.
- **List** the six steps in problem solving.
- **Describe** an effective problem statement.

Explore the Photo ▷

Solving Problems Brainstorming is a group technique that helps generate possible solutions to a problem quickly. Many people can freely call out possible solutions. *Why should you consider all ideas in a brainstorming session, including silly ones?*
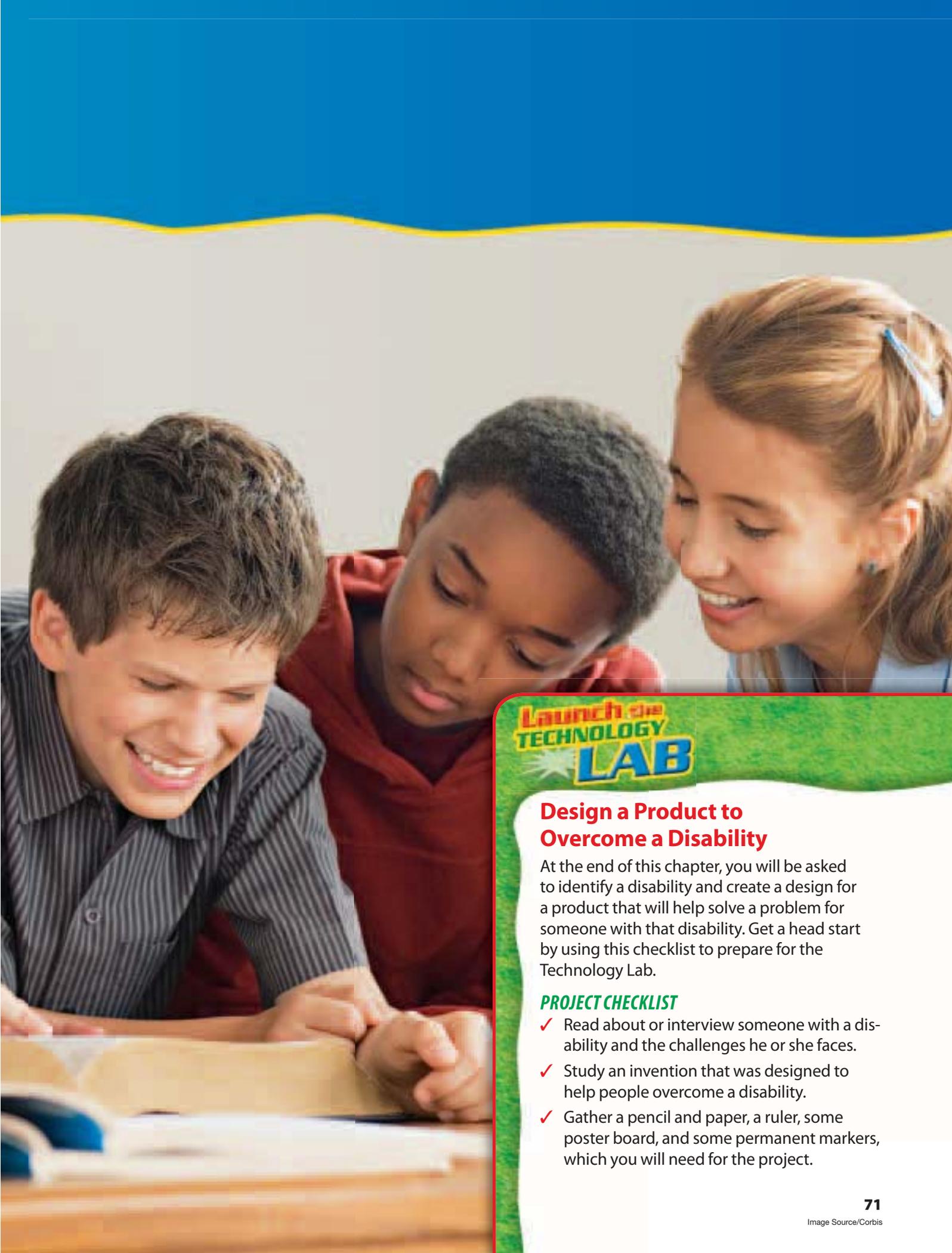
Launch the TECHNOLOGY LAB

Design a Product to Overcome a Disability

At the end of this chapter, you will be asked to identify a disability and create a design for a product that will help solve a problem for someone with that disability. Get a head start by using this checklist to prepare for the Technology Lab.

PROJECT CHECKLIST

- ✓ Read about or interview someone with a disability and the challenges he or she faces.
- ✓ Study an invention that was designed to help people overcome a disability.
- ✓ Gather a pencil and paper, a ruler, some poster board, and some permanent markers, which you will need for the project.

Reading Guide

Before You Read

Preview What is the first step in the design process?

Content Vocabulary
- innovation
- invention
- human factors engineering
- balance
- proportion
- unity
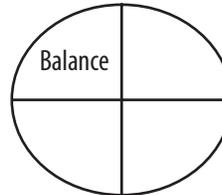
Academic Vocabulary

You will see these words in your reading and on your tests. Find their meanings at the back of this book.

- theory
- range

Graphic Organizer

Draw the section diagram. Use it to organize and write down information as you read.

Principles of Design

Balance

Go to **glencoe.com** to this book's OLC for a downloadable graphic organizer and more.

TECHNOLOGY STANDARDS

STL 1 Characteristics & Scope of Technology

STL 10 Troubleshooting & Problem Solving

ACADEMIC STANDARDS
Mathematics

NCTM Algebra Represent and analyze mathematical situations and structures using algebraic symbols.
Science

NSES Content Standard E Abilities of technological design

STL *National Standards for Technological Literacy*

NCTM *National Council of Teachers of Mathematics*

NCTE *National Council of Teachers of English*

NSES *National Science Education Standards*

NCSS *National Council for the Social Studies*

The Role of Creativity

How does creativity influence design?

As You Read

Connect What role does engineering play in the design of new products?

The design of all new products and processes begins with an idea. In 1837, John Deere was the first person to use a steel plow. Previously, farmers had used only wooden or iron plows. Deere must have done some creative thinking, which is the first step in the design process. Creativity often leads to ideas that are original and imaginative.

John Deere improved on the wooden plow. Modifying an existing product is ==innovation==. Thomas Edison owned 1,093 patents, the most patents ever granted to one person by the U.S. Patent Office. Edison's favorite invention was the phonograph. No one before him had ever attempted to patent a similar recording device. ==Invention== is turning ideas and imagination into new devices or systems.

Earth-Friendly School Supplies These lunch bags are creative and reusable. They were designed to insulate food and drinks separately. *Why do these lunch bags come in different colors and patterns?*

The Role of Engineering

How is engineering similar to design?

Design influences how well things work. A cell phone with buttons that are slightly raised is easier to use than one with buttons that are flat or flush with the surface. Engineers make sure the product works well. They also make sure it is durable, reliable, and easy to maintain.

Engineers use mathematics and science to help calculate strength and other important characteristics of a design. Designers and engineers must be able to think in terms of principles and theories as well as objects.

Human Factors Engineering

Engineering also considers how a product relates to the human body. This application is called ==human factors engineering==, or "ergonomics." Clothes are more comfortable, playgrounds are safer, and tools are easier to use when designers think about how these things will fit the people who use them.

Flexibility

Engineering can also determine a product's flexibility. The design may have to be flexible enough to meet the needs of many potential users. Some refrigerator doors can be hinged on either the left side or right side. Clothing marked "medium" must include a range of sizes of people. In addition, some software works with more than one computer operating system.

Reading Check **Discuss** How does engineering influence the design of new products?

Green Design

Designers are trying to create products that do not harm the environment. They are building automobiles, electronic devices, and schools that use less energy and make less waste. This is called "green design."

You've Got Green The computer manufacturing company HP has already built a "green" computer. The rp5700 slim desktop PC contains no toxic materials. It is made so that it can be taken apart and recycled easily. For the computer's casing and packaging, HP used recycled materials.

English Language Arts/Writing

More or Less? You are designing a new computer. You could use materials that are good for the environment, but they will cost more.

1. You must choose to charge more for the computer or make less money.
2. Write a short paragraph explaining what you would do and why.

The Role of Appearance

What makes a product attractive?

The appearance of a product is usually important. Dinnerware, for example, is designed to be attractive, as are clothes, cars, and MP3 players. The function of all of those products is enhanced when they are attractive. An unattractive cell phone might work just as well as one with a sleek, high-tech design. However, the attractive one looks better and gives an impression of quality to most people.

We all have different ideas about what we find attractive. That is one reason why products come in a variety of designs. Designers follow certain principles that usually produce attractive and successful results. These design principles include balance, proportion, contrast, and unity.

- **Balance**—A sense of balance is achieved when different elements in a design are arranged to seem stable and steady. For example, you probably would not place all the furniture on one side of your living room. The arrangement would seem off balance.
- **Proportion**—Different parts of a design should be in proportion to one another. Proportion is the proper relation of sizes or quantities. Putting huge tractor wheels on a tiny car would create a problem of proportion.
- **Contrast**—Sometimes, differences in size or materials can deliberately call attention to one part of a design. This effect is called "contrast." For example, a designer might place a red collar on a white shirt for contrast.

- **Unity**—How do you know when everything in a design works together? The design has <mark>unity</mark>—which means function and form are carefully planned and are in harmony.

Reading Check   **Explain**   What makes a product attractive?

Evaluating Design

How are designs evaluated?

During the design process, the design needs to be checked and critiqued. Sometimes basic ideas about a design are changed. For example, someone designing an energy-efficient light bulb may learn about a new technology that will make the original idea out of date. Designers are always refining and improving ideas.

After a new design is developed, engineers construct a model or prototype on which to test it. When an airplane company designs a new aircraft, the engineers build one for flight testing. A test pilot follows a carefully planned flight procedure. Engineers evaluate the tests, and the airplane is changed if necessary before manufacturing begins.

Today engineers use special computer programs to test many product designs. These programs analyze different aspects of the design, such as safety factors.

EcoTech

Packing Your Lunch

Did you know that one student's average school lunch generates about 67 pounds of waste a year? Plastic bags, plastic bottles, plastic forks and spoons, food packaging, and paper bags go in the trash and might not be recycled.

Try This Place your food in containers and lunch bags or boxes designed to be washed and reused. You can reuse plastic bottles and recycle them.

section 4.1 assessment
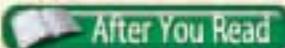
After You Read Self-Check

1. Explain why creativity is the first step in the design process.
2. Identify the influence engineering has on a design.
3. Name at least three principles that designers follow when considering appearance.

Think

4. Name some items with which you are familiar and that you think are well designed. Explain why. Name some you think are poorly designed. Explain why.

Practice Academic Skills

STEM Science

5. Obtain a glider airplane made of balsa wood. Fly it several times to observe flight characteristics. Make a list of its criteria and constraints. Make some design changes by trimming a little wood from both ends of the wing and see how it flies. Do the same for the top of the vertical fin at the rear and the ends of the horizontal stabilizer at the rear. Keep trimming and flying. Write your observations and conclusions.

STEM Mathematics

6. Kyle is designing and constructing a small storage locker. The base needs to be 12.5 feet long by 8.6 feet wide. He needs the locker to hold 1,677 cubic feet of material. How high should he make the walls?
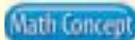
Math Concept Algebra   It helps to construct equations to solve problems. Use variables such as x or y to represent unknown quantities.

1. The equation for volume is volume = length × width × height.
2. Use h to represent the height.

For help, go to **glencoe.com** to this book's OLC and find the Math Handbook.

Reading Guide

Before You Read

Preview How might problem solving relate to design?

Content Vocabulary
- problem statement
- brainstorming

Academic Vocabulary
- sequence
- evaluate

Graphic Organizer

Draw the section diagram. Use it to organize and write down information as you read.

Six Steps in Problem Solving

1. Define the Problem
2.
3.
4.
5.
6.

Go to **glencoe.com** to this book's OLC for a downloadable graphic organizer and more.

TECHNOLOGY STANDARDS

STL 8 Attributes of Design

STL 9 Engineering Design

STL 10 Troubleshooting & Problem Solving

ACADEMIC STANDARDS
Science

NSES Content Standard E Understandings about science and technology
English Language Arts

NCTE 7 Conduct research and gather, evaluate, and synthesize data to communicate discoveries.

STL	*National Standards for Technological Literacy*
NCTM	*National Council of Teachers of Mathematics*
NCTE	*National Council of Teachers of English*
NSES	*National Science Education Standards*
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Problem Solving Steps

How can you apply problem solving to designing?

Problem solving is a part of the design process. The steps in problem solving help designers arrive at a design that does the best job. These steps are: 1) defining the problem, 2) collecting information, 3) developing possible solutions, 4) selecting one solution, 5) putting the solution to work, and 6) evaluating the solution. You can perform these steps in **sequence** and repeat them.

As You Read

Predict What is the purpose of a problem statement?

Reading Check

List What are the six steps in problem solving?

Define the Problem

What does it mean to "define the problem"?

Before you can solve a problem, you must identify it. Design problems are seldom clearly defined. However, even when the problem is easy to identify, it is important to define it.

The Problem Statement

Engineers and product designers create a problem statement. A problem statement clearly identifies the problem that the product will solve. Suppose your friends have asked you to design a bookcase for them. (See **Figure 4.1**.) To write a problem statement, you need to know something about the bookcase, such as its location, capacity, and cost.

Writing the Problem Statement

A problem statement for the bookcase might look like this: *Design a bookcase with two shelves that measures 28 inches tall, 33 inches wide, and 12 inches deep. It must be made from wood that is finished to match the living room furniture, which is made of walnut. Cost of materials must not be more than $75.*

A problem statement helps focus your thinking. A poorly worded problem statement results in wasted effort. "Design an improved animal carrier" is not an effective statement.
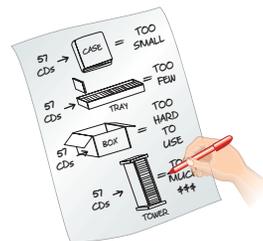
Figure 4.1 **The Problem Solving Process**

Define the problem

Collect information

Develop possible solutions

Select a solution

Put the solution to work

Evaluate the solution

Step by Step The steps in the problem solving process can be repeated as often as needed. *Why is it important to define the problem?*

Revising the Problem Statement

An improved problem statement for the animal carrier might be: *Design a plastic and wire-screen carrier for cats weighing up to ten pounds. It must have a latching door hinged at the side and a top-mounted handle.* (See **Figure 4.2**.)

Criteria and Constraints

Criteria are usually identified once the problem is defined. These criteria may be included in the problem statement. They are the requirements and specifications that help establish what designers must achieve. Designers must determine the constraints, or limits, on the design at the beginning, or they may waste time.

Reading Check **Explain** How can you write a good problem statement?

Collect Information

Why should you find out about past solutions to problems?

If other people have already worked on a similar problem, look at what they have done. This could save you time and lead to a better solution. You also need to learn about all the factors associated with the problem. For example, you might want to test other animal carriers to learn which are most appealing to cats.
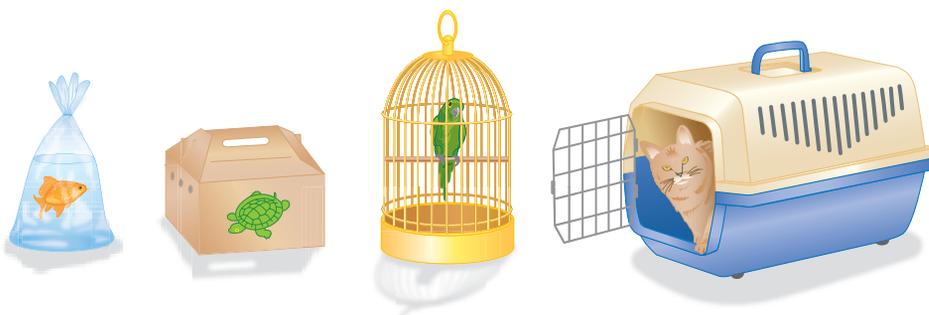
Develop Possible Solutions

Does every problem have one perfect solution?

Most problems have more than one possible solution. However, some solutions may work better than others. Some may be more practical, less costly, more efficient, or easier to produce. At this stage, it is time to develop the solutions that seem to have the most potential. Always try to explore at least two.

Figure 4.2 **Defining the Problem**

Animal Carriers Be clear when wording your problem statement. *What criteria might affect a fish carrier design?*

Brainstorming

Brainstorming is a group technique that helps you develop possible solutions to a problem very quickly. The group chooses a leader who states the problem. Many people in the group freely call out possible solutions. Someone writes down all the ideas, no matter how silly they may seem. No one criticizes or explains. Silly ideas often trigger other ideas that will work. Brainstorming can provide inspiration.

Reading Check **Summarize** How does brainstorming help find solutions to problems?

Select One Solution

What should you consider when selecting a solution?

The most important factors to consider when selecting a solution are the criteria and constraints set down when defining the problem. Then each solution can be **evaluated** in terms of its advantages and disadvantages. For example, suppose two kinds of plastic are proposed for your animal carrier. Both meet all the requirements, but one is more attractive than the other. The appearance of the carrier may mean nothing to a cat, but it might mean something to the cat's owner.

Tech Stars

Ernesto Blanco
Inventor, Engineer, Teacher

Ernesto Blanco was born in Cuba, where he majored in engineering at Havana University. He came to the United States in 1949 to work and to further his studies. Blanco is best known for inventing the stair-climbing wheelchair with retractable, spring-loaded spokes, and the electric Braille typewriter. Many of his inventions were designed to assist the physically challenged.

Back to School Blanco has taught at several universities. As a professor at the Massachusetts Institute of Technology, he is one of the school's most highly-respected creative thinkers and teachers.

English Language Arts/Writing Have you ever had an idea for an invention? Think of an invention and write a short essay about how it might work and who might use it.

Go to **glencoe.com** to this book's OLC to learn about young innovators in technology.

Put the Solution to Work

What is the best way to test a solution?

The best way to test a solution is to put it to work. If the solution is a process, you might carry it out. If you want to mass-produce animal carriers, you might set up work stations and do a test run. If the solution is a product, you would make a prototype and test it.

The best kind of test involves actual use. If you made a prototype cat carrier, you would want to test it with a real cat. Did the cat easily damage it? Did users find it unattractive? Every solution must be evaluated, and most designs must be refined.

Evaluate the Solution

Should you always stick with your first idea?

Did your product work the way you thought it would? Did it meet all the criteria and constraints? If you cannot identify the source of a problem, you can try troubleshooting. Troubleshooting helps identify the cause of a malfunction in a system. It is done through a step-by-step process.

Look for better solutions and use new knowledge gained from experimentation to create new and better solutions. Do not feel that you must stick to your first solution. Any results or processes must be communicated to team members, coworkers, or customers. If you choose a new solution, you will repeat the problem-solving steps.

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section **4.2** assessment

After You Read **Self-Check**

1. Name the six steps in problem solving.
2. Describe a brainstorming session.
3. You test and adjust your solution. Identify which system you are using—open-loop or closed-loop.

Think

4. Identify what you think is the most important step in problem solving. Explain.

Practice Academic Skills

English Language Arts-Writing

5. Think of a tool or type of technology that you use on a regular or semi-regular basis. It could be something at home, work, or school. Write a complete problem statement for this item. Share your problem statement with others in your class. See how well it defines the problem that is solved by your chosen item.

STEM **Science**

6. As part of a small group, brainstorm ideas for a product that would make a bicycle more useful. Use the problem solving process to design the product. Build a model and evaluate your solution.

Exploring Careers in Technology

Mike Bickford
COMPUTER-AIDED DESIGN (CAD) TECHNICIAN

Q: *What do you do?*

A: I use AutoCAD, which is a computer-aided design software that is used to produce drawings and designs. I work primarily with civil engineers, who are responsible for the design. Sometimes I convert paper drawings to 3D images on the computer. My company specializes in land development, as well as mapping for public and private subdivisions.

Q: *What kind of training and education did you need to get this job?*

A: When I was a freshman in high school, I took a drafting class and really enjoyed it. After that, I continued taking drafting classes every year, because I knew that's what I wanted to do. Also, taking math classes was very helpful. It laid the foundation for my advanced training. At ITT, I focused on CAD classes and learned to use various types of software. Once I got my associate's degree and started working, I learned more specific skills that apply to my day-to-day job.

Q: *What do you like most about your job?*

A: I like the fact that I am always learning and being challenged. For example, I am always learning new ways to use software to do my job better. Also, my work environment is very diverse, and I do not feel pinned down to one aspect of the job.

John Madere/Corbis
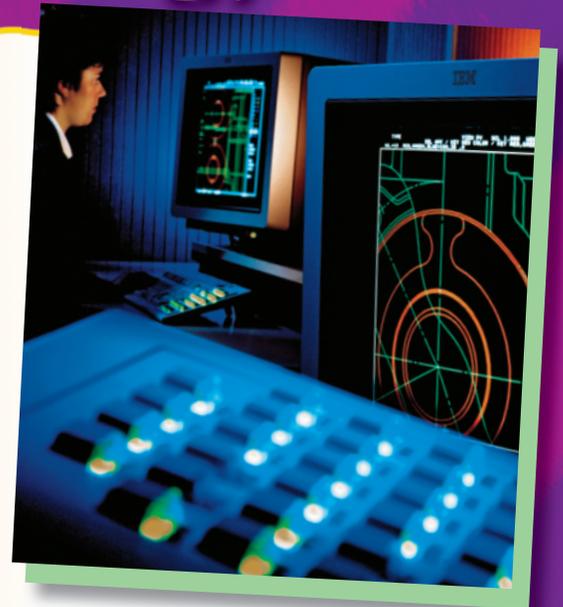
English Language Arts/Writing

Design a Survey You have been asked to design a new cereal. You will need to collect information about your classmates' cereal preferences.
1. Write and carry out a survey. Ask your classmates at least five questions about the kinds of cereal they like.
2. Graph your data by hand or by using graphing software.
3. Summarize your findings in a one paragraph conclusion and present them to your class.

See the Teacher Manual for answer.

Go to **glencoe.com** to this book's OLC to learn more about this career.

Real-World Skills
Problem-solving, communication, computer technology

Academics and Education
Mathematics, science, art

Career Outlook
Growth slower than average for the next ten years

Source: *Occupational Outlook Handbook*

Chapter Summary

Section 4.1 The design of new products begins with an idea in someone's mind. Invention is turning ideas into new devices. Innovation means modifying and improving existing ones. Engineering makes sure the product works well and is reliable. Designers follow certain principles: balance, proportion, contrast, and unity. Engineers test new designs on a model or prototype.

Section 4.2 Problem solving steps include defining the problem, collecting information, developing possible solutions, selecting one solution, putting the solution to work, and evaluating the solution. A problem statement clearly identifies the problem that a product will solve. The most important factors to consider when selecting a solution are the criteria and constraints.

Review Content Vocabulary and Academic Vocabulary

1. On a sheet of paper, use each of these terms and words in a written sentence.

   Content Vocabulary
   - innovation
   - invention
   - human factors engineering
   - balance
   - proportion
   - unity
   - problem statement
   - brainstorming

   Academic Vocabulary
   - theory
   - range
   - sequence
   - evaluate

Review Key Concepts

2. **Explain** how creativity influences design.
3. **Discuss** the importance of engineering and appearance in design.
4. **Discuss** ways to evaluate design.
5. **List** the six steps in problem solving.
6. **Write** an effective problem statement.
7. **Describe** what makes a product attractive.
8. **Discuss** how problem solving is applied to design.
9. **Explain** what a problem statement includes.
10. **Discuss** what is involved in finding solutions to problems.

Image Source/Corbis

11. Evaluating Design Find two tools at home that are designed for the same purpose. You might choose tools designed to open cans or stir sauces. Write a paragraph comparing the design of the tools and telling which you think is easier to use and why. Suggest any improvements.

STEM **Technology Skill**

12. Cut Down a Tree Imagine there is a tree at school with a broken branch about to fall. You must cut it down.

- **a.** Use the Internet to research techniques for cutting down a tree. Consider different processes and tools.
- **b.** Write a plan for solving the problem. List the tools you will use and why.

STEM **Science**

13. Think of a technology item that you think has a design problem. Develop several possible solutions. Write a few paragraphs describing the possible solutions. Share what you write with another student for feedback.

STEM **Mathematics**

14. Stacy's car used to get 25 miles per gallon of gas, but now it gets 22 mpg. If gas cost $2.75 a gallon, how much more would she pay for gas on a 132-mile trip?
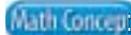
Math Concept **Multi-Step Problems** Write down all the information a question gives you, and all of the things it is asking you to solve. Then go through the steps for each of those things.

TSA **WINNING EVENTS**

Problem Solvers

Situation You are preparing for a team problem-solving competition. The problems must be solved within two hours. You must apply the following problem-solving strategies:
- Work well as a team and team member.
- Use simple hand tools safely and effectively.
- Identify the problem precisely.
- Know the problem's criteria and constraints.

Activity Work with a teammate to solve the following: Use 30′ of fishing line, 1 large plastic cup, 3 balloons, 3 pins, 7 paper clips, 3 ping-pong balls, 3 sheets of 8½" × 11" paper, and white glue; design a device that will travel 15 feet; pop the inflated balloon; and deposit the balls into the cup.

Evaluation Your device will be evaluated by the criteria stated in the activity.

Go to **glencoe.com** to this book's OLC for information about TSA events.

Standardized Test Practice

Directions Choose the letter of the best answer. Write the letter on a separate piece of paper.

1. What is the average speed of a car that travels 140 miles in 3.5 hours?
- **A** 42 mph
- **B** 35 mph
- **C** 45 mph
- **D** 40 mph

2. A problem statement clearly defines a problem to be solved.
- **T**
- **F**

Test-Taking Tip Exercising for a few days before the test can help reduce stress.

TECHNOLOGY LAB

Design a Product to Overcome a Disability

People who live with disabilities face challenges. In the past a person with a physical disability often faced significant limits to what he or she could accomplish. Today people can more easily work with a disability by using new devices that advanced technologies have made possible.

Tools and Materials
- ✓ Pencil and paper
- ✓ Ruler
- ✓ Poster board
- ✓ Permanent markers

Set Your Goal

You and your team will identify a disability and produce the design for a product that will help solve a problem for someone with that disability. An example might include a device to help a blind person identify the color of clothing.

Know the Criteria and Constraints

In this lab, you will:

1. Design a product that safely aids a person with a physical disability.
2. Create a new invention or an improvement on an existing device.
3. Produce a poster or a simple model of your product. A poster must include a drawing of the product.
4. Turn in a problem statement and an explanation of your solution.

Design Your Project

Follow these steps to design your product and complete this lab.

1. Discuss some of the difficulties of daily living that people with disabilities encounter. Consider people who rely on wheelchairs or who have vision or hearing impairments. Do some research. If possible, interview someone who has a disability and learn about the obstacles that person must overcome.

Dennis MacDonald/age fotostock

2. Identify one problem to solve. Here are some suggestions. Be original and think of others.
   - A device to pick up small items from the floor for a person who uses a wheelchair.
   - A system to enable a visually impaired person to locate the entrance to a public building.
   - A system to awaken a hearing-impaired person in the morning.
3. Write a problem statement.
4. Brainstorm to arrive at a potential solution to the problem.
5. Select two or three potential solutions and develop them with sketches and written descriptions.
6. Review all the sketches and descriptions. As a team, select one idea that meets all the criteria and constraints in your problem statement. Make any adjustments that are necessary to refine it.
7. Create a poster with a drawing or simple model that shows how your solution will work. Your poster or model must include the problem statement and a brief explanation of the solution.
8. Present your solution to the class.

Evaluate Your Results

After you complete this lab, answer these questions on a separate piece of paper.

1. Why did your team decide to work on this particular design?
2. How did the problem statement help you as you worked?
3. How did each team member contribute when brainstorming?

Academic Skills Required to Complete Lab				
Tasks	English Language Arts	Math	Science	Social Studies
Research the difficulties experienced by people with disabilities.	✓			✓
Write a problem statement.	✓		✓	
Brainstorm solutions and decide which to present.	✓		✓	
Create model or poster of device.	✓		✓	
Present solution to the class.	✓		✓	