STEM Applications

1. **MATH:** Create a timeline to show a pictorial history of technological advances in one of the following categories:
   - Food
   - Shelter
   - Clothing
   - Transportation
   - Communication
   - Health

   Use one or more poster boards or a long sheet of roll paper to allow space to place pictures of the items at their proper locations on the timeline. For each item you include, find out the year or century (for older items) in which the item was invented. Then decide on a scale for the timeline. For example, you may decide to allow 10 inches (25.4 centimeters) for every 10,000 years. Label the timeline accurately according to your scale. Place the items at their correct locations on the timeline.

2. **TECHNOLOGY:** Name five technical objects you believe will be invented 20 years from now. For each object, describe:
   A. How it will work.
   B. Who will benefit from its use.
   C. What potential problems may occur as a result of using it.

CHAPTER 2

Generating and Developing Design Ideas

The Aquaduct could help people in developing countries transport clean drinking water to their homes.

Better by Design

The IDEO team uses brainstorming to generate ideas quickly

In developing countries, people often carry heavy vessels over long distances every day to collect water. The water then has to be purified before it can be used. So the team at IDEO designed the Aquaduct, a cycle that allows a person to transport and sanitize water simultaneously. As the rider pedals, a pump attached to the pedal crank draws water from a large tank, through a carbon filter, and into a smaller, clean tank. The clean tank is removable and is closed for contamination-free home storage and use.

Where did the team get this good idea? The best way to have a good idea is to have a lot of ideas. The team used brainstorming to generate dozens of ideas for possible solutions very quickly. ***Brainstorming*** is a group problem-solving method of generating new ideas in which everyone's ideas are welcome—no idea is too crazy.

Designers brainstorm at the start of a project.

"Designers can get good ideas by looking at existing products, books, and magazines; and by sitting quietly thinking, doodling, and sketching." —Tom Kelley, IDEO

The team that created the Aquaduct design.

Reading Target

Finding the Main Idea

As you read this chapter, look for the key points, or main ideas, in each part of the chapter. Then look for important details that support each main idea. After you have read the entire chapter, use the Reading Target graphic organizer at the end of the chapter to organize your thoughts about what you have read.

Key Terms

balance
brainstorming
complementary colors
contrast
design brief
designer
design problem
design process
elements of design
engineering design process
ergonomics
experimentation
form
function
harmony
innovation
invention
lines
model
pattern
primary colors
principles of design
proportion
prototype
rhythm
secondary color
shape
style
sustainable design
tertiary color
texture
troubleshoot
unity

Objectives

After reading this chapter, you will be able to:

- Explain the role of the designer.
- Identify items you design in your daily life.
- Use design process skills to solve a design problem.
- Summarize other problem-solving techniques and explain when they should be used.
- Recall the elements of design.
- Identify the principles of design.
- Summarize the five basic types of design decisions.

Useful Web sites:
www.ideo.com/
www.pbs.org/wnet/innovation/

Every product we use has to be designed by someone, somewhere. These products may be as simple as a paper clip or as complex as a hospital operating theater. In most cases, a *designer* identified a group of users with a need that could be satisfied by a redesigned or new product.

The Role of the Designer

There is no such thing as "the perfect design." However, by keeping the needs of the user in mind, a designer increases the probability that the product or service will be a success. If the product or service makes people safer, more comfortable, more efficient, or just plain happier, then the designer has succeeded. Design determines the shape and height of a shoe heel, the special effects in films, and the curving sweep of the support of a bridge.

Design plays a key role in careers such as architecture, engineering, fashion design, graphic design, industrial design, interior design, and stage design. Businesses employ engineers and industrial designers to develop new products. Graphic designers give products an identity that will appeal to customers. Architects design buildings to fulfill our space needs for living and working. Interior designers make offices and shopping centers comfortable environments in which to live and work.

Sometimes designers work alone, but more often they work in teams. Each member of the team has something he or she does especially well that contributes to the overall success of a design project.

Designers make decisions about the size, shape, materials, colors, and finish of a product. The product can be as small as a table lamp or as large as a building or even an entire neighborhood in an urban plan.

Are You a Designer?

You may think of designing in grand terms such as developing a video game or a line of summer clothes. But designing can also mean reorganizing a drawer, building a sand castle or a tree house, constructing shelves for books or trophies, or decorating a birthday cake. See **Figure 2-1** and **Figure 2-2**. Young designers like you can be good at generating and developing new ideas.

The list of products and services you can design is almost endless. For example, you can design a display for a school exhibition, a flower arrangement, or a flag or pennant for a club. Rearranging your room so that it reflects your tastes, painting a child's wagon, designing a birdhouse or a playhouse, or making a funny face mask are all forms of design. In each case, you design something that may make your life, or that of others, more interesting, more comfortable, or happier.

Figure 2-1. Each design project has its own special requirements. What design problems might you encounter when building this tree house?

Figure 2-2. Design principles can be applied to desserts and other foods. What did the designer of these cupcakes have to think about?

Solving a Design Problem

Designing and making a product requires the designer or engineer to use a number of skills. These skills include doing research, sketching, 3D modeling, and testing. The general process used to solve design problems is called a *design process*. If solving the problem requires a knowledge of science and mathematics, it is often called an *engineering design process*. See **Figure 2-3**.

Sometimes you will hear people talk about "the design process" as though the way in which you design a product is the same every time. This is not true. The steps a designer or engineer uses to produce a solution to a problem depend partly on the problem. For example, a dress designer works differently from an architect. The work of both is different from that of a graphic designer. However, all designers and engineers use some common steps and design process skills. See **Figure 2-4**.

Defining the Problem

The process of designing begins when one or more users have a need. In some cases, the designer may develop an entirely new product. An example of this is a global positioning system (GPS). When a product is entirely new, it is known as an *invention*. However, in most cases, the

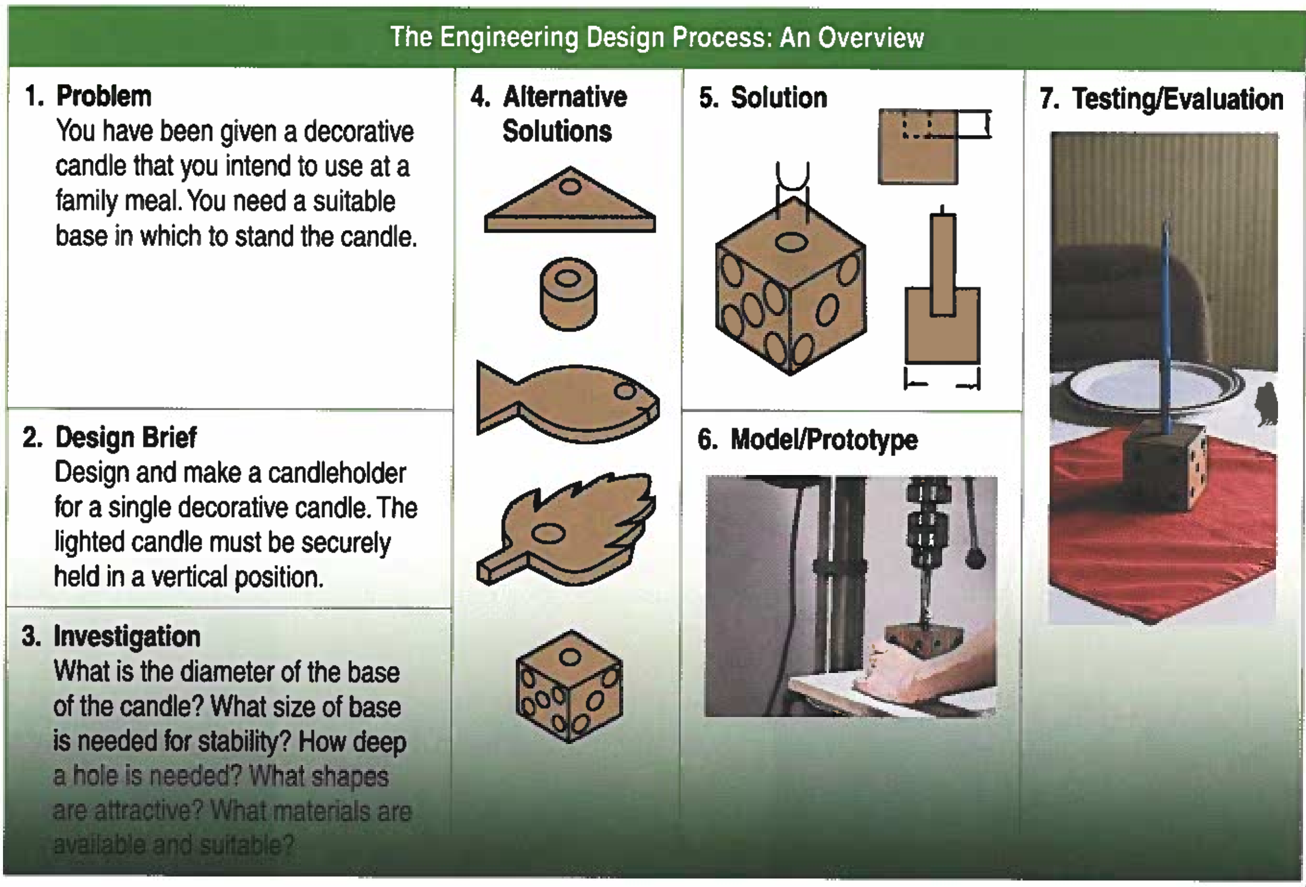


Figure 2-3. Each time you design, you will use some or all of these design steps.

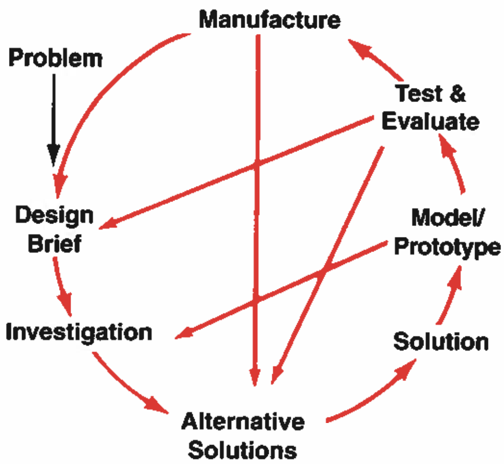


Figure 2-4. Following an orderly design process helps you create a good solution for a design problem. What other solutions can you think of for a candleholder?

designer improves an existing design. For example, cookie sheets are now coated with a nonstick material. The process of improving existing designs is called *innovation*. See **Figure 2-5**.

Before you can decide whether to use invention or innovation, you must define the *design problem*, or need, exactly. For example, imagine that you use several pens, pencils, and highlighters to do your homework. These items are currently scattered all over your desk.

Figure 2-5. Design solutions can be new inventions or innovations that improve an existing design. Are these products inventions or innovations?

Writing the Design Brief

Let's think about the need in this example. You want to design a product that will keep the writing tools together and organized. The first step is to create a statement that describes simply and clearly what is needed. Such a statement is called a *design brief*. The design brief defines the criteria and constraints that must be met by the designed product.

The design brief should be as specific as possible. A good design brief addresses some or all of the following questions:

- What sort of product (or service) is needed?
- Who it is for?
- Where will it be used?
- When will it be used?
- Where might it be sold?
- Who is likely to buy it?

An appropriate design brief for the pencil holder might be: "Design a container to hold at least two pens, three pencils, and two highlighters. Items must be easily identified and removed."

Investigating

Once you have a clear design brief, you can begin to investigate, or gather information. List all the information you think you may need. Some things to consider include:

- Function
- Appearance
- Materials to be used
- Construction
- Safety issues
- Environmental impact

Function

An object that does not *function* well fails as a design solution. The products we use should do what they are intended to do. They should also be easy, efficient, and safe to use. This is sometimes difficult to achieve. Humans vary in many ways. A simple example is that a baby needs a high chair, but an adult needs an adult-size chair. In addition, not all adults are the same: they vary in size.

The study of how a person, the products used, and the environment can be best fitted together is called *ergonomics*. Ergonomics includes these considerations:

- Body sizes—can people fit the object?
- Body movement—can everything be reached easily?
- Sight—can everything be seen easily?
- Sound—can important sounds be heard, and are annoying ones eliminated?
- Touch—are parts that a person touches comfortable?
- Smell—are there any unpleasant smells?
- Taste—are any materials toxic?
- Temperature—is the environment too hot, too cold, or comfortable?

Not all of these apply to every product. Look at **Figure 2-6**. In the design of a computer console, the seat, keyboard, and screen should adjust in various directions. Different sizes of people must be able to use the same console.

Figure 2-6. A good product design takes ergonomics into consideration. How could this computer station be designed to fit people of different heights?

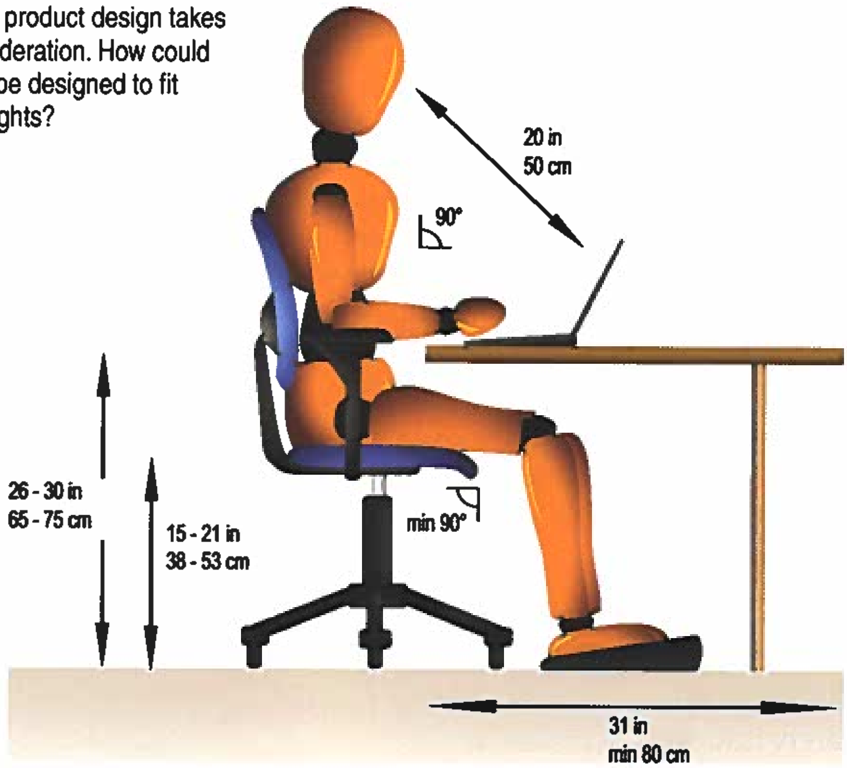


Figure 2-7 shows two pairs of scissors. Those on the left have been designed to fit most people's hands. Their color makes them easy to see.

Appearance

As the designer, you must make decisions about how the product will look. What shapes, colors, and textures should you use? What will appeal to the identified group of users? Must the product fit with existing products?

Materials

What materials are available for the product? How much do they cost? Do they have the right physical properties, such as strength, rigidity, color, and durability? What effects will they have on the environment?

Construction

How will the parts of the product fit together? What tools and techniques will you need to cut, shape, form, join, and finish the materials?

Safety

The object you design must be safe to use. Keep in mind the age and abilities of the intended users. Your product should not cause accidents.

Environmental Impact

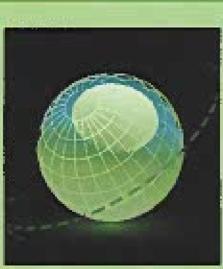
Are the materials used in the product or its manufacture harmful in any way to the environment? What will happen to the object when it is no longer useful? Can the product be recycled?

Sources of Information

Now that you know the questions to ask, you can begin looking for the answers. Where do you begin? Consider these sources:

- Existing solutions—look around you for similar articles, examine them, and collect pictures showing examples of other people's solutions.
- Libraries—search in your school or local library for magazines, books, and catalogs with relevant information and pictures.
- Internet—use a search engine (online software that searches the Internet for words or terms) to find possible solutions.
- Experts—seek out people in industries, schools, and colleges who have this type of problem in their daily work.

Figure 2-7. Small design changes can result in more functional products. Which of these pairs of scissors would you rather use? Why?



Think **Green**

Sustainable Design

As you design a new product, be sure to consider its environmental impact. A *sustainable design* is one that has little or no negative impact on the environment and society. To be sustainable, a design should be:

- Constructed of renewable natural resources.
- Free of toxic chemicals and other items that cause damage to the environment or to human, plant, or animal life.
- Easily recyclable or reusable indefinitely, or be biodegradable in common landfill conditions.

Sustainable design can be applied to small items we use every day, as well as large projects such as community planning. However, for best results, sustainability should be considered at the design stage.

Developing Alternative Solutions

After you have gathered information, you are ready to develop your own designs. It is very important that you write or draw every idea on paper as it occurs to you. Making these design sketches is an excellent way to remember, explore, develop, and communicate ideas. **Figure 2-8** shows some solutions one designer identified for the pencil holder design problem.

You may find that you like several of the solutions. Eventually, you must choose one. Usually, careful comparison with the original design brief will help you select the best. You must also consider:

- Your own skills
- The materials available
- Time needed to build each solution
- Cost of each solution

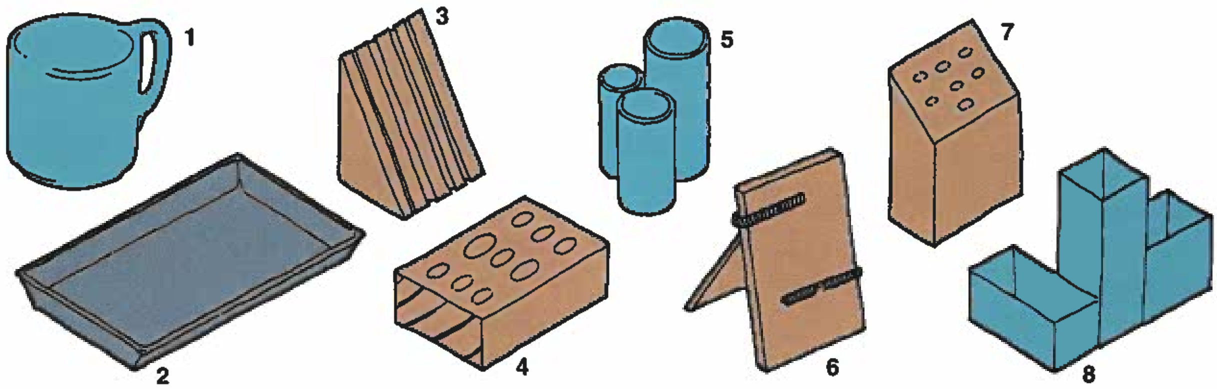


Figure 2-8. Eight possible solutions for the pencil holder design problem. Can you think of other solutions?

Choosing a Solution

Deciding among the several possible solutions is not always easy. It helps to summarize the design requirements and solutions by making a chart like the one in Figure 2-9.

Three solutions—numbers 5, 7, and 8—satisfy all of the design requirements listed. Which would you choose? The designer chose number 7. This design not only meets the 10 criteria listed, but also can be made economically and packaged and shipped easily.

Next, create a detailed drawing of the chosen solution. See Figure 2-10. This type of drawing must include all of the information needed to make the pencil holder, including:

- The overall dimensions
- Detail dimensions
- The material to be used
- How it will be made
- What finish will be required

Design Requirements	Alternative Solutions							
	1	2	3	4	5	6	7	8
Holds four pens?	✓	✓	✓	✓	✓	✓	✓	✓
Holds three pencils?	✓	✓	✓	✓	✓	✓	✓	✓
Pens and pencils separated?			✓	✓	✓		✓	✓
Are pens and pencils easily removed and replaced?	✓	✓	✓	✓	✓		✓	✓
Is container stable?	✓	✓	✓	✓	✓		✓	✓
Attractive?					✓		✓	✓
Possible to make?		✓	✓	✓	✓	✓	✓	✓
Uses appropriate materials?	✓	✓	✓	✓	✓	✓	✓	✓
Tools are avalable?		✓	✓	✓	✓	✓	✓	✓
Materials are available?	✓	✓	✓	✓	✓	✓	✓	✓

Figure 2-9. This chart allows you to evaluate the solutions at a glance.

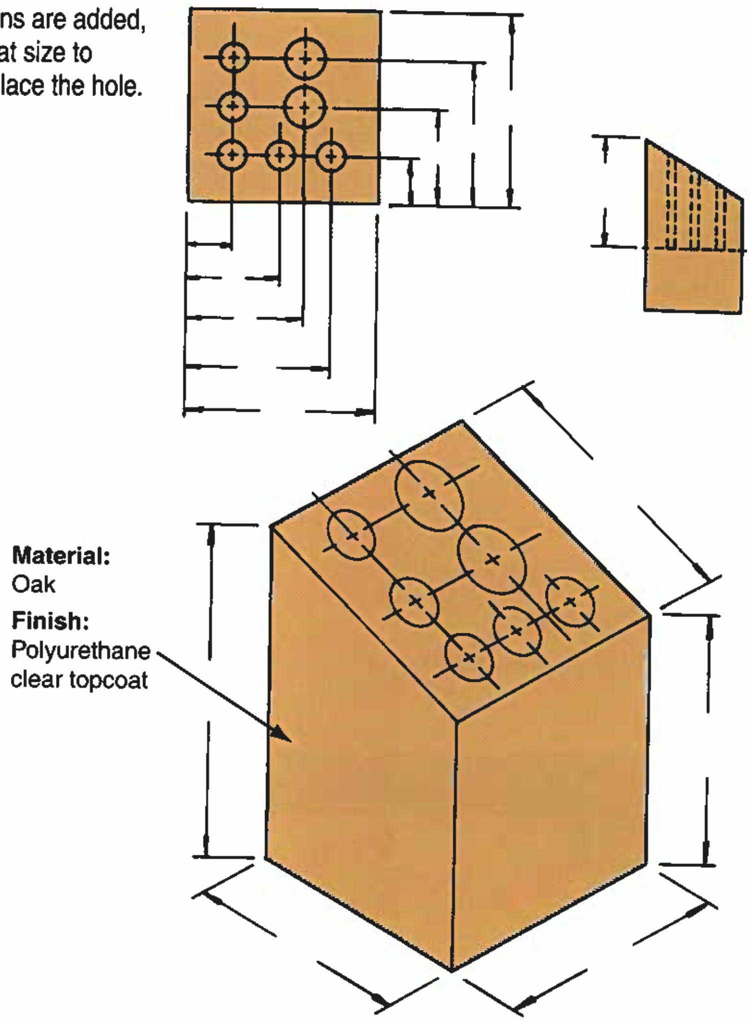


Figure 2-10. When dimensions are added, this detailed drawing will tell what size to make the holder and where to place the hole.

Making 3D Models and Prototypes

Now you can choose what to do next. You can make a model and later a prototype, or you can go directly to making a prototype.

Architects, engineers, and designers use *models* to help communicate their design ideas. It is far easier to understand an idea that you can see in three-dimensional form. If the object is very large or small, a scale model is used. Building a model allows them to view the design from various angles. They can then correct any errors they see. See **Figure 2-11**.

For a simple object, such as the pencil holder, the designer probably would not make a model. He or she may go directly to a prototype. See **Figure 2-12**. A *prototype* is the first working version of the designer's solution. It is generally built at full size and is often handmade. The designer uses the prototype to help plan the steps for making the product. For example, the designer would:

- Select the materials
- Plan the steps for cutting and shaping the material
- Choose the correct tools

Figure 2-11. Using a clay model, the designers can view a product from various angles. They can correct any errors they see.

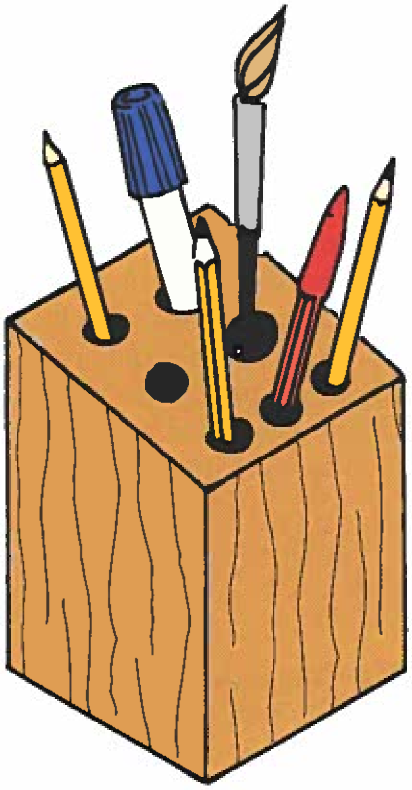


Figure 2-12. A prototype allows designers to test a design in a real-life situation.

- Cut and shape material
- Apply the finish

The steps will vary depending on the object you are making. Some products have many parts that must be assembled. The important thing is that you plan ahead.

Testing and Evaluating

Testing and evaluating a design answers three basic questions:

- Does it work?
- Does it meet the design brief?
- Will modifications improve the solution?

The question "Does it work?" is basic to good design and must be answered. An engineer designing a bridge, the designer of a baby stroller, or an architect planning a new school would ask this same question. What would happen if the holes in the pencil holder were too small to accommodate pencils? What if it were top-heavy? The holder would not work. Sometimes, however, poor design can be dangerous. If a designer makes mistakes in the design of a seat belt for a car, someone's life may be in danger!

Manufacturing

When the prototype satisfies the designer, it is time to produce a small number of samples. These samples are given to typical users who report their experiences to the manufacturer. Did it work well? How could it be improved? Is it attractive? Is it priced right? Designers use this feedback to make final changes. As they make the design changes, they must also remember that the product must be sold at a reasonable profit.

When the company is satisfied with the design, it then decides how many to make. Products may be made in low volume or mass-produced in high volume. Some items, such as specialized medical equipment or airplanes, are produced in the hundreds. Other products, such as nuts and bolts, may be produced in the millions. See **Figure 2-13**.

Other Problem-Solving Methods

The steps described in the previous section are general ones. Most designers and engineers use them to some extent. However, other problem-solving methods also exist. Examples include the I-DREAM method, experimentation, and troubleshooting.

Figure 2-13. An accurate estimate of the demand for a product is critical to planning its manufacture. How might this denim manufacturing company decide how many pairs of jeans to produce?

I-DREAM Method

I-DREAM stands for:

- Identify and accept the problem.
- Define the problem.
- Research and evaluate ideas.
- Execute the design by building a model or prototype.
- Assess whether the design meets the design criteria.
- Modify the design if it does not meet the design criteria.

You might notice that these steps are very similar to those used in an engineering design process. Sometimes steps are performed more than once or in a different order. For example, suppose you assess a solution and find that it does not meet the design criteria. To modify the design, you may need to go back to the research stage or even the define stage.

Experimentation and Troubleshooting

What should you do when you know a problem exists, but you can't put your finger on it? You may need to do some experiments. *Experimentation* means trying different ideas. You can use experimentation to define a problem or even to solve it.

You can also try to *troubleshoot* a problem. This involves systematically eliminating possible causes of the problem. Troubleshooting is a good method to use when you know what the problem is, but you do not know what is causing it. For example, suppose your computer monitor is not displaying an image. To troubleshoot this problem, you might use the process shown in Figure 2-14. First check to see if the monitor is plugged into an electrical outlet. If it is, you might check to see if the monitor is turned on. Then check to see if the computer is turned on, and so on. By finding the reason for the problem, you can often solve the problem.

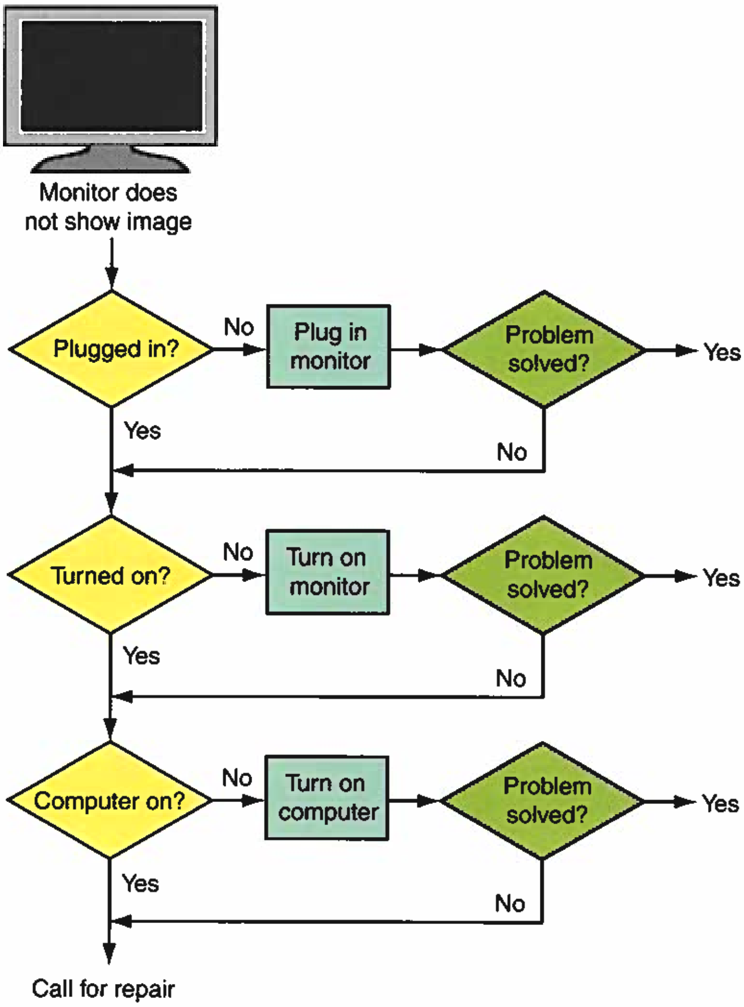
Elements of Design

All products appeal to our senses in some way. We buy clothing that looks good. We enjoy the smooth feel of the polished wooden arm of a chair. A meal on a plate must not only look attractive but also should taste and smell good. The sound of musical chimes is preferable to the harsh sound of a door buzzer.

When you see something you like, ask yourself what is it you like about the product. Is it the color? Is it the shape or form? Is it the texture? Does its texture remind you of the beauty of things found in nature?

Line, shape and form, texture, and color are the four *elements of design*. They are what most people notice when they look at an object. When you examine any object, you will find that the elements of design have been combined to create a unique look.

Figure 2-14. In troubleshooting, you eliminate possible causes one by one.



Line

Lines describe the edges or contours of shapes. They show how an object will look when it has been made. Lines can also be used to create some special effects in the finished product. For example, straight lines suggest strength, direction, and stability. See Figure 2-15. Curved or jagged lines may give a feeling of motion, grace or softness, depending on their shape. See Figure 2-16. Heavy lines suggest more strength than thin lines, as shown in Figure 2-17.

Shape and Form

All objects occupy space or possess volume. The *shape* of an object is two-dimensional, and the *form* of an object is three-dimensional. See Figure 2-18.

Shapes and forms may be geometric, organic, or stylized. See Figure 2-19. Geometric shapes can be drawn using rulers, compasses, or other instruments. Organic shapes and forms mimic nature and contain curved

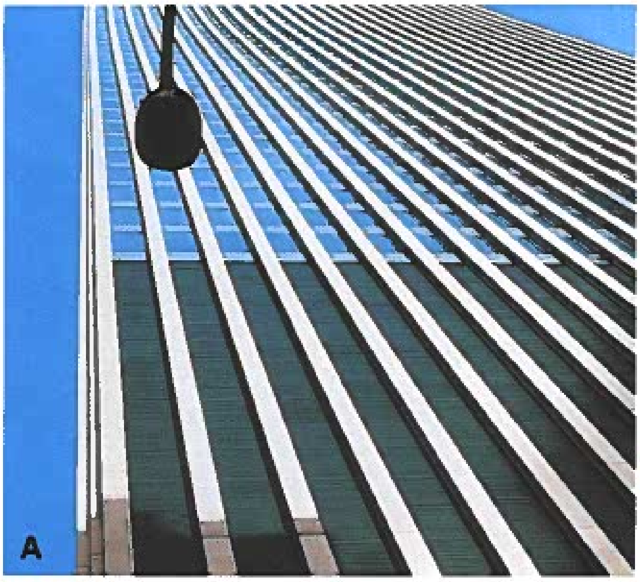


Figure 2-15. A—Vertical lines show strength. B—Horizontal lines give a feeling of stability.

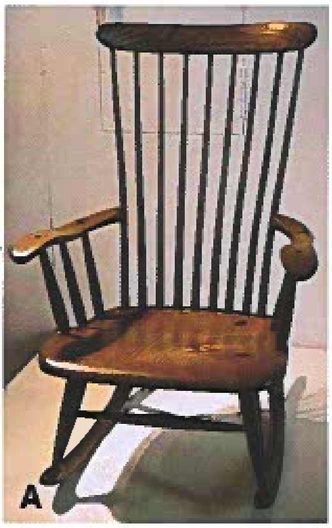


Figure 2-16. A—Curved lines give a sense of grace and softness. B—Jagged lines seem harsh and unfriendly.

Figure 2-17. A—Thin lines appear fragile. B—Heavy lines indicate strength.

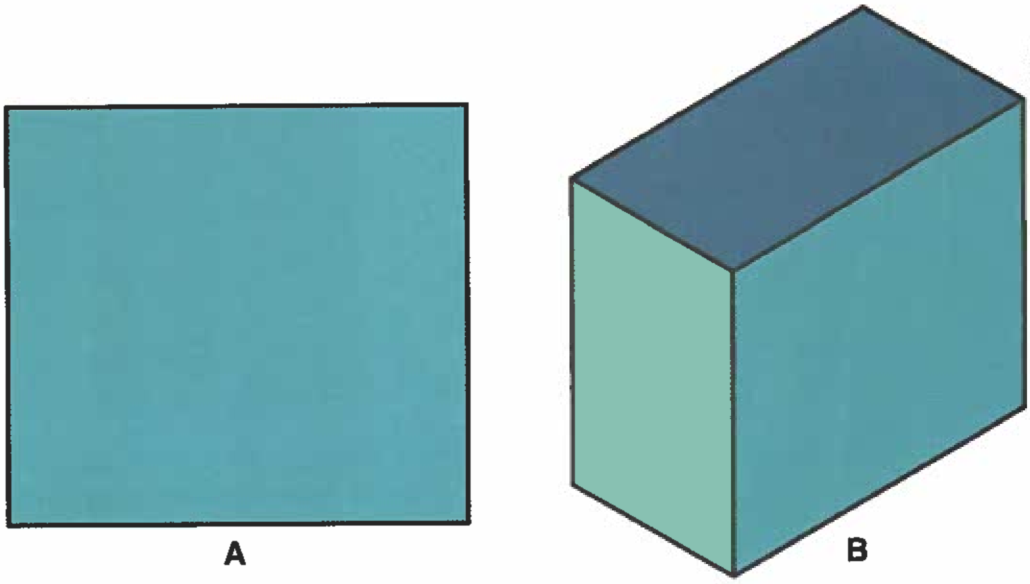


Figure 2-18. A—In design, a shape has two dimensions—width and height. B—Form has three dimensions: width, height, and depth. The shape in A was used to create the form in B.

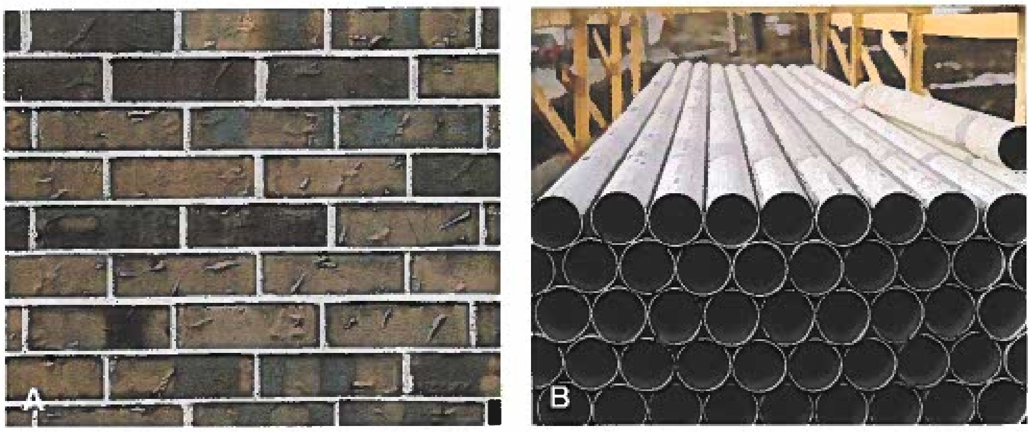


Figure 2-19. Geometric shapes: A—Bricks are rectangles (2D) or boxes (3D). B—Pipes are circles (2D) or cylinders (3D).

flowing lines. See **Figure 2-20**. Stylized shapes and forms have been simplified or streamlined, as shown in **Figure 2-21.** Organic and stylized shapes and forms are sometimes drawn freehand.

Texture

Texture refers to the way a surface feels or looks. We can describe a surface as rough, smooth, hard, slippery, fuzzy, or coarse. Sandpaper feels rough. Glass feels smooth. Rock feels hard. Ice feels cold and slippery.

A designer can choose materials according to their natural texture. She or he might also choose materials because of the way the texture can be changed. **Figure 2-22** and **Figure 2-23** show how texture can be used in wood and stone.

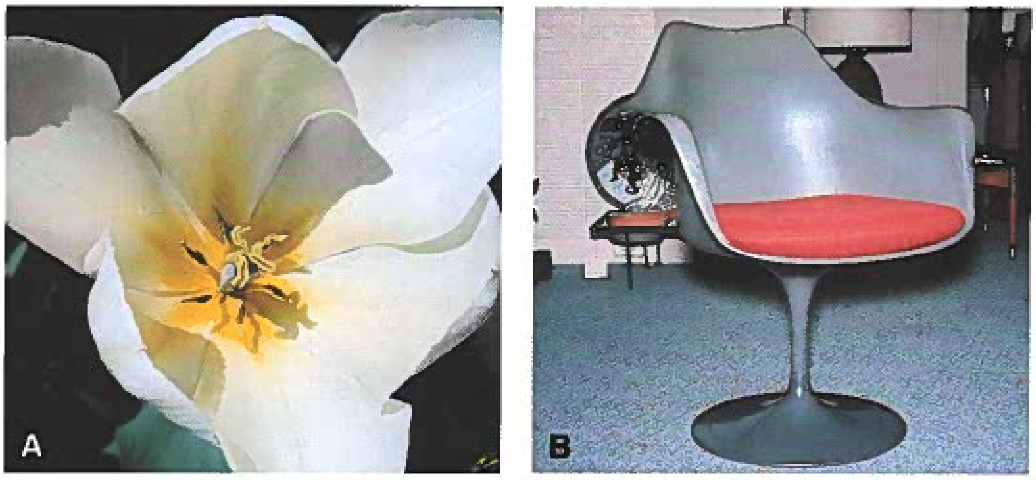


Figure 2-20. Organic shapes are found in natural and manufactured products. A—Blossoms are natural organic shapes. B—The curved, free-form shape of this chair is organic.

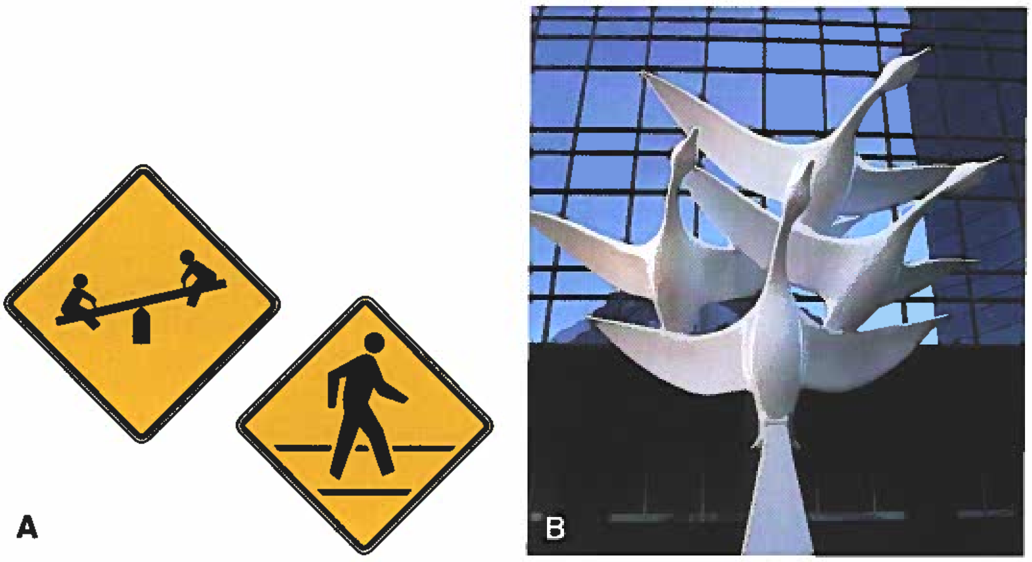


Figure 2-21. A—Stylized shapes can provide information. B—Stylized form is seen in many sculptures.

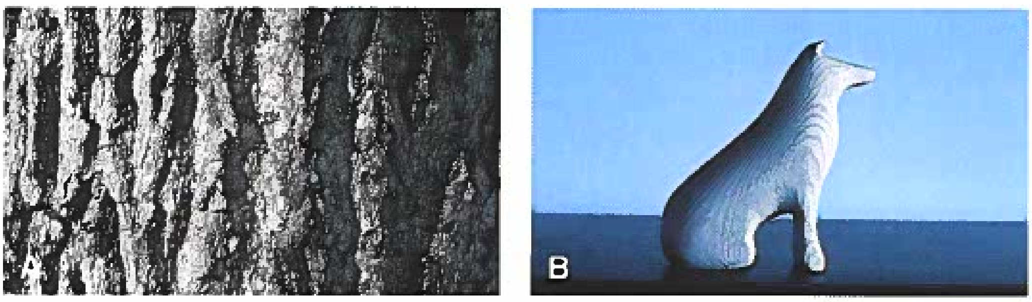


Figure 2-22. The texture of wood can be changed. A—Wood shingles on a roof. B—Wooden sculpture.

Figure 2-23. The texture of stone is attractive in a wall (A) or in the Inuit carving (B).

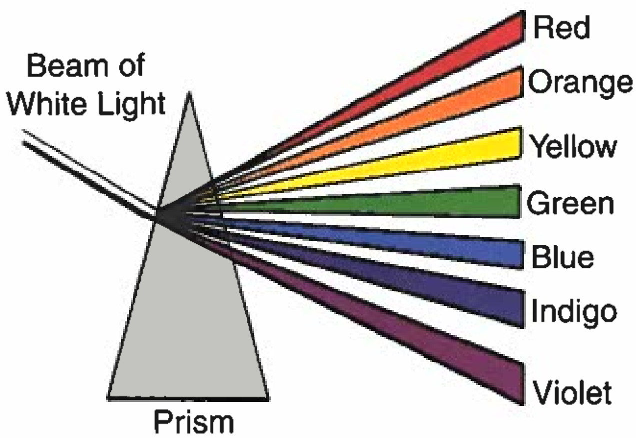
Color

Different colors invoke different moods. Yellow is both cheerful and exciting, while blue is associated with being calm. Green is relaxing. When people are happy, they generally prefer light colors. When they are sad or worried, they often prefer dark colors.

Isaac Newton discovered that white light is made up of rainbow colors. When a beam of white light shines through a glass prism, the path of light is bent. It splits into rainbow hues that bend at different angles. The colors can then be seen individually. These seven colors form a spectrum. See **Figure 2-24**.

We see color when light shines on objects. All objects react to light energy by absorbing certain wavelengths of light and reflecting the rest. An object that reflects all the light appears to be white. One that absorbs all the light appears to be black. Grass reflects the green wavelengths and absorbs the others.

Figure 2-24. The seven colors in white light separate when the light passes through a prism. Where do you see this happen in nature?



Red, yellow, and blue are called *primary colors*. If you mix equal parts of two primary colors, you obtain a *secondary color*. Red plus yellow makes orange. Yellow plus blue makes green. Blue plus red makes violet. Mixing equal parts of a primary and a secondary color creates a *tertiary color*. See **Figure 2-25**.

Designers use colors to produce certain reactions or effects. See **Figure 2-26**. Traffic signs use red to indicate danger. Yellow serves as a traffic warning. We also associate colors with objects. An apple is red. Grass is green. Charcoal is black, and milk is white.

Color can also be used to control temperature. Dark materials are best able to radiate or absorb heat. A black T-shirt, worn on a hot day, will heat up more in the sun than a white one. Houses in hot climates are painted white because white reflects sunlight.

Primary	Secondary	Tertiary
red	red + yellow → orange	red + orange → red-orange
		yellow + orange → yellow-orange
		yellow + green → yellow-green
yellow	yellow + blue → green	blue + green → blue-green
		blue + violet → blue-violet
blue	blue + red → violet	red + violet → red-violet

Figure 2-25. Mixing two primary colors produces a secondary color. Mixing a primary and secondary color creates a tertiary color.

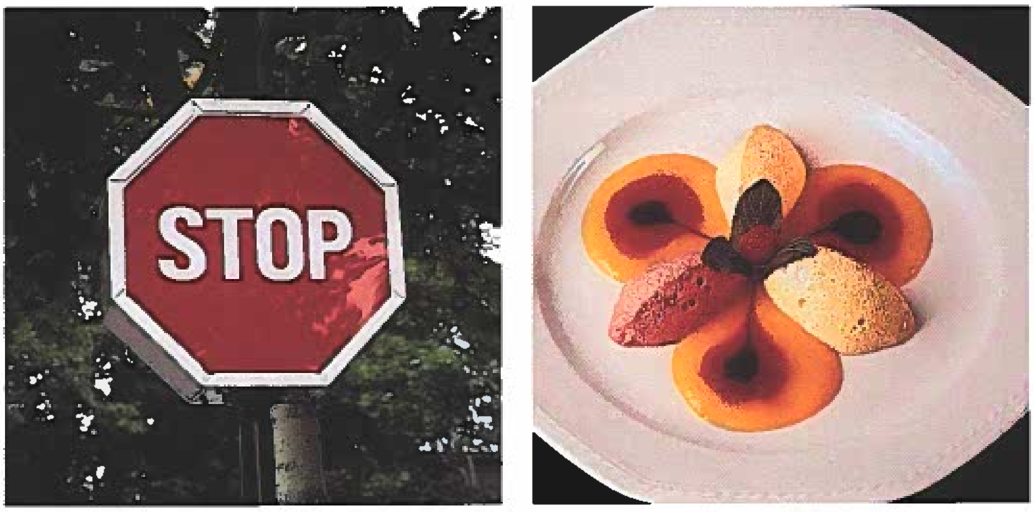


Figure 2-26. Color can be used to create special effects. How was color used in these items?

Principles of Design

You learned earlier that line, shape and form, texture, and color are the elements of design. You can think of these as building blocks that can be put together in many different ways. The guidelines for combining these elements are called the *principles of design*. They are balance, proportion, harmony and contrast, pattern, movement and rhythm, and unity and style.

Balance

When you think of balance, think about a tightrope walker moving along a cable. She or he keeps balance using arms and a balancing pole. It is important to match or balance the mass of the body on both sides. *Balance* is also very important in design. It means that the mass is evenly spread over the space used. The three types of balance in design are symmetrical, asymmetrical, and radial. See **Figure 2-27**.

Proportion

Look at **Figure 2-28A**. Something seems to be wrong—the person is too big for the chair. Now look at **Figure 2-28B**. The person appears to

Figure 2-27. A—The designer of the Manchester Millennium Bridge combined symmetry with a creative design to provide both beauty and function. B—In an asymmetrical design, the two sides are in balance visually, but they are not mirror images. C—Like all Ferris wheels, the London Eye has radial balance. The mass moves outward in all directions from the center point.

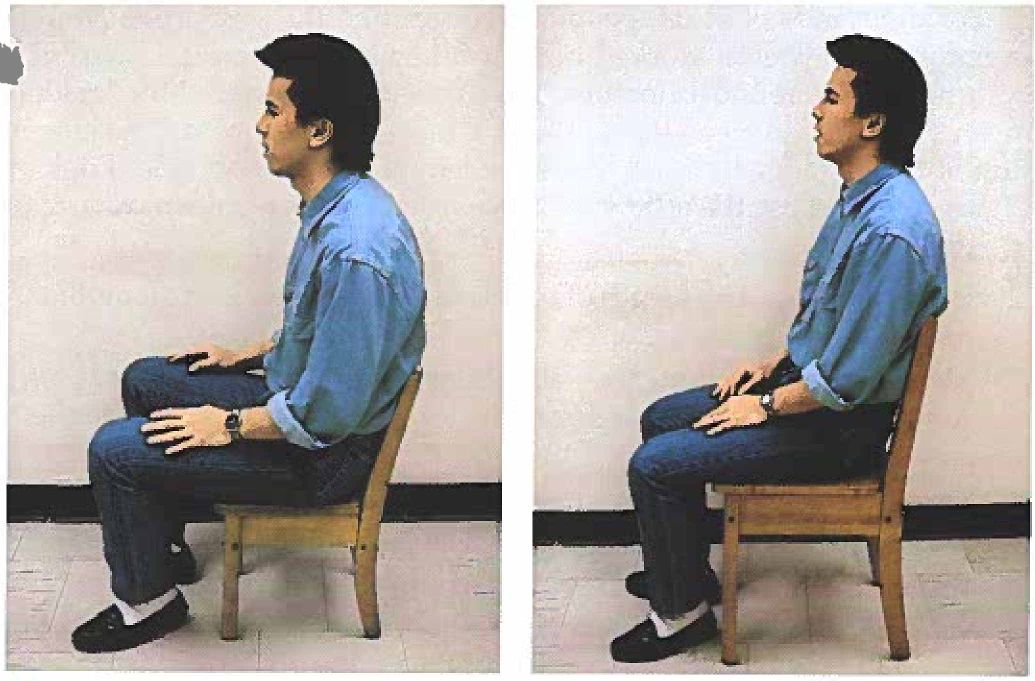


Figure 2-28. A—The person and chair are not in proportion to one another. B—The person and chair are in proportion.

be very comfortable. The relationship between the person and the chair seems to be right. The relationship between the sizes of two things is called *proportion*.

Proportion can also apply to the parts of an object. Look at the contents of the mobile home in **Figure 2-29**. Although the items are smaller than usual, their size is related to the overall size of the mobile home. They are in proportion.

Figure 2-29. Everything inside this mobile home is scaled down and in proportion to the space available.

For thousands of years, people have admired the proportions found in nature. The Greeks worked out a mathematical formula to describe the proportions found in nature. They called this formula the "golden mean." The golden mean has a ratio of 1:1.618. In other words, the longer side of the rectangle is 1.618 times the length of the short side. Look at **Figure 2-30** and use the following procedure to draw a golden rectangle:

1. Draw a base line.
2. Draw a square. The length of one side of the square is the length of the short side of the rectangle.
3. Measure halfway along the base of the square. Put the point of your compass here. Draw an arc from the top corner of the square to the base line.
4. The point where the arc touches the base line is the right-hand corner of the rectangle. Draw a vertical line upward from it.
5. Extend the top line of the square to complete the rectangle.

The golden mean also appears in the human body and in many living things. In **Figure 2-31**, the lion's proportions fit the golden mean.

Mathematics is important to designers. Still, they do not rely on mathematics alone to decide the proportions of an object. They must adjust the proportions until they look right. Look at the chest of drawers in **Figure 2-32**. Notice that the drawers at the bottom are larger than those at the top. If all the drawers were of the same height, the chest of drawers would seem to be top-heavy.

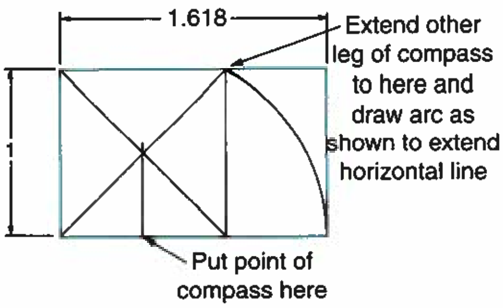


Figure 2-30. To draw a golden rectangle, begin by drawing a square.

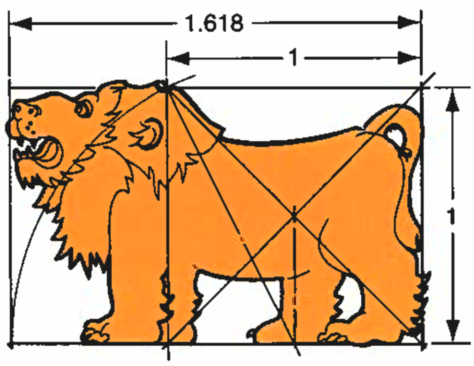


Figure 2-31. The lion's body fits the golden mean so often found in nature.

Figure 2-32. Good proportion sometimes requires using mathematically unequal parts.

Harmony and Contrast

Observe the best figure skaters and you will notice that their movements seem to flow with the music. We say they are in harmony with the music. *Harmony* is the condition in which two things, such as color or musical notes, naturally go together.

Designers use the idea of harmony in the objects they create. Buildings and their environment should be in harmony. The dishes in **Figure 2-33** are in harmony.

Sometimes designers want to surprise you. They may want to make you feel excited about what you see. They may simply want to catch your attention. To do this, designers create an obvious difference between things. This difference is called *contrast*. While harmony makes you feel comfortable, contrast adds excitement.

The red cross on an ambulance contrasts with its white background. A jagged mountain contrasts with the calm waters of a lake. The lines and shape of an old building may contrast with those in a new office tower. See **Figure 2-34**.

Figure 2-33. These objects are in harmony. Both color and shape go well together.

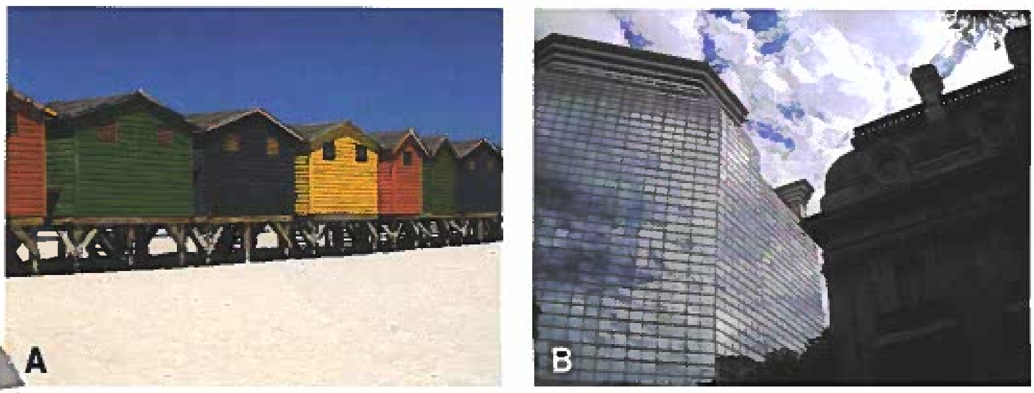


Figure 2-34. Contrast can be achieved by using color (A) or lines and shape (B).

You should also consider harmony when you are selecting colors for a design. You may want the colors to be similar or to contrast. You can find similar colors next to one another on a color wheel. See **Figure 2-35**. For example, if you first choose orange, similar colors include red-orange and yellow-orange.

Suppose you want colors to contrast with each other, yet still work well together. In this case, select colors that are at the opposite side of the color wheel. For example, blue contrasts with orange. Contrasting colors are also called *complementary colors*.

Pattern

A *pattern* is a shape or form that is repeated many times in a design. See **Figure 2-36**. Patterns are found both in nature and in objects that people have designed. Sometimes they are used to make an uninteresting surface appear more attractive, as seen on the surface of the egg. At other times, the pattern may serve a particular function, as when two different colors make a pattern on a chessboard.

Rhythm and Movement

Patterns are closely related to *rhythm*, or the suggestion of movement. Some patterns, such as ocean waves, naturally create a sense of movement. See **Figure 2-37**. The rhythm of a design can be smooth and flowing or fast and dynamic. In **Figure 2-38A**, the tulip bowl creates a sense of smooth, easy movement through its use of shape and line. The spiral of the printed pattern in **Figure 2-38B** suggests a more lively feeling of movement.

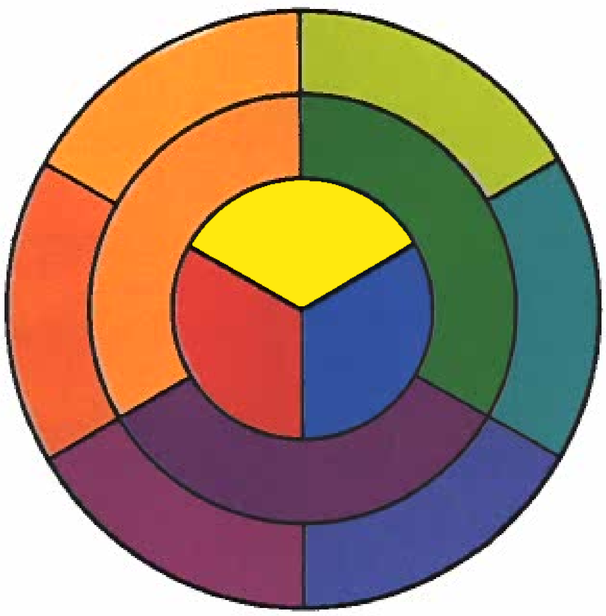


Figure 2-35. Use a color wheel to choose similar or contrasting colors for a design.

Technology Application

Art, Nature, and Technology

The shapes and patterns of technological designs are often inspired by nature. Many patterns are based on shapes that we know quite well: leaves, flowers, birds, and animals. If you look around, you may find examples of sunflower tiles on a floor, leaf patterns on a carpet, sofas and fabrics decorated with wild grasses, or a necklace of ivory pieces, each carved in the shape of a bird. Usually, the patterns are not exact copies, but abstract versions that were inspired by the objects. For example, the design for the faucet shown below may have been inspired by a tree similar to the one shown.

The shape of any object we use is influenced by our sense of touch. Have you noticed that very young children want to touch everything? They don't "know" an object until they have touched it. When we are adults, our sense of touch still influences the value we place on objects we use. For example, we prefer a door handle that is easy to grasp and operate, or a chair that feels comfortable.

Technology Activity

Design a mug for drinking your favorite beverage. Think of shape and pattern. First draw the outside shape. The shape must be easy for the user to hold. Then develop a pattern for the surface of the mug using an idea that comes from nature. Make sure the exterior shape and the surface design are in harmony with each other. Create detailed sketches to document your design.

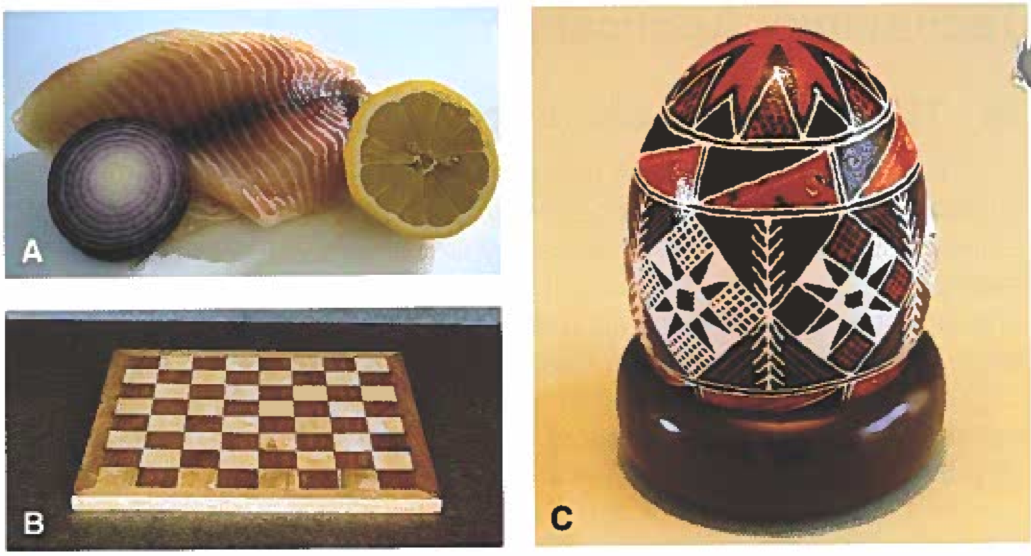


Figure 2-36. Patterns occur in nature and in human-designed objects. A—The interior of different foods form patterns. B—The squares on a chessboard have a function. They are needed to play a game of chess. C—This egg shell has been painted in a complex pattern.

Figure 2-37. Some patterns suggest movement. Waves are an example of a rhythmic pattern in nature.

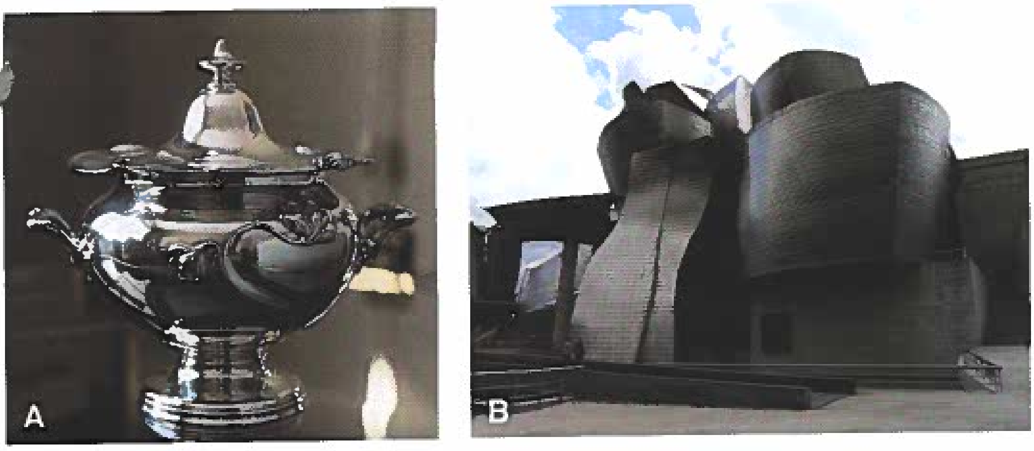


Figure 2-38. Shapes and lines create a sense of movement. A—A tulip bowl. B—A building design that suggests dynamic movement.

Unity and Style

A well-designed product must have a sense of *unity*. The parts of a design must have a sense of belonging or similarity so that visually they fit well together. See **Figure 2-39**. Not only should there be a sense of unity within an individual object but also between each object and its environment.

Style is a feature or quality that is typical of designs created by a specific person or during a specific time period. Style depends on many things:

- The availability and cost of materials: achieving the most with the least.
- The tools and techniques available to shape the materials.
- Cultural preferences.
- A knowledge of the elements and principles of design.

Figure 2-39. Each of these items has a sense of unity and the designer's unique style.

Making Design Decisions

Design principles do not provide hard and fast rules. They act only as a guide. You must make the actual design decisions. The five basic types of design decisions are conceptual, marketing, technical, constructional, and aesthetic decisions.

Conceptual Decisions

Conceptual design decisions have to do with the overall purpose of the design. What sort of product is needed? For example, what sort of product could students in your school make and sell to raise funds for a school trip? Should you design printed T-shirts, birthday cards, or jewelry? You ask a number of parents and friends which they might purchase and discover that jewelry is most popular. Choosing jewelry is a conceptual design decision.

Marketing Decisions

Who will use the product you are designing? Where and how will they use it? These questions will help you make marketing design decisions. Marketing decisions might also include where the product will be sold and the selling price. For example, you could decide to design jewelry for teens, a special friend, or a favorite aunt. You could design jewelry to give as presents, to sell in a trendy boutique, or to sell at a festival celebrating a special occasion. See **Figure 2-40**.

Technical Decisions

Technical design decisions explain how the design will work. What individual pieces are required? What materials are best for each component? What size will you make the overall product and each

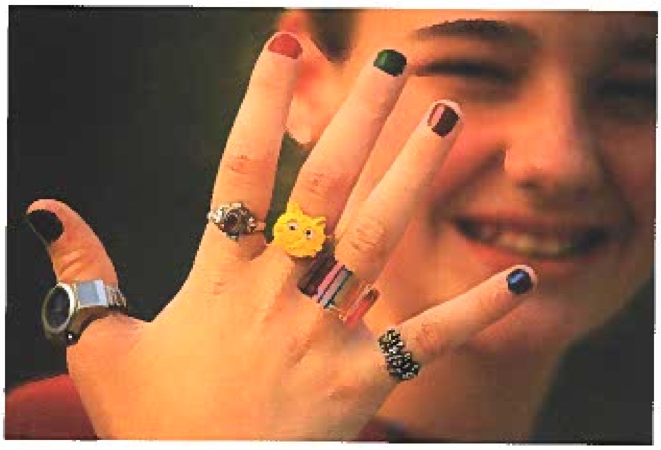


Figure 2-40. Marketing decisions include how and where you will sell the item. What types of jewelry might you create to sell to people in your age group?

component? What are the safety requirements? For example, you could decide to design jewelry using natural materials such as wood and feathers. You could decide to use an easily worked metal such as copper, or recycled materials such as bottle tops. If the jewelry uses electronics, will it contain lights or sound? How will the lights be controlled? What components are needed to make sound?

Construction Decisions

Decisions about how the product will be made and assembled are construction design decisions. What tools and techniques will you need to form small pieces of copper into the shape you have chosen? How will the individual pieces fit together? What joining techniques will you use? For example, how can you join the copper pieces to create a necklace? How could they be attached to a leather cord or metal chain?

Aesthetic Decisions

Aesthetic (artistic) design decisions determine what the design will look like. What overall effect do you want? Will you make large, clunky jewelry or small, delicate jewelry? What shapes might a pendant have? Will you use natural or geometric shapes? What colors might you use? What textures could you use?

Although these five types of design decisions are described separately, they are highly interconnected. If you change one decision, you may have to change others. For example, suppose you decide to use a leather cord at first. Later you change your mind and decide to use a metal chain (technical design decision). This will affect how the decorative elements are attached (constructional design decision).

End Note

The process of designing has evolved over the centuries. Our earliest designs responded to basic needs. For example, in early times, methods of lighting a fire were vital. Fire-lighting designs were probably invented by accident in many cases. Today's designers create products or services that fulfill not only the needs, but also the wants, of a group of users.

Many of our newer designs have even been developed to create a new need or demand. New products are designed to appeal to the interests, attitudes, opinions and values of users. For example, you may be pleased with the portable music device you currently own. However, if a company offers one that can store much more music in a product half the size, you may be tempted to buy it. Articles are also being increasingly personalized. One shoe manufacturer lets you customize its soccer shoe. One automobile manufacturer lets you have your own emblem on the car instead of the manufacturer's logo. As new technologies are developed, designers will have even more freedom to create new and exciting products.

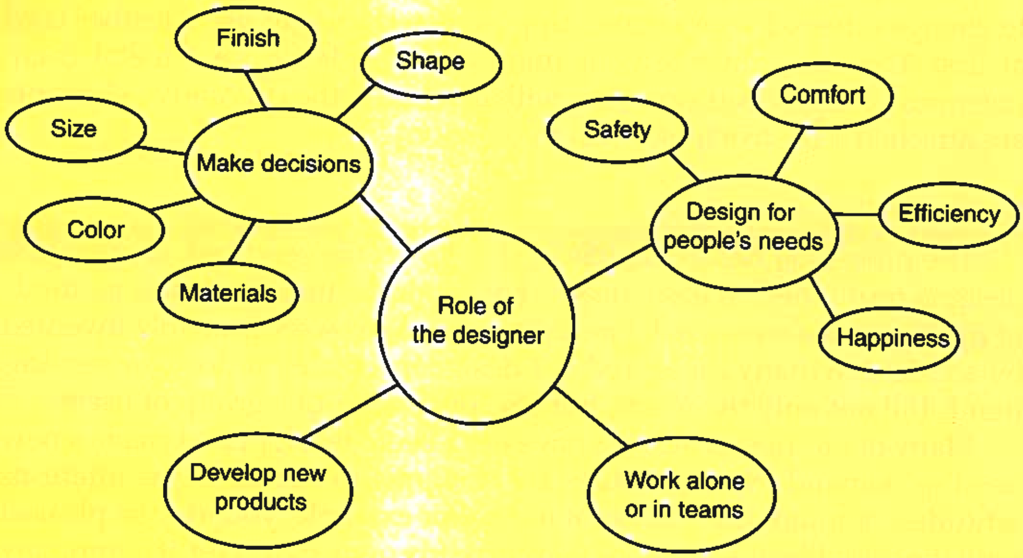
Summary

- Designers play an important role in industries such as architecture, engineering, fashion design, industrial design, and others.
- To some extent, everyone is a designer. Designs do not have to be grand schemes They can be as simple as making a flower arrangement or rearranging your room.
- Engineers and designers use specific design process skills to solve design problems.
- Problems can be solved using a design process, the I-DREAM model, experimentation, troubleshooting, or other methods. The method used depends on the problem to be solved.
- The elements of design are the qualities people notice when they look at an object.
- The principles of design are guidelines for combining design elements.
- During the design process, several different types of decisions need to be made. Decisions made in each area may affect the other types of decisions.

Reading Target

Finding the Main Idea

Create a bubble graph for each main idea in this chapter. Place the main idea in a central circle or "bubble." Then place the supporting details in smaller bubbles surrounding the main idea. A bubble graph for the first part of the chapter is shown here as an example.



Test Your Knowledge

Write your answers to these review questions on a separate sheet of paper.

1. Why are most new products developed?
2. List the steps in a design process.
3. Compare invention to innovation. How are they similar? How are they different?
4. Explain the roles of engineering, technology, and society in invention and innovation.
5. Given a design problem, why might an engineer sketch several possible solutions?
6. What is the purpose of a prototype?
7. What word describes the study of how a person, product, and environment or surroundings can best be fitted together?
8. What specific questions would you ask if you were testing and evaluating a new wheelchair?
9. Why might a designer create a product for which there is currently no need?
10. Explain why there is no perfect design.

Critical Thinking

1. Think of one object you have seen and find attractive. Write a paragraph describing the object and explaining how the elements of design make it attractive to you.
2. Write a one-page paper comparing and contrasting the steps of the design process/engineering design process with the steps used in the scientific method. The scientific method is described in Chapter 1. In your paper, include an introductory paragraph, one paragraph for each main idea, and a summary paragraph.
3. Imagine that you overslept this morning because your alarm clock did not wake you up. What steps would you take to troubleshoot this problem?

Apply Your Knowledge

1. Collect or draw pictures showing three natural objects. Collect three more pictures to show comparable technical objects. For example, suppose you collected a picture of a bird's nest (a natural object). A comparable technical object might be a house, because both are habitats.
2. Collect four pictures to illustrate two elements of design and two principles of design. Show your pictures to a group of four classmates. Ask your classmates to analyze the pictures.
3. Sketch as many different designs as you can showing how compact discs could be stored. Consider horizontal, vertical, and diagonal designs.
4. Often a new and exciting invention of today becomes the "old" technology of tomorrow. Think of an invention or innovation that was created more than 25 years ago. Do research and gather data to answer the following questions.
   - A. What need was the product designed to meet?
   - B. Is the need still important today?
   - C. Is the need still being met by the same product? If so, have innovations improved the product? If not, what newer invention has replaced it?

   Write a report explaining your findings. Use data and statistics from your research to support your ideas.
5. Write an essay identifying changes in society caused by the use of inventions and innovations. Explain how new needs and wants may be caused by the use of new products.
6. Form a group with three or four classmates. Brainstorm ideas for a new product that is currently *not* needed or wanted. Use a design process to develop the idea to the prototype stage. Then create persuasive marketing tools such as color advertisements, signs, or banners. Display the marketing pieces in the classroom for a week. Then present the prototype to the rest of the class using a persuasive speech. How many of your classmates would buy your new product based on the "need" or "want" you created?
7. Carefully observe some activities in your home. Make a list of design problems that need to be resolved. Examples: storing spices in the kitchen or making sure that your baby sister doesn't fall downstairs. From your list of design problems, choose one that you will try to solve.
   - A. Write a design brief that describes the criteria and constraints for the design.
   - B. Sketch or describe a number of solutions to the problem and select the most appropriate solution.
   - C. Use the elements and principles of design to develop the design idea.
   - D. Make a list of the steps involved to build a model and/or prototype of your solution. Include information about safety precautions for using tools.
   - E. Build, test, and evaluate your prototype. Be sure to follow all safety measures. Keep a good record in the form of notes and sketches. Document all changes to the prototype.
   - F. Recommend further improvements to the design.
   - G. Begin a design portfolio for your design ideas. Place your documentation for this design in your portfolio.

STEM Applications

1. **ENGINEERING** Make an engineering design journal in which you can store design ideas. To start the journal, record the design ideas you created for this chapter. Start each design on a new page. Include sketches drawn to scale and notes to explain your ideas. As you work through this course, add all of your design ideas to this journal.
2. **ENGINEERING** Work with a team of four other students. Brainstorm ideas for a product that will make one task easier for a person with a special need, such as a handicapped or elderly person. Use an engineering design process to build the device. Demonstrate your design in class and ask for comments and suggestions. Document your design and any changes you make. Place the documentation in your design portfolio.
3. **MATH** Look around and find an object in nature that has the proportions of the golden mean. Draw a sketch of the object. Include dimensions to show how the object satisfies the size requirements of the golden mean.

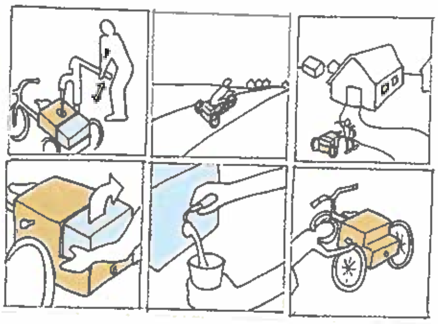
CHAPTER 3

Communicating Design Ideas

Better by Design

The IDEO team uses 2D and 3D models to communicate ideas

Designers use 2D and 3D modeling to communicate and evaluate their design ideas. The team of Adam Mack, John Lai, Eleanor Morgan, Paul Silberschatz, and Brian Mason at IDEO first built a 3D model of the Aquaduct using cardboard, masking tape, and a hot glue gun. They used a ***storyboard*** to visualize how the Aquaduct cycle might be used. They drew detailed plans and modeled parts. Next, they built a full-size working model for testing. The next step is to involve the end users in the design process to help ensure that the product meets their needs.



Storytelling can showcase the proposed design solution to the user.

"Prototyping allows for quick and inexpensive exploration of potential solutions to problems."
— Tom Kelley

The IDEO team created the first 3D model of the Aquaduct from readily available objects.