Chapter 10  Developing Design Solutions

Learning Objectives

After studying this chapter, you will be able to do the following:

- Recall the two major areas in which designers develop solutions to technological problems and opportunities.
- Explain what system design is.
- Recall the two major types of technological products and systems created with product design.
- Summarize some advantages of using a design team over an independent designer.
- Recall the three main steps followed in developing technological designs.
- Recall the ways in which ideas can be stimulated when developing design solutions.
- Compare the kinds of design sketches.
- Recall the three major types of information required for detailed sketches when building models.
- Recall the three types of pictorial sketches used in product design.

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
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<tr>
<td>brainstorming</td>
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<td>classification</td>
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<td>convergent thinking</td>
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<td>detailed sketch</td>
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<td>divergent thinking</td>
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<td>isometric sketch</td>
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<td>oblique sketch</td>
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<td>refined sketch</td>
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<td>rough sketch</td>
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Technological devices are designed to meet identified problems and opportunities. See Figure 10-1. These problems and opportunities can be either of the following:

- System-design problems and opportunities.
- Product-design problems and opportunities.

No matter what the area, though, developing design solutions involves three major steps. We will discuss those steps after we differentiate between system design and product design.

System Design

System design deals with the arrangement of components to produce a desired result. For example, automotive braking systems are a result of system-design efforts. Look at the drum brake system shown in Figure 10-2. This design brings

Figure 10-1. Designers create both systems and products.

Figure 10-2. This brake system was the result of system-design efforts.

Types of Design

<table>
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<tr>
<th>System Design</th>
<th>Product Design</th>
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Pressing the brake pedal causes the mechanical linkage to move the piston in the master cylinder.

The hydraulic pressure the brake fluid creates moves the piston in the wheel cylinder out, forcing the brake shoe against the brake drum in the wheel.

Figure 10-2. This brake system was the result of system-design efforts.
together mechanical and hydraulic components into a speed-reduction system. The brake-pedal unit is a mechanical linkage. When the pedal is depressed, a plunger in the master cylinder is moved. This motion causes the fluid to move in the hydraulic system connecting the master cylinder to the wheel cylinders. The fluid movement pushes the pistons outward in the wheel cylinders. These pistons are attached to the brake shoes. The piston movement causes the shoe to be forced against the brake drum. The mechanical action creates friction between the shoe and the drum, which slows the automobile.

This design can be used in all technological areas. For example, it is an important part of construction technology. See Figure 10-3. Electrical, heating and cooling, plumbing, communication, and electrical systems for buildings.

Figure 10-3. System designers devise heating and cooling, plumbing, communication, and electrical systems for buildings.

Manufactured parts and structures are designed using product-design procedures. Of natural gas–distribution systems. Doctors and hospitals provide patient care in health-care systems.

Product Design

Product design deals with two areas: manufactured products (involving designers) and constructed structures (involving architects). See Figure 10-4. The goal of both activities is to develop a product or structure meeting the customer’s needs. The product or structure must function well, operate safely and efficiently, be easily maintained and repaired, have a pleasant appearance, and deliver good value.

In addition, products and structures must be designed so they can be produced economically and efficiently. They must also be sold in a competitive environment. In short, the product or structure must be designed for the following:

- **Function.** The product or structure must be easy and efficient to operate and maintain.
- **Production.** The product or structure must be easy to manufacture or construct.
- **Marketing.** The product or structure must be appealing to the end user.

The Design Team

In early times, products were often designed by a single person or craftsman. Paul Revere was a silversmith who designed and produced products he sold in his shop in Boston. As technology advanced, however, this single-person approach was replaced with design teams. This allowed various people to contribute their special talents to the project. For example, a design team for a large building might include architects, civil and mechanical engineers, interior designers, graphic designers, computer-aided drafting operators, and 3D illustrators. They would be involved with the many aspects of designing, planning, and constructing the building. No one person on the team could do

Figure 10-4. Manufactured parts and structures are designed using product-design procedures.
Steps for Developing Design Solutions

System and product designs start with a clear definition of the situation or opportunity. We learned the procedures for developing the definition in the previous chapter. This problem definition leads to the next step in product design—developing design solutions. These solutions often evolve through three steps:

1. Developing preliminary solutions.
2. Isolating and refining the best solution.
3. Detailing the best solution.

As these three steps are completed, often, the problem is redefined or refined. The steps can then be repeated until a final design is developed. This circular system is shown in Figure 10-6.

This process can be described as “imagining.” First, the designers use their imagination to develop a number of unique solutions or designs. These solutions are then engineered back to reality through design-refinement and detailing activities. The first step starts with broad thinking. This kind of thinking is called divergent thinking. Divergent thinking seeks to think of as many different (divergent) solutions as possible. The most promising solutions are then refined and reduced until one “best” answer is found. The refinement of ideas requires convergent thinking. The goal is to narrow and focus (converge) the ideas until the most feasible solution is found.

The best solution might not be the one that works best or is the least expensive. As we noted earlier, criteria and constraints can compete with one another. Trade-offs often occur among appearance, function, and cost. Many of us cannot always afford the very best answer. Our budget and the length of time we expect to keep the product enter into our product choices. For example, you might find it unwise to purchase a $900 racing bicycle because you are only going to use the bicycle to ride occasionally to the park. If you regularly ride a bicycle to work or go on cycling vacations, you might be able to justify the expensive model. Likewise, the “snapshot” photographer probably does not need the most expensive digital camera. The professional photographer would choose such a camera, however. Product-design activities produce a wide range of products. This variety allows consumers to select one that meets their performance needs and financial resources.

Developing Preliminary Solutions

Designs start in the minds of designers, engineers, or architects. Ideas can be stimulated in various ways. Three popular techniques are brainstorming, classification, and what-if scenarios. After people have put forth their ideas, they then record the ideas in rough sketches.

Brainstorming

Brainstorming is a process requiring at least two people, although most people find that having three or more participants in the process is more productive. This process involves seeking creative solutions to an identified problem. Members of the group offer individual solutions that they think will work. See Figure 10-7. Proposed solutions often cause other members of the group to think of more ideas. The strategy uses a concept called synergism. Synergism builds on the individual contributions of the participants to make a larger whole. The number of ideas the group generates is more than the number they could develop if each person worked alone.

Brainstorming activities work best when the group accepts some basic rules. These rules include the following:

- **Encourage wild, far-out ideas.** There are no bad or stupid ideas. Wild, but promising, ideas can always be engineered back to reality.
- **Record the ideas without reacting to them.** Many people stop offering some of their ideas if they are criticized. To avoid criticism, they provide only those ideas they think the group will like.
- **Seek quantity, not quality.** The chances of good ideas emerging are increased as the number of ideas increases.
- **Keep up a rapid pace.** A rapidly paced session keeps the mind alert and reduces the chance of judging the ideas.
Classification

One person or a group of people can conduct classification. **Classification** involves dividing the problem into major segments. Each segment is then reduced into smaller parts. For example, buildings can be classified as business and commercial, homes, and industrial. Homes can be further classified as houses, apartments, and condominiums. A house can be classified by its major features: foundations, floors, walls, ceilings, roof, doors, windows, and so on. Foundations can then be classified as poured concrete, concrete block, wood posts, timber, and so on. This process might result in a classification chart. A classification chart is often developed as a tree chart, with each level having a number of branches below it. See Figure 10-8. This chart ends up looking very similar to a family tree people use to trace their ancestors.

**What-If Scenarios**

**What-if scenarios** start with a wild proposal. The proposal’s good and bad points are then investigated. The good points can be used to develop solutions. For example, peeling paint is a problem for housepainters. They must remove the old paint from a house before repainting. A wild solution suggests mixing an explosive material with the paint before it is applied. Whenever the building is ready to be repainted, the old paint can be blown off the building. Obviously, exploding house paint is ridiculous. The proposal, however, can lead to a solution. Paint sticks to a house through the adhesion between the paint and the siding. Maybe a material can be mixed with the paint that causes the paint to lose adhesion when a special chemical is applied. At repainting time, the chemical can be sprayed on to loosen the paint. The paint can then be easily removed from the siding.

**Rough Sketching**

Once designers have conceived of a number of ideas, they must record the ideas. The most common recording method is to develop rough sketches of the products, structures, or system components. See Figure 10-9. These sketches are as much a part of the thinking process as they are a communication medium. Designers are forced to think through concepts such as size, shape, balance, and appearance. The sketches then become a library of ideas for later design efforts.

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**Figure 10-8.** A classification chart divides the design problem or opportunity into segments to develop solutions more easily. This type of chart is called a tree chart.

**Figure 10-9.** Designers use rough sketches to record their ideas.

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**Mathematics**

**Solid Geometry**

Designers should be familiar with some basic geometric concepts in order to create effective pictorial sketches. They use the concepts of solid geometry, for example, when drawing such three-dimensional images as pyramids, cones, cylinders, and cubes. A pyramid, to use the first example, is a solid figure with a polygon as a base. A polygon, as you might recall from earlier geometry lessons, is a closed plane figure bounded by three or more straight lines. (The word polygon comes from the prefix poly-, meaning “many,” and the suffix -gon, meaning “angle.” Thus, a polygon is a many-angled figure.) The faces (surfaces) of the pyramid are triangles with a common vertex, or point where they intersect.

In a regular pyramid, the base is a regular polygon. The faces are congruent triangles. Again, as you might remember from earlier geometry, congruent means “equal in size and shape.”

The other three-dimensional images share some characteristics, but they differ in others. For example, in what way or ways is a cone similar to a pyramid? In what way or ways is it different?

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**Standards for Technological Literacy**

**Figure Discussion**

Discuss Figure 10-8 and then have groups of students develop a classification of business/commercial buildings.

**Figure Discussion**

Discuss the quick techniques used in the rough sketches shown in Figure 10-9.

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“Design and innovation are about exploration and experimentation and accepting that your first solution may not be right. Creativity is about challenging your assumptions.” —Dr. Bettina von Stamm, London Business School.

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“Design and innovation are about exploration and experimentation and accepting that your first solution may not be right. Creativity is about challenging your assumptions.” —Dr. Bettina von Stamm, London Business School.
The term rough is not used to describe the quality of the drawing. Rough sketches are not necessarily crude. They often represent good sketching techniques. The term rough describes the state of the design ideas. This term suggests that the designs are incomplete and unrefined.

Isolating and Refining Design Solutions

The rough sketches allow designers to capture a wide variety of solutions for the design problem or opportunity. The sketches are similar to books in a library. They contain a number of different thoughts, views, and ideas. These sketches can be selected, refined, grouped together, or broken apart.

Isolating and refining original designs in the “library of ideas” is the second step in developing a design solution. See Figure 10-10. Promising ideas are chosen and then studied and improved. This process might involve working with one or more good rough sketches. The size and shape of the product or structure might be changed and improved. Details might be added, and the shape might be reworked. In short, the design is becoming refined as problems are worked out and the proportions become more balanced.

Refined design ideas might also be developed by merging ideas from two or more rough sketches into a refined sketch. The overall shape might come from one sketch, and specific details might come from others. This approach is one of integration, which blends the different ideas into a unified whole. The new idea might not look at all similar to the original rough sketches.

Detailing Design Solutions

Rough and refined sketches do not tell the whole story. Look back at the sketches shown in Figure 10-10. What size is the product in the sketch? You cannot tell. The sketches communicate shape and proportion. They do not communicate size. For this task, we need to add more details, and thus, we need a third type of sketch, called a detailed sketch. This sketch communicates the information needed to build a model of the product or structure. Detailed sketches can also be used as a guide to prepare engineering drawings for manufactured products and architectural drawings for constructed structures. Engineering and architectural drawings are discussed in Chapter 12.

Detailed sketches are helpful when models of products or structures are made. Building models requires three major types of information. See Figure 10-11:

- **Size information.** This information explains the overall dimensions of the object or the sizes of features on an object. Size information might include the thickness, width, and length of a part, the diameter and depth of a hole, or the width and depth of a groove.

- **Location information.** This information gives the positions of features within the object. Location information might establish the location of the center of a hole, the edge of a groove, or the position of a taper.

- **Geometry information.** This information describes the geometric shapes or relationships of features on the object. Geometry information can communicate the relationship of intersecting surfaces (square or 45° angle, for example), the shapes of holes (rectangular or round, for example), or the shapes of other features.

Designers often use pictorial-sketching techniques to capture and further refine product-design ideas. These techniques try to show the artifact very similarly to how the human eye will see it. Therefore, a single view is used to show how the front, sides, and top will appear. Designers produce three different kinds of pictorial sketches when refining ideas. These sketches are the following:

- Oblique sketches.
- Isometric sketches.
- Perspective sketches.

### Oblique Sketches

Oblique sketches are the easiest pictorial sketches to produce. These sketches show the front view as if a person is looking directly at it. The sides and top extend back from the front view. They are shown with parallel lines that are generally drawn at 45° to the front view. The depth lines may be drawn at a different angle, such as 30° or 60°, depending on the intended result.

To produce an oblique sketch, the designer completes steps similar to those shown in Figure 10-12.

1. Lightly draw a rectangle that is the overall width and height of the object.
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2. Lightly extend parallel lines from each corner of the box. Draw the depth lines at 45°, or at a different angle such as 30°.
3. Lightly mark the extension lines at a point equal to the depth of the object.
4. Lightly connect the depth lines to form a box.
5. Add any details, such as holes, notches, and grooves, onto the front view.
6. Extend the details the depth of the object.
7. Complete the sketch by darkening in the object and detail outlines.

The procedure listed above produces a cavalier oblique drawing. This type of drawing causes the sides and top to look deeper than they are. To compensate for this appearance, designers often use cabinet oblique drawings. See Figure 10-13. This type of drawing shortens the lines projecting back from the front to one-half their original lengths.

Isometric Sketches

Isometric sketches are the second type of pictorial drawings used to produce refined sketches. The word isometric means “equal measure.” Isometric sketches get their name from the fact that the angles that the lines in the upper-right corner form are equal. Each angle is 120°. Designers use isometric sketching when the top, sides, and front are equally important. The object is shown as if it is viewed from one corner.

Figure 10-12. Designers create oblique sketches through a series of steps.

Designers follow four major steps when creating isometric sketches. See Figure 10-14. These steps are the following:
1. Lightly draw the upper-right corner of an isometric box that will hold the object.
2. Complete the box by lightly drawing lines parallel to the three original lines.
3. Locate the major features such as notches, tapers, and holes.
4. Complete the drawing by darkening the features and darkening the object outline.

Figure 10-13. The two types of oblique drawings are cavalier oblique and cabinet oblique. Cabinet oblique drawings use one-half the depth of the object for a more natural appearance.

Figure 10-14. Designers follow four major steps when creating isometric sketches.

Standards for Technological Literacy

Figure Discussion:
Use Figure 10-12 as a basis to show your students how to make a simple oblique sketch.

Quotes
“It is probably a myth to imagine that it was ever enough for a company to start up, start making something (consumer perhaps), sell them and then carry on doing so as they had always done. If that world ever existed it has been gone for many years now. Businesses can only survive, prosper and grow in a voraciously competitive global economy if they continue to innovate.”—Gordon Brown, Creativity Works.

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Figure 10-13. The two types of oblique drawings are cavalier oblique and cabinet oblique. Cabinet oblique drawings use one-half the depth of the object for a more natural appearance.

Figure 10-14. Designers follow four major steps when creating isometric sketches.

Standards for Technological Literacy

Figure Discussion:
Explain why cabinet oblique techniques produce more appropriate kitchen cabinet sketches than cavalier oblique techniques.

Quotes
“Today's consumers live in a world where rapid and constant change is now the ‘norm’, therefore, it is not a question of how much change, but rather ensuring that these changes are handled intelligently and artfully. Design must be used as a tool to facilitate accurate and engaging communication, as opposed to creating superficial camouflage.”—Peter Knapp, Executive Creative Director, Landor Associates.
Perspective Sketches

Perspective sketches show the object as the human eye or a camera sees it. This realism is obtained by having parallel lines meet at a distant vanishing point. If you look down a railroad track, you see a similar effect. The rails remain the same distance apart, yet your eye sees them converge (come together) in the distance.

Three major types of perspective views exist: one point, two point, and three point. The difference between these types is determined by the number of vanishing points used. See Figure 10-15.

A one-point perspective shows an object as if you are directly in front of the object. All the lines extending away from the front line converge at one point. The one-point perspective is similar to an oblique drawing with tapered sides and a tapered top.

A two-point perspective shows an object as if you are looking down on the object (aerial view), directly at it (general view), or up at it (ground view). The two-point perspective is constructed very similarly to an isometric drawing. Again, the sides are tapered as the lines extend toward the vanishing points.

A three-point perspective shows how the eye sees the length, width, and height of an object. All lines in this drawing extend toward a vanishing point. The appearance of a perspective drawing changes as the horizon changes. See Figure 10-16.

Changing the position of the horizon line can cause the object to be seen as if the observer is looking down on the object (aerial view), directly at it (general view), or up at it (ground view). The designer must decide which of these views best suits the object and the audience who will see the sketch.

When developing the basic structure for one-, two-, or three-point perspective sketches, designers follow the same basic steps. See Figure 10-17. These steps are the following:

1. Establish the horizon line, vanishing point(s), and front of the object. Connect the front line(s) to the vanishing point(s).

2. Establish the depth of the objects along the lines extending to the vanishing point(s).

3. Connect the depth lines to the vanishing point(s). Darken in the object.

Designers then add details to complete the sketch. Perspective sketches are often shaded to add to their communication value. Developing the perspective, or “human eye,” view is more difficult than developing the oblique or isometric views. Perspectives are, however, the most realistic of the three pictorial sketches.

Figure 10-16. Changing the location of the horizon changes the appearance of a perspective drawing.

Figure 10-17. Designers follow three basic steps in developing perspective sketches.

TechnoFact
The design of a product is something that is begun in the concept stage, and it should be constant throughout the process.
Section 4  The Problem-Solving and Design Process

Summary

Design problems and opportunities in technological areas can be divided into two major areas: systems and products. System design deals with the arrangement of components to produce the desired result. Product design deals with manufactured products and constructed structures. In both system and product design, though, designers must first study the definition of the problem or opportunity before developing design solutions. They must then generate a number of possible solutions and create rough sketches of their ideas. These sketches become a library of design ideas. From this library, designers select specific ideas and refine them to bring the solution into focus. Finally, they describe the refined ideas through detailed sketches.

Test Your Knowledge

Write your answers on a separate piece of paper. Please do not write in this book.

1. What are the two major areas in which designers develop solutions to technological problems and opportunities?
2. Designing the arrangement of components to produce a desired result is called ______.
3. Product design deals with developing ______ products and ______ structures.
4. A group of people who work together to create a design is called a(n) ______.
5. List the three steps followed in developing design solutions.
6. What is the difference between divergent and convergent thinking?
7. The best solution is always the least expensive one. True or false?
8. Name one of the rules used for effective brainstorming.
9. Definition involves dividing the problem into increasingly specific categories.
10. A what-if scenario is a wild hypothetical situation that can be used to help develop solutions.

Answers to Test Your Knowledge Questions

1. System design problems and opportunities. Product design problems and opportunities.
2. System design
3. Manufactured, constructed
4. Design team
5. Developing preliminary solutions.
6. Isolating and refining the best solution.
7. False
8. Student answers may include any of the following: Encourage wild, far-out ideas. Record the ideas without reacting to them. Seek quantity, not quality. Keep up a rapid pace.
9. Classification involves dividing the problem into increasingly specific categories.
10. A what-if scenario is a wild hypothetical situation that can be used to help develop solutions.

STEM Applications

1. Develop a set of rough sketches for the following design definition:
   Problem or opportunity: The director of the school cafeteria would like a holder containing a saltshaker, a pepper shaker, 20 rectangular (1″ × 1 1/2″) packages of sugar, and a bottle of ketchup. The holder should be easily removable from the table at the end of the lunch period.
2. Refine the best sketch you produce for the lunchroom-table organizer.
3. Develop a detailed sketch for your lunchroom-table organizer.
4. Select a device in the technology laboratory and develop a perspective sketch of it.

Matching questions: For Questions 15 through 23, match each definition on the left with the correct type of pictorial sketch on the right. (Note: Answers can be used more than once.)

<table>
<thead>
<tr>
<th>Definition</th>
<th>Pictorial Sketch</th>
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<tr>
<td>Used when the top, sides, and front are equally important.</td>
<td>C. Perspective</td>
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<tr>
<td>Shows the object as the human eye sees it.</td>
<td>B. Isometric</td>
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<td>Sides extend back at 45°.</td>
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<td>The angles that the lines in the upper-right corner form are equal.</td>
<td>B. Isometric</td>
</tr>
<tr>
<td>Shows the front view as if you are looking at it.</td>
<td>C. Perspective</td>
</tr>
<tr>
<td>Most difficult of three sketches to develop.</td>
<td>C. Perspective</td>
</tr>
<tr>
<td>Parallel lines meet at distant vantage point.</td>
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<tr>
<td>Always has one corner made up of three 120° angles.</td>
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