Curriculum

Understanding the Design Process

Overview:

A) **Session 1: Jump Into Design**

B) **Session 2: The Designed World**

Curriculum

Understanding the Design Process

A 10-step Design Process is introduced and practiced in this session. The design process used for students' project development is the same one that guides the work of professional engineers and designers. In *Session 1: Jump Into Design*, students learn how to look at the world from a designed perspective by examining and redesigning everyday objects.
In *Session 2: The Designed World*, students develop skills by thinking creatively about designed things they use. They also learn to identify problems that lead to opportunities for new design solutions.

Session 1

Jump Into Design

Understanding the Design Process

In This Session:

A) **Build a Better Paper Clip (60 minutes)**
- Student Handout
- Student Reading

B) **The Design Process (45 Minutes)**
- Student Handout
- Student Reading

C) **Toothpaste Cap Innovations (45 Minutes)**
- Student Handout

Jump Into Design orients students to a design process that guides the work of engineers and designers. Three hands-on activities build understanding of the role of engineering and design in producing effective solutions to real-world problems.

In *1A: Build a Better Paper Clip* students carefully examine the form and function of standard paper clips. Given a set of wires and tools, they are challenged to design a new paper clip that meets predetermined requirements. This design challenge provides a firsthand connection with a 10-step design process that is introduced in a group activity, *1B: The Design Process*. The design process forms the foundation for work on students' own projects, and each step is revisited in greater depth in subsequent sessions. In the final hands-on design activity in this session, *1C: Toothpaste Cap Innovations*, students examine a designed solution to the problem of conventional screw-top toothpaste caps as they walk through the steps of the design process.

Supplies

- For each student: straight pins, safety pins, and a variety of different types of paper clips of varying sizes
- 20 feet (4 meters) each of 4 different types of wire cut into lengths of 1 foot (30 cm) for designing paper clips
- Several pairs of wire cutters and needle-nose pliers
- Stack of scratch paper to test solutions
- Additional materials for embellishment, such as beads, buttons, glue, etc.
- Toothpaste cap samples: screw top and flip-top cap
- Flip chart and markers, white board and markers, or computer to display discussion points
- Safety goggles

Jump Into Design

Key Concepts: Session 1

Throughout Session 1, students are introduced to the concept of design and engineering as a *formal process* through a series of hands-on activities. They begin with redesigning a simple object—the paper clip—in order to develop a common reference point as they begin their experience with **the design process**. Another product example follows and is used to practice and reinforce understanding. These experiences with the design process build the important foundation for the rest of the activities in *Design and Discovery* as the design process forms the basis of the curriculum.

Key Concepts

The Design Process: A systematic problem-solving strategy, with criteria and constraints, used to develop many possible solutions to solve a problem or satisfy human needs and wants and to winnow (narrow) down the possible solutions to one final choice.

The design process is a recognized set of generally defined steps designers and engineers use based on a problem-solving strategy that leads to product development. It begins with the identification of a problem through a series of exploratory and data-gathering stages, to the creation of a solution. Though the process is introduced as a series of sequential steps, it is important to understand that the process is not truly linear—it is much more like a design *cycle* since many of the steps are intended to be revisited as more information is gathered. Because this forms the core of this curriculum, adults working with students must be comfortable with the process and how it plays out in the subsequent activities.

If you recall "the scientific method" you were introduced to in science classes, you will recognize the similarity of a sequenced set of steps, used as reference by professional scientists. There are natural and logical steps that facilitate the desired outcome. However, the scientific method and the design process are fundamentally different. While scientists propose a "solution" up front (the hypothesis) and then test it through experimentation to see if it is correct, designers identify the problem, define it as a design challenge, then brainstorm, research, gather data, and test to identify *what the correct solution should be*. The "solution" is arrived at later as a result of the process of data gathering and experimentation. Both represent the formal process used by each profession from each field, though inquiry and experimentation are at the heart of both.

Key Concepts Session 1 (continued)

Students are introduced to the design process in *1B Handout: The Design Process*. Become familiar with the steps.

1. **Identify a design opportunity.**
   The design process begins with identifying a need. Notice that opportunities to design a new product or redesign an existing one are everywhere. They often come from a

   problem that has been experienced personally. The goal is to identify many design opportunities and narrow them down later.

2. **Research the design opportunity.**
   Gather a lot of information about the nature of the problem in order to help narrow down your choices. Find out if other people experience the same problem and research any existing products or solutions that may currently be used to solve the problem. Choose a design opportunity to address. Write a problem statement.

3. **Brainstorm possible solutions to the problem.**
   Try to come up with as many ideas as you can for solving the problem or addressing the design opportunity. Brainstorming may involve the use of SCAMPER and other techniques. Then, narrow down your solutions and choose one to three to pursue further.

4. **Draft a design brief.**
   Write a design brief to help outline the problem. A design brief includes a problem statement, a description of the user needs, a proposed solution, and often a sketch of the idea or solution. This is a working document that can be changed.

5. **Research and refine your solution.**
   Do a literature review and talk to experts in related fields and users to find similar solutions and other approaches to the problem. Analyze your solution for feasibility, safety, and practicality.

6. **Prepare design requirements and conceptual drawings.**
   Define the criteria the solution must meet (design requirements) and sketch conceptual drawings.

7. **Build models and component parts.**
   Analyze the project design for its systems, components, and parts. Consider

appropriate materials and methods for constructing a model. Now build a model of the entire design and/or its systems.

8. **Build a solution prototype.**
   Develop detailed project specifications, consider material properties required, choose materials, and create a working prototype.

9. **Test, evaluate, and revise your solution.**
   Evaluate the prototype for function, feasibility, safety, aesthetics, and other criteria. Consider how it could be improved. Modify your prototype or create another and test it.

10. **Communicate the solution.**
    Present your design solution to an audience. Gather feedback and revise and redesign your product as necessary.

More About the Design Process

Garratt, James. *Design and Technology*. New York: Cambridge University Press, 1993.

Petroski, Henry. *Invention by Design; How Engineers Get From Thought to Thing*. Cambridge: MA: Harvard University Press, 1998.

Petroski, Henry. *To Engineer Is Human: The Role of Failure in Successful Design*. Reprint, New York: Vintage Books, 1992.

Technology Student, www.technologystudent.com*
This site supports the UK's Design Technology course. The information covers a wide range of topics, including the design process, electronics, and gear systems.

Session 1, Activity A

Build a Better Paper Clip

Goal

Experience the design process by re-engineering an everyday object.

Outcome

Design and engineer a new paper clip that meets requirements.

Description

After careful observations of how different kinds of paper clips function and perform, participants design a new paper clip that meets several requirements including a unique look. They construct them using a selection of materials and prepare drawings of the various designs. Each designer presents a new paper clip model.

Supplies

- For each student: straight pins, safety pins, and a variety of different types of paper clips of varying sizes
- 20 feet (4 meters) each of 3 or 4 different types of wire cut into lengths of 1 foot (30 cm) for designing paper clips
- Several pairs of wire cutters and needle-nose pliers
- Stack of scratch paper to test solutions
- Additional materials for embellishment, such as beads, buttons, superglue, etc.
- Safety goggles

Safety Guidelines

Safety goggles should be worn during this activity when either you or the student is cutting wire.

Note About Wire

Wire needs to be flexible but have sufficient springiness to retain its shape after some bending. Recommended: Steel or copper wire, 14 or 18 gauge. Floral stem wire (18 gauge steel) is available in craft stores and floral shops.

Preparation

1. Read *1A Reading: The Perfect Paper Clip.*

1A: Build a Better Paper Clip (continued)

2. Optional: Invite mentors to the first activity. Review the mentor section in Implementation for more information on mentors.

Procedures

Introduction

1. Introduce students to their design notebooks. Remind students that the notebook is a place to record ideas, inspirations, discoveries, sketches, and notes. They will begin using the design notebook in this first activity to record their thoughts and ideas. Some general guidelines include:
    - Leave a few pages blank at the beginning to create a table of contents.
    - Date and sign each page.
    - Number each page.
    - Never remove pages.
    - Do not erase.

2. Mentors could be brought in and assigned to students during this activity. They offer the ability to provide guidance and prompt discussion while the students are designing their paper clip.

3. At the start of this activity, identify the problem by introducing students to the Design Challenge: The owners of P&C Office Supplies are seeking new designs for paper clips. The company has come across hard times and believes a new paper clip design could revive its once-thriving business. It is up to you to save their company. Use your imagination and creativity to invent a new paper clip design. After researching their paper clip sales pattern, the owners have come up with requirements for the design. Please refer to them before you begin. (Refer to the handout with the design requirements, and allow time for students to read it thoroughly.)

    Describe the materials and tools for the design challenge. Discuss the different types of wire the students will be using and what is meant by wire gauge—the size of the wire's diameter. The higher the gauge number, the smaller the diameter and the thinner the wire. Pay special attention to the needle-nose pliers and wire cutters. Some students may not have experience with these tools. Take time to show students the correct way to hold and use the tools. Review the requirements with students before they begin brainstorming solutions to the design challenge.

4. Before students begin designing a new paper clip, they should explore the existing designs you have provided and make observations in their design notebooks. Remind them that all these fasteners represent different solutions to the same problem—holding papers together.

Exploration

1. Encourage students to experiment carefully with all the examples provided, exploring the ability of various materials to hold paper.
2. Remind students to make sketches and take notes about their observations of different materials and paper clip designs in their design notebooks.
3. Move among the students and discuss their observations about the materials and the extent to which different materials bend and spring back, retaining the ability to "hold" materials (evidence of Hooke's Law).

Design

1. Monitor progress to allow at least 25 minutes for designing, engineering, and testing a new paper clip prototype.
2. Remind the students to draw quick sketches in their design notebooks of their ideas and note test results.

Supplementary Information

Paper Clip History

The radio show, "Voices of Innovation" (www.voicesofinnovation.org*), provides listeners with two-minute sound portraits of engineering wonders and the people who developed them. These sound clips can be downloaded and played for students.

The following clips talk about the invention of the paper clip:

- www.voicesofinnovation.org/archives/Sept_02/P17_9_24_02.asp*

The Early Office Museum (www.officemuseum.com/paper_clips.htm*) provides a brief written history of the paper clip and a gallery showing early paper clip designs.

Paper Clips and Hooke's Law

Robert Hooke, a contemporary of Sir Isaac Newton, was an early advocate of the microscope. He examined things like the points of needles and edges of razor blades, noting the qualities of objects and thus making suggestions for improvements in their performance. He also identified what has come to be called Hooke's Law: *Ut tensio sic vis* (Latin) which means, "As the extension so the force." Each object stretches in proportion to the force applied to it. The more we stretch something, the more resistance it offers in response. In engineering, this law is

applied to airplane wings, bridges, skyscrapers, and paper clips.

Read more about paper clips and Hookes Law: Petroski, Henry. *The Evolution of Useful Things: How Everyday Artifacts—From Forks and Pins to Paper Clips and Zippers—Came to be as They Are.* Chapter 4: From Pins to Paper Clips. New York: Vintage Books, 1992.

Wrap Up

Each student presents a brief explanation and demonstration of his or her paper clip design. Have students read *1A Reading: The Perfect Paper Clip*, an excerpt from *Invention by Design* by Henry Petroski. This can be done as a group, reading sections out loud, time permitting. Otherwise, students can take it home to read.

Follow With

In the next activity, *1B: The Design Process*, students become familiar with the design process which they will use throughout the sessions.

Build a Better Paper Clip

Handout: Session 1, Activity A

Exploration of Existing Paper Clips

Explore the paper clips and pins (two types of fasteners) that you have in front of you. Pins were used to fasten paper together before the invention of the paper clip. Pay close attention to your hands and fingers as you use each one to fasten together pieces of paper. What do you notice?

You might notice the action needed to separate the paper clip loops so it slips onto the papers, or the way your fingers direct the clip onto the papers. Each of these actions is unconscious, and the ease with which the object is used indicates a successful design.

Explore the properties of the shape and the materials of each paper clip design. Observe the operation of each design, make notes about each, and apply what you learn to designing a unique, new paper clip. What is common about the way each shape works to do the job? What properties in the material allow each to do the job of fastening paper together?

Investigation of Materials and Tools

Investigate the materials and tools provided to you. Notice the different types of wire. The wire's diameter is measured in order to determine its gauge. The higher the gauge number, the smaller the diameter and the thinner the wire. The needle-nose pliers may be used to bend the wire into specific shapes.

Design Challenge

The owners of P&C Office Supplies are seeking new designs for paper clips. The company has come across hard times and believes a new paper clip design could revive its once thriving business. It is up to you to save their company. Use your imagination and creativity to invent a new paper clip design. After researching their paper clip sales pattern, the owners have come up with requirements for the design. Please refer to them before you begin.

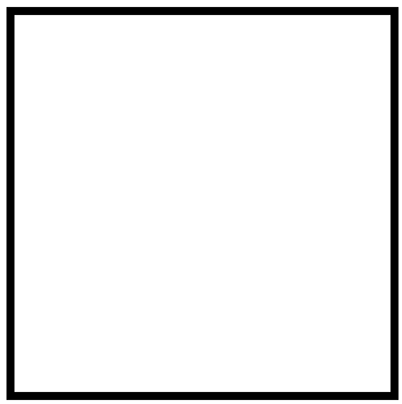
Try out all your ideas and make drawings of your designs. Choose one design to engineer and test. Be prepared to present your model.

1A Handout: The Perfect Paper Clip (continued)

Requirements

- Your paper clip will be unique. It cannot look like any paper clip you have ever seen before, but it may have features of other clips.
- It can be no bigger than 2 inches by 2 inches (5 cm x 5 cm).
- It must hold 10 pieces of paper together.
- You may use other materials to enhance your design, but your main material must be wire.
- It must not have sharp ends.
- You should use your design notebook to draw your various designs.

You may use this square to test for the paper clip size requirement.



The Perfect Paper Clip

Reading: Session 1, Activity A

Why in the world would you study a paper clip as you learn about engineering and design? Henry Petroski, a professor of civil engineering, has written many interesting books about design and engineering in everyday things. In his book, *Invention by Design*, he devotes a whole chapter to paper clips. He notes that the paper clip, although one of the simplest of objects, can provide many lessons about the nature of engineering.

We take paper clips for granted—it seems as if they've always been around. In fact, they've been in use only since the time of the Industrial Revolution. Before that, paper was held together with straight pins. However, the straight pin was difficult to thread through more than a few sheets of paper because it left holes in the paper, and it bulked up piles of paper.

With the developments of the Industrial Revolution, however, volumes of paper increased as technology enabled business to expand nationally and internationally. The paper clip had a clear advantage over the straight pin in holding together a group of papers, and eliminated pricked fingers! The increase in technology associated with the Industrial Revolution also allowed paper clips to be produced in quantities that kept the cost per clip low.

Early versions of the paper clip had problems that later versions sought to remedy. The paper clip we know and love today, with its (almost) perfect design, did not start out that way. Earlier models got tangled together, slipped off too easily, had too much "springiness" or not enough...

As Henry Petroski notes, the paper clip we are familiar with works because:

"... its loops can be spread apart just enough to get it around some papers, and when released, can spring back to grab the papers and hold them. This springing action, more than its shape per se, is what makes the paper clip work. Springiness, and its limits, are also critical for paper clips to be made in the first place."

The most successful paper clip yet designed is the Gem* clip. The shape of the Gem clip was introduced in England in the late 19th century by a company known as Gem, Limited. The classic Gem has certain proportions that seem to be "just right."

1A Reading: The Perfect Paper Clip (continued)

Petroski quotes an architecture critic who had the Gem in mind when he wrote:

"Could there possibly be anything better than a paper clip to do the job that a paper clip does? The common paper clip is light, inexpensive, strong, easy to use, and quite good-looking. There is a neatness of line to it that could not violate the ethos of any purist. One could not really improve on the paper clip, and the innumerable attempts to try—such awkward, larger plastic clips in various colors, or paper clips with square instead of rounded ends—only underscore the quality of the real things."

The Gem became to paper clips what Kleenex* is to facial tissue because of a patent issued to William Middlebrook, of Waterbury, Connecticut, in 1899. The unique aspect of Middlebrook's patent was that, although there were many inventors patenting all sorts of sizes and shapes of paper clips, Middlebrook was patenting the machine that would form the paper clip economically.

Petroski writes:

"The complexity of Middlebrook's machine is clear from his patent drawings, and it is apparent that he was engaged in serious mechanical engineering…The principles upon which the machine works, bending wire around pegs, are well suited to the Gem design and it to them. In short, Middlebrook's machine and the Gem were made for each other."

So the combination of a well-designed paper clip and a well-designed machine led to the success of the Gem clip today.

The architecture critic aside, many believe that even the Gem could use improvement: It goes on only one way; it doesn't just slip on; it doesn't always stay on; it tears the papers; it doesn't hold many papers well.

This is what makes engineering and inventing so challenging. All design involves conflicting objectives and thus compromise. The best designs will always be those that come up with the best compromise.

Of course, inventors will always look for ways to improve upon an object. They will continue to look for ways to make a better paper clip. Newer clips, for instance,

1A Reading: The Perfect Paper Clip (continued)

may be plastic coated, or shaped like Gems, yet their proportions never seem to be quite right. One improvement to the paper clip has been the introduction of a turned-up lip on the end of the inner loop. This allows the paper clip to slide onto the papers without actually opening the clip. As mentioned above, design involves tradeoffs. This "improvement" adds to the bulk of bundled papers.

One key point to remember is that the laws of nature always bind invention, design, engineering, and manufacturing. Change in one area of design may lead to design weakness in another.

To inventors, the quest for the perfect paper clip remains elusive. Perhaps the simple paper clip isn't so simple a device after all!

Adapted from:
Petroski, Henry. *Invention by Design: How Engineers Get from Thought to Thing.* Cambridge, MA: Harvard University Press, 1996.

Session 1, Activity B

The Design Process

Goal
Become familiar with the design process.

Outcome
The experience with designing paper clips is formalized into a design process that guides students throughout their design and engineering projects.

Description
A small group discussion of the paper clip design activity collects the students' experiences with the design process they experienced directly. The discussion moves to connecting their experience to a general design process outlined on *1B Handout: The Design Process*. A short reading that clarifies the relationship among design, engineering, and scientific research wraps up the activity.

Supplies
Flip chart and markers, white board and markers, or computer to display discussion points.

Preparation
Set up flip chart and markers, white board and markers, or computer to display discussion points.

Procedures
Brief Discussion

1. Ask students to reflect on their experience with designing a new paper clip. You might prompt them to think about:
   - What gave them their ideas?
   - What stages or steps did they go through as their ideas took shape?
   - What helped them move their idea into a prototype?

2. Ask students to share their experience with their designs. Have each person share. Make quick notes on flip chart paper or white board. Call attention to areas of common experiences.

1B: The Design Process (continued)

Design Process Review

1. Look at the *1B Handout: The Design Process*, and have students take turns reading each step out loud.

2. Discuss any connections between the students' experience and the design process as you go through each step.

3. Emphasize that the design process consists of several steps that are revisited throughout the stages of designing a product. The process may go through cycles as ideas are refined and information is gathered. Reinforce the idea that mistakes and failures are part of the process and can help develop a better solution to a problem.

4. Introduce the idea that students will be using this process to identify a need that could be met by redesigning, modifying, or improving an existing product or designing a new product.

Wrap Up

Ask participants to look around the room and discuss:

- What things in the room were designed?
- Which ones were engineered?
- Why do people design things?
- What frustrations do you have with products you use?
- How would you improve those products?

Follow With

The *1C: Toothpaste Cap Innovations* activity walks students through the design process using a designed solution to the problems of conventional screw-top toothpaste caps.

The Design Process

Handout: Session 1, Activity B

Getting From "Think" to "Thing"

You will be using a design process to guide the development of your project from an idea to the design of a prototype. The steps of the design process are iterative, or cyclical. That means that throughout the stages of designing a product, you will revisit many of these steps as you refine your ideas.

1. **Identify a design opportunity.**
   The design process begins with identifying a need. Notice that opportunities to design a new product or redesign an existing one are everywhere. They often come from a problem that has been experienced personally. The goal is to identify many design opportunities and narrow them down later.

2. **Research the design opportunity.**
   Gather a lot of information about the nature of the problem in order to help narrow down your choices. Find out if other people experience the same problem and research any existing products or solutions that may currently be used to solve the problem. Choose a design opportunity to address. Write a problem statement.

3. **Brainstorm possible solutions to the problem.**
   Try to come up with as many ideas as you can for solving the problem or addressing the design opportunity. Brainstorming may involve the use of SCAMPER and other techniques. Then, narrow down your solutions and choose one to three to pursue further.

4. **Draft a design brief.**
   Write a design brief to help outline the problem. A design brief includes a problem statement, a description of the user needs, a proposed solution, and often a sketch of the idea or solution. This is a working document that can be changed.

5. **Research and refine your solution.**
   Do a literature review and talk to experts in related fields and users to find similar solutions and other approaches to the problem. Analyze your solution for feasibility, safety, and practicality.

1B Handout: The Design Process (continued)

6. **Prepare design requirements and conceptual drawings.**
   Define the criteria the solution must meet (design requirements) and sketch conceptual drawings.

7. **Build models and component parts.**
   Analyze the project design for its systems, components, and parts. Consider appropriate materials and methods for constructing a model. Now build a model of the entire design and/or its systems.

8. **Build a solution prototype.**
   Develop detailed project specifications, consider material properties required, choose materials, and create a working prototype.

9. **Test, evaluate, and revise your solution.**
   Evaluate the prototype for function, feasibility, safety, aesthetics, and other criteria. Consider how it could be improved. Modify your prototype or create another and test it.

10. **Communicate the solution.**
    Present your design solution to an audience. Gather feedback and revise and redesign your product as necessary.

Form Follows Function—What Does That Mean?

Reading: Session 1, Activity B

"The scientist seeks to understand what is; the engineer seeks to create what never was." —attributed to Theodore Von Karman, engineer (1881-1963)

Every thing is supposed to function—it's supposed to do something, to work. Engineering is about function: Does the product work? Does it meet specifications? Can it be manufactured efficiently? All of this involves solving problems. We are going to be problem solvers and create things that function; we will think like engineers.

We will also learn the skills of good industrial designers. The *form* of an object (how it is designed and constructed) should *follow* the task it is to perform. In other words, you must know exactly what you want something to do before you can design and build it. How effectively something *functions* is often related to its *form*, or the quality of its design. Designers are concerned with qualities such as ease of use, efficient operation, and appealing aesthetics. We will pay attention to form in our project development. Though we will not focus on packaging design or marketing aesthetics, we will talk about the subtle but powerful influences of the "visual attraction" and "tactile appeal" of a product. Our goals are to meet an identified need with an idea that could work.

Science, Engineering, and Design: Where Do They Intersect?
While both engineers and scientists experiment and research problems, they differ in the kind of problems they work on. Engineers tend to work on problems that are of immediate concern to many people's daily lives. Scientific problems often build on basic understanding and may not have an immediate application in daily life.

The work of designers and engineers overlaps as well. Both seek to develop solutions to specific and immediate problems and needs. While design is involved in the entire process, engineering is the more specific process of making the idea meet specifications and function. One is useless without the other.

The First Step to a Good Design Is a Good Description of the Real Problem
The ability to really see a need, and then be able to describe that need, is at the

heart of successful product development. It requires a heightened awareness of the way people use things, and an ability to observe one's surroundings. Watching for difficulties people experience in doing a task, or how a particular product is used in an unintended way, takes practice and skill. Our job will be to learn to watch for opportunities for improving a tool or product.

Session 1, Activity C

Toothpaste Cap Innovations

Goal
A thorough review of the design process.

Outcome
Experience with each step of the design process.

Description
This activity takes students through each step of the design process by focusing on the problem of toothpaste screw caps. This is started in a whole-group think-and-discuss format. Students may then work with a partner to complete remaining steps.

Supplies

- Toothpaste tubes with flip-top cap (1-2 for each group)
- Toothpaste tubes with screw cap (1-2 for each group)
- Other examples of toothpaste containers (1-2 for each group)

Preparation
None

Procedures
The Process

1. Walk through the design process using the toothpaste screw cap as the identified problem. Use the questions on the handout to guide discussion. Work with the whole group on steps 1 to 3.

2. Have students work with a partner on steps 4 to 10.

3. Below is a sample of how the handout could be filled out. This activity can either be open-ended, where the students come up with their own designs for a toothpaste cap, or it can focus on the development of the flip-top cap as a design solution. The sample "answers," which reflect the development of the flip-top cap, can be used to prompt students during the activity.

1C: Toothpaste Cap Innovations (continued)

Sample Responses

1. **Identify a design opportunity.**
   What is the problem or need? Describe in detail.

   The toothpaste screw cap poses many problems for people. When taken off, the cap may be easily dropped into the sink drain, on the dirty floor, or even into the toilet. The cap is usually placed on the sink and often leaves toothpaste on surfaces. Furthermore, toothpaste usually gets onto the exterior of the cap. If the cap has grooves in it, it is difficult to clean, which means that the next person to use the toothpaste will end up with toothpaste on her hands.

2. **Research the design opportunity.**
   What is important to know about the nature of this problem? Who are the "users" in this case? How could you find out more about the "users" and their behavior?

   In this case, the users are those who use toothpaste—everyone. However, a younger person might have different complaints about the cap than an older person. User information could be gathered by observing family members' use of toothpaste, surveying, and interviewing people. A trip to the local pharmacy to see what else is on the market might be helpful, too.

3. **Brainstorm possible solutions to the problem.**
   What solutions can you come up with? Take five minutes to brainstorm as many ideas as you can for solving this problem.

   A flip-top cap, a pump, all-in-one toothbrush and toothpaste.

Steps 4 to 10 can be done in small groups or pairs. Students can complete the steps using the flip-top cap example or any of the other examples brainstormed together.

4. **Draft a design brief.**
   Clearly define the current situation or need in a "problem statement," and describe a proposed solution. This is just the first part of the design brief.

1C: Toothpaste Cap Innovations (continued)

The current most-popular toothpaste cap is a screw cap. This cap poses many problems for the users, including: the cap falling off and getting lost or dirty, the cap leaving toothpaste on the sink and on the outside of the cap. A flip-top cap could solve this solution. This cap would remain on the toothpaste tube so that it could not be lost or dropped. It would not be separately placed on the sink and would therefore not make the sink top dirty.

5. **Research and refine your solution.**
   What questions would be needed to gather the right data? Have other people tried to solve this problem? Are some materials more appropriate than others? If so, what are they? What about manufacturing costs associated with your idea? How would you analyze solution for feasibility, safety, and implications of the idea?

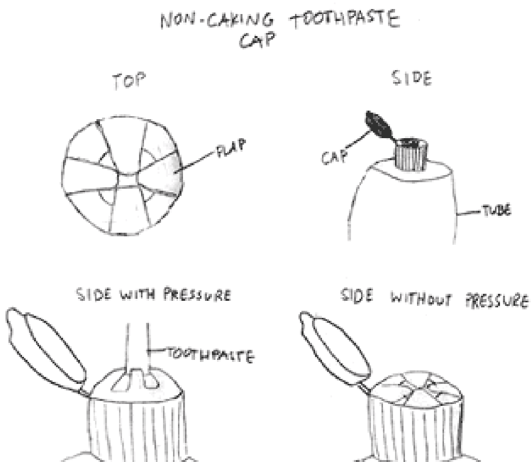
   I would need to do some research to see what types of toothpaste caps are out there. I might do a patent search, look online, go to the library, and browse the toothpaste aisle of the pharmacy. I would think that plastic would need to be used—something lightweight, cheap (it's disposable), and nontoxic. I think this product could be manufactured cheaply since many can be made at one time.

   I think it is feasible to make this product since it is similar to what is already on the market. In terms of safety, the cap would have to be able to screw on tightly so that it would not present a choking hazard to young children. It would have to open and close easily.

6. **Prepare design requirements and conceptual drawings.**
   Outline design requirements—general ways the product will meet the need of the users—and draw a quick sketch of your best ideas here.

   The cap would need to:

   - *Fit on a standard toothpaste tube*
   - Have an attached flip-top cap
   - *Screw on to the tube*
   - *Create an even flow of toothpaste*
   - *Be made of a lightweight, cheap, nontoxic material*
   - *Be leakproof*



7. Bui

Does your solution have parts or components? What could you use to build a quick model of your best solution?

A model could be built out of Styrofoam. The flip-top cap could be cut out of the Styrofoam and attached with a piece of rubber. The nozzle might be a separate component.

8. Build the prototype.

What are the specifications for the product? What materials would you need to build a prototype?

The specifications for the flip-top cap are:

- *Plastic top with 3/8 in. (1 cm) opening*
- *Dispensing nozzle*
- *Outer tube: 1 7/16 in. (3.5 cm) diameter*

9. Test, evaluate, and revise your solution.

How would you test your prototypes? What criteria would be useful to evaluate the solution? How would you know if your solution was going to solve the problem? How can I improve my solution based on feedback from my testing?

I would establish criteria, such as: It is easy to use, it stays clean, it stays sealed, and the toothpaste flows easily. I would conduct user-testing focus groups and observe how people used the product.

10. **Communicate the solution.**
    How would I present my design solution to an audience? How would I gather feedback from the audience?

    I would present my solution through a presentation to peers and community members or I would enter a local science and engineering fair. I would create a feedback form that I would hand out to my audience so I could capture their comments and questions and incorporate them into the next phase of revisions to my design solution.

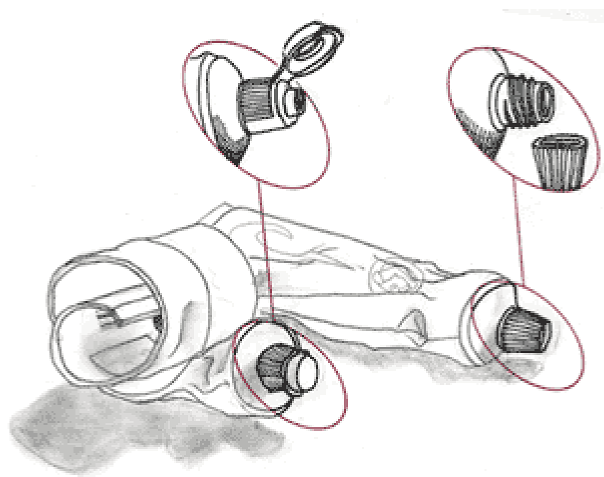
Wrap Up
Have teams describe their solutions or results of specific steps.

Follow With
In Session 2, *The Designed World*, participants learn how to look for design opportunities everywhere.

Toothpaste Cap Innovations

Handout: Session 1, Activity C

In this exercise you will have the opportunity to better understand the design process by applying it to a toothpaste cap. Currently, the most common toothpaste cap is the screw cap. However, many people are dissatisfied with this cap and would like an alternative. What else is on the market? What ideas can you come up with? The first question is done for you. As a group, you'll do the next three together. The remaining questions you will do on your own.



1. **Identify a design opportunity.**
   The toothpaste screw cap poses many problems for people. When taken off, the cap may be easily dropped into the sink drain, on the dirty floor, or even into the toilet. The cap is often placed on the sink and often leaves toothpaste on surfaces. Furthermore, toothpaste usually gets onto the exterior of the cap. If the cap has grooves in it, it is difficult to clean, which means that the next person to use the toothpaste will end up with it on her hands.

2. **Research the design opportunity.**
   What is important to know about the nature of this problem? Who are the "users" in this case? How could you find out more about the "users" and their behavior?

1C Handout: Toothpaste Cap Innovations (continued)

3. **Brainstorm possible solutions to the problem.**
   What solutions can you come up with? Take five minutes to brainstorm as many ideas as you can for solving this problem.

4. **Draft a design brief.**
   Clearly define the current situation or need in a "problem statement," and describe a proposed solution. This is just the beginning of the design brief.

5. **Research and refine your solution.**
   What questions would be needed to gather the right data? Have other people tried to solve this problem? Are some materials more appropriate than others? What are those materials? What about manufacturing costs associated with your idea? How would you analyze solution for feasibility, safety, and implications of the idea?

6. **Prepare design requirements and conceptual drawings.**
   Outline design requirements—general ways the product will meet the need of the users— and draw a quick sketch of your best ideas here.

7. **Build models and component parts.**
   Does your solution have parts or components? What could you use to build a quick model of your best solution?

8. **Build the prototype.**
   What are the specifications for the product? What materials would you need to build a prototype?

9. **Test, evaluate, and revise your solution.**
   How would you test your prototypes? What criteria would be useful to evaluate the solution? How would you know if your solution was going to solve the problem?

10. **Communicate the solution.**
    How would I present my design solution to an audience? How would I gather feedback from the audience?

Session 2

The Designed World

Understanding the Design Process

In This Session:

A) **Design Opportunities Are Everywhere (50 minutes)**
- Student Handout

B) **Mapping Out a Problem (25 Minutes)**
- Student Handout

C) **Design Improvements (30 Minutes)**
- Student Handout

D) **SCAMPER and Backpack (45 Minutes)**
- Student Handout

Home Improvement
- Student Handout

This session builds appreciation for the designed world around us and prepares students for finding a design and engineering project. Students learn to identify problems that lead to opportunities for new design solutions. They also develop skills by thinking creatively about designed things they use. The first activity, *2A: Design Opportunities Are Everywhere*, involves students taking a short field trip or walking tour to practice recognizing problems and needs around them. The activity ends with students developing a list of design opportunities that interest them and could be used as the first step of their project development. The next activity, *2B: Mapping Out a Problem*, introduces Activity Mapping, a technique used to help students identify problems and design opportunities.

In *Activity 2C: Design Improvements*, students learn about and practice a seven-part creative technique for improving existing designs known as SCAMPER. The next activity, *2D: SCAMPER and Backpack*, reinforces generative thinking using the SCAMPER technique with another object, a backpack.

A Home Improvement activity, *Improvement of Everyday Things*, has students make distinctions between functional and superficial improvements with objects in their homes.

Supplies

- Water bottles in multiple styles
- For each pair of students: 1 backpack (have students bring their own)
- Additional backpacks with other designs
- Clipboards (optional, but handy for taking notes during walking tour)
- Chart paper for posters and markers

The Designed World

Key Concepts: Session 2

In Session 2, students are introduced to three brainstorming techniques. Although many strategies exist to encourage creativity, this session focuses on **Activity Mapping**, **SCAMPER**, and **Brainwriting**. These techniques help students think creatively about designed objects. Another important aspect of this session is a short field trip or walking tour. Students use this field trip as an opportunity to practice recognizing design problems. The final goals of this session include introducing students to the idea of design opportunities and the development of a list of design opportunities that interest them.

Key Concepts

Problem Identification and Activity Mapping

The Activity Mapping technique allows for keen observation into processes needed to accomplish a certain activity. Describing four process stages in detail helps determine if any design opportunities might exist. In addition to the "packing for a trip" example introduced in 2B: Mapping Out a Problem, another example of the four phases of Activity Mapping for "brushing your teeth" is shown below.

Four primary user goals summarize what people are trying to accomplish when engaging in daily oral care.

Prepare ↓	Get Paste Locate Brush Wet Brush Load Brush Cap Paste	**Prepare** Preparation involves all the tool preparation steps that need to be done before users actually brush their teeth.
Mouth Cleaning ↓	Brush Upper Lower Interior Exterior Tongue	**Mouth Cleaning** Mouth cleaning begins when the cleaning surfaces of the toothbrush are applied to the inside of the mouth. This is the active part of the brushing, where all efforts are physically focused on the removal of food debris, night films, mouth freshening, and gum maintenance.
Cleanup ↓	Spit Rinse Mouth Rinse Hands Wipe Mouth Dry Hands Store Brush Store Paste	**Cleanup** Cleanup has three elements: tool maintenance, tool storage, and personal rinsing. Tool maintenance is focused primarily on getting brushes, sinks, and toothpaste rinsed and ready for next use. Tool storage involves keeping a bathroom tidy and getting the brush, paste, cups, etc. to a safe place where they are less likely to be contaminated. Personal rinsing refers to removal of saliva and paste from the mouth and hands. Rinsing is followed by towel drying.
Assessment	Mouth Feels Clean Looks Good Tastes Good	**Assessment** Assessment allows users to determine whether they've accomplished their personal goals with respect to mouth cleaning. Methods include visual inspection in the bathroom mirror, tactile inspection with the tongue, and self-perception of a minty mouth and fresh breath.

Key Concepts Session 2 (continued)

Students can look back on the processes involved with any activity (in this case, brushing your teeth) and see if any design opportunities can be identified. Students could be asked these questions to help them isolate a design challenge.

What products are involved in each process?
Are there problems with any of these products?
What existing product could be improved or modified?
What new product could be designed?

SCAMPER
The SCAMPER technique is a brainstorming method that builds one idea into several ideas by asking questions about the actions represented by the SCAMPER acronym. Alex Osborn, an early teacher of creativity, first introduced the idea of using questions to spur idea creation in his book Applied Imagination. This technique was later adapted by Bob Eberle and is now used often as a method for new idea generation. Students are introduced to the SCAMPER technique by examining an everyday item—water bottles.

Substitute
Combine
Adapt
Minimize/**M**agnify
Put to other uses
Eliminate/**E**laborate
Reverse/**R**earrange

Some questions to ask students as they use this technique and some examples to illustrate the concepts are shown below:

Substitute: What can be used instead? What can you use instead of the materials, objects, places, or methods now used? Meatless burgers and disposable cameras are examples of products that illustrate substitution.

Combine: Which parts or ideas can you blend together? What could be added? How can I combine uses with something else? Can you combine materials? Scented markers and clock radios are examples of combinations.

Adapt: What else is like this? What can be copied or imitated? How can it be adjusted to fit another purpose? What else is like this? What has worked before? What would you copy? Running shoes and hiking boots are examples of adaptations.

Minimize: Can it be smaller, lighter, less frequent, or divided? How can it be made smaller or shorter? How can it take less time? Mini-staplers and pocket-sized cell phones demonstrate how objects can be minimized.

Magnify: Can it be stronger, larger, higher, exaggerated, or more frequent? What happens if I exaggerate a component? How can it be made larger or stronger?

Key Concepts Session 2 (continued)

What can be duplicated? Repeated? Big-screen televisions and oversized floor pillows illustrate products that have been magnified.

Put to Other Uses: Can it be used in a way other than how it was intended to be used? Who else might be able to us it? What other market can it be used in? What else can it be used for other than its original purpose? Old tires used as swings and drinking cups used as pen and pencil holders illustrate the idea of "put to other uses."

Eliminate: What can you take away or remove? What parts aren't really necessary? Cordless telephones and wireless keyboards are examples of eliminating something.

Rearrange: Can parts be exchanged or the pattern changed? Can any components be interchanged? Can it be laid out differently? Ergonomic keyboards and recumbent bicycles are examples of products that have been rearranged.

Brainwriting

The brainwriting technique encourages students to produce ideas by silently recording the ideas in their design notebooks. This technique gives every student a voice in generating ideas. This is especially true for students who don't naturally speak out during "talking out loud" brainstorming sessions. The goal of this technique is to encourage more idea creation through the eventual sharing of students' written ideas.

Once ideas have been generated individually, they can be shared in a variety of ways. For example, students could write three of their ideas on a piece of paper (leaving room between the ideas) and pass the papers around the classroom. The other students could note suggestions, provide feedback, or ask questions relating to each of the three ideas. Students may now refine their ideas or list new ones based on the feedback and suggestions provided by others.

More About Brainstorming

Eberle, Bob. *Scamper: Games for Imagination Development*. Waco, TX: Prufrock Press, 1996. This book provides a description of SCAMPER and also activities that can be used with students to practice the technique.

Eberle, Bob. *Scamper On*. Waco, TX: Prufrock Press, 1997. This book provides more guided activities encouraging students to think in creative ways.

IDEO. *IDEO Method Cards: 51 Ways to Inspire Design*. San Francisco: William Stout Architectural Books, 2003.
www.ideo.com/methodcards/MethodDeck/index.html*
IDEO, a design firm, publishes cards illustrating methods they use to inspire innovative ideas. Sharing these methods with students will provide additional ways to look creatively at design solutions.

Key Concepts Session 2 (continued)

Michalko, Michael. *Cracking Creativity: The Secrets of Creative Genius*. Berkeley, CA: Ten Speed Press, 1998.
This book provides creative thinking strategies, stories, and exercises to use with students.

Michalko, Michael. *Thinkpak: A Brainstorming Card Deck*. Berkeley, CA: Ten Speed Press, 1994.
Thinkpak is a deck of cards focusing on the SCAMPER technique. The cards may be used to develop new and innovative ideas through the practice of the SCAMPER technique.

Osborn, Alex. *Applied Imagination*. New York: Scribners, 1953.
This book discusses the idea of brainstorming and the study of creativity. Published in 1953, this book influenced the development of creative thinking techniques and idea generation.

Session 2, Activity A

Design Opportunities are Everywhere

Goal

Learn to identify problems, needs, and opportunities for design improvements.

Outcome

Students generate a list of problems that they see as opportunities for design solutions.

Description

This activity helps students begin identifying problems that they could use for their own design project. Through a short field trip or walking tour, students expand their awareness into many possible opportunities for designed solutions. This outing can be as simple as a walk within the facility where you meet or a walk across the street to a park. A field trip to any convenient public place such as a department store or a mall will work well.

This activity should involve mentors and other experts as resources for students to interview about problems or needs. Students collect their observations and information and begin creating a list of possible opportunities for designing new solutions. Students will revisit and refine this list of problems and begin to work on solutions in Sessions 7 and 8.

Supplies

Clipboards (optional, but handy for taking notes during walking tour)

Preparation

1. Identify the location and make any arrangements for a walking tour of public places. As an alternative: make arrangements for a panel of guest speakers (mentors) to bring problems or needs from their lives.

2. Make arrangements for mentors to join you during or after the walking tour.

3. Review the *Field Trips* section in *Implementation Strategies*

Procedures

Asking Questions

1. Introduce the field trip task using the handout.

2. Lead a warm-up discussion about students' experiences with problems or product needs:

2A: Design Opportunities are Everywhere (continued)

- What problems are you aware of?
- Think about something in the physical world that frustrated you recently. What do you find frustrating?
- Have you ever broken your arm or been in a wheelchair? If so, what was most difficult about this experience?
- Is anyone left-handed? What do you find most challenging as a left-handed person?
- What things, services, or processes that you use regularly could be improved?

3. Point out that these same questions could be asked of anyone—friends, parents, mentors.

4. Ask students to think of other questions to ask.

Walking Tour

1. Orient students to the field trip, the location, logistics, and responsible behavior.

2. During the field trip be sure to stop, observe, and identify problems. This should be reinforced with the entire group. Students should jot down notes as they see problems that interest them.

3. After the field trip, students complete a "brainwriting" exercise to generate problems that interest them. Have students share a couple of their ideas with the rest of the group. Encourage students to share any ideas that were triggered as they listened to each other. For example, "That's a great idea. Have you thought about…?" The sharing of ideas may trigger other ideas.

4. Encourage students to take the list home and talk to family and friends to add to their list of design opportunities. This list will be added to throughout Design and Discovery.

5. In the future, have students practice looking at the world differently by taking time before an activity to ask them specifically about a designed object. It could be something as simple as a chair, pencil sharpener, or notebook. Ask them what needs are being met by the design. Have them conjecture why it was designed the way it was. This brief practice of looking at designed objects may help students find other design opportunities to add to their list.

Wrap Up

End with a brief discussion about how design is all around us. Remind students to keep looking at the world as a designed environment. Have them think about what they use and interact with every day as being intentionally designed.

2A: Design Opportunities are Everywhere (continued)

Follow With
Activity 2B: *Mapping Out a Problem* introduces students to a problem identification technique called Activity Mapping.

Design Opportunities Are Everywhere

Handout: Session 2, Activity A

Problem identification: What makes a good problem to solve?
Many important engineering and design ideas start with a problem or need. You have the capacity to solve important problems and make amazing things happen. Good ideas are inside you. Good problems often start with things you know about or have some personal connection to. Perhaps it's something that bothers you and you think about how it could be different. Maybe you have a relative or friend who struggles with something. Sometimes a problem to solve just comes from an idea of yours that sounds like a fun or easier way to do something.

In this activity, you will practice identifying design opportunities. Some of these opportunities may be problems, while others may be needs or simple improvements.

Who knows about problems? What kinds of problems are there?

- Health problems: Doctors and nurses would know, researchers too. Safety problems: Emergency room staff would know, firemen and police would know.

- Problems of a specific group: The elderly, the very young, people in wheelchairs, left-handed people, short people, deaf people. Try to understand through experience what it would be like to be in their shoes. Research the associations or organizations of these groups.

- Inconvenient problems: What bugs you? Always losing your keys?

Make a list, in your design notebook, of the people or organizations you could call for more information about problems or things that don't work well enough.

Where can you find problems to solve?
The answer is: everywhere. With attention and focus on designed things you see and use wherever you go, you will see all kinds of problems just waiting for your ideas and creativity. You will be taking a trip today to observe a public place (a mall, a park, or a store). Look for problems to solve. Watch how people use things in that place. Look for problems to solve. Study a few objects and items in that place. Look for problems to solve. Take notes in your design notebook.

What problems would you like to solve?
They can be big problems or small problems. You decide. Creativity takes practice and patience. And it takes a few good strategies. One strategy is called "brainwriting." Brainwriting is different from brainstorming because you don't talk. You write your ideas on paper, quietly.

Write down "problems" or "design opportunities" you are aware of (these may be from the field trip). Include things that exist that could use improvement. Write this list in your design notebook.

2A Handout: Design Opportunities are Everywhere (continued)

Save this list. Revisit it as you work through the other *Design and Discovery* sessions. Add new design opportunities as you think of them.

Session 2, Activity B

Mapping Out a Problem

Goal
Introduce and practice Activity Mapping, a creative technique for identifying design opportunities.

Outcome
Learn and practice the Activity Mapping technique.

Description
This activity introduces a brainstorming technique, Activity Mapping, where students analyze an activity, think about the steps in this activity, and identify problems and design opportunities.

Supplies
None needed

Procedures
ZIBA Design Activity Mapping

1. Activity Mapping is used as a way to identify processes, the products used in the processes, and problems that arise in the processes. Use the Activity Mapping example below to model strategies for identifying design opportunities. Examine the processes and products involved with packing for a trip and consider if opportunities for improvement exist. This technique is used by ZIBA Design, www.ziba.com*, an international design firm that has designed products for many global companies, including FedEx, Microsoft, Intel, Fujitsu, Black & Decker, Sony, Pioneer North America, Dial, and Clorox. Students practice using Activity Mapping as a group by exploring the processes used in brushing teeth.

2. Explain that Activity Mapping has four primary user goals that summarize what people are trying to accomplish when engaging in an activity.

Activity Mapping

1) Pre-activity: Describes what is done before the activity

↓

2) Activity: Explains what is involved in the activity

↓

3) Post-activity: Includes what is involved after the activity

↓

4) Assessment: Involves how one knows if the activity has been successful

2B: Mapping Out a Problem (continued)

3. Using chart paper, ask students what is involved for each phase of "packing for a trip." In the example below, "prepare" is the pre-activity, "packing" is the activity, and "unpacking" is the post-activity. The Activity Mapping should look something like this:

		Four primary user goals summarize what people are trying to accomplish when engaging in packing for a trip.
Prepare ↓	Check weather Make a list of items Wash clothes Locate needed items Buy any needed items	**Prepare** Preparation involves gathering all the information and items needed to pack your luggage completely.
Packing ↓	Fold and lay out clothes Put items in luggage Check list Secure luggage	**Packing** Packing means making sure all items will fit inside your luggage or bags securely, ensuring there is a place for everything.
Unpacking ↓	Put clothes in drawers or hang up Put toiletries in bathroom Place shoes in closet Store luggage	**Unpacking** Unpacking has two main elements: removing and storing items, and storing luggage. All clothes, toiletries, shoes, and miscellaneous items should be stored in appropriate locations—closet, dresser, and bathroom. Luggage storage involves putting any suitcases or bags out of the way.
Assessment	Packed for the right weather Had enough clothes Did not need to buy any additional items	**Assessment** Assessment allows users to determine whether they've packed correctly for the weather and the circumstances. Methods include taking an inventory of items not used and any items that were forgotten.

4. Ask students what products are involved in each process. Ask them to consider if there are any problems with any of these products, any suggestions they have for improving a product or inventing a new product. What could make life easier for people when they pack for a trip? Explain that this is one way to identify problems and begin to consider solutions.

5. Students can apply this tool to identifying other problems and ultimately coming up with solutions.

Error Analysis

Error Analysis (used by the IDEO* design team) is another technique for identifying problems or design opportunities. With this method, students list all the things that

2B: Mapping Out a Problem (continued)

can go wrong when using a product. For example, some of the possible things that could go wrong when using a backpack include: a stuck zipper, easily torn material, or poorly adjusting shoulder straps. Any of these features could be identified as a design opportunity and researched further to come up with a solution to the problem.

Wrap Up

Remind students of the 10-step design process introduced in *Activity 1B.* Discuss how the Activity Mapping technique addresses the first step in the process—identify a design opportunity. By using the Activity Mapping technique, problems can be identified by analyzing something they have experienced personally. One of these identified design opportunities could be one they pursue for their independent project.

Follow With

Activity 2C: *Design Improvements* introduces students to SCAMPER, a brainstorming technique that helps them generate ideas for improving existing designs.

Mapping Out A Problem

Handout: Session 2, Activity B

Problem Identification and Activity Mapping
As a group, you'll do a practice Activity Mapping on packing for a trip. This is a useful tool for identifying problems. Activity Mapping has four primary user goals that summarize what people are trying to accomplish when engaging in an activity.

Activity Mapping

1) Pre-activity: Describes what is done before the activity

↓

2) Activity: Explains what is involved in the activity

↓

3) Post-activity: Includes what is involved after the activity

↓

4) Assessment: Involves how one knows if the activity has been successful

Answer the following questions in your design notebook.

What products are involved in each process?
Are there any problems with any of these products?
What suggestions do you have for improving a product, or inventing a new product?
What could make life easier for people when they pack for a trip?

This process is one way to identify problems and begin to consider solutions.

Now, do your own Activity Mapping, in your design notebook, for a common activity you experience—for example, making a sandwich, washing the dog, or cleaning your room. This process may help you identify a problem or design opportunity. If you identify a problem, add it to the list you began in *2A Handout: Design Opportunities Are Everywhere.*

Session 2, Activity C

Design Improvements

Goal
Introduce and practice SCAMPER, a creative technique for improving existing designs.

Outcome
Learn and practice the SCAMPER process.

Description
Students learn about and use SCAMPER, a systematic technique for generating ideas about improving existing designs. This technique can be used to develop possible solutions to design problems, such as ones found during the walking field trip or Activity Mapping process. To get students started, they study a variety of water bottles and use SCAMPER to generate ideas about water bottle improvements.

Substitute
Combine
Adapt
Minimize/**M**agnify
Put to other uses
Eliminate/**E**laborate
Reverse/**R**earrange

Supplies

- Water bottles in multiple styles (ask students to bring in examples)
- Clipboards (optional, but handy for taking notes during walking tour)
- Chart paper for posters and markers

Preparation

1. Read through the SCAMPER technique for expanding thinking about improvements.
2. Practice using SCAMPER to come up with an improvement yourself!

   Note: The SCAMPER technique may be used on a variety of items. You may substitute something else for water bottles in this activity or use additional items as extra practice.

2C: Design Improvements (continued)

Other possible items include: headphones, shoes, wrenches, hand drills, watches, telephones, umbrellas, and coats.

Procedures

1. Distribute water bottles among groups of students.
2. Present each step of the SCAMPER process using water bottles as an example. Use the student handout to go through each step.
3. Assign a different letter of SCAMPER to seven groups and have them create and display posters of the SCAMPER technique using the letters and keywords from the handout.
4. Provide time for groups to study different types of water bottles. Have participants come up with additional water bottle improvements using their assigned SCAMPER step and add it to their poster—include sketches of their ideas.
5. Share posters and ideas with the whole class.
6. Together, compare two different water bottle designs and determine which step of SCAMPER was applied.

Wrap Up
Discuss any other strategies for generating new ideas and approaches to existing solutions.

Follow With
Activity 2D: SCAMPER and Backpack applies the SCAMPER technique to another item, a backpack.

Design Improvements

Handout: Session 2, Activity C

Ready to SCAMPER? SCAMPER is a technique that gets you to think about improving an existing design. It is an acronym that helps you remember seven different ways to think up new improvements. It is useful for being creative in a systematic way. It generates ideas you might not have on your own. Try it!

S Substitute one thing for another.

C Combine with other materials, things, or functions.

A Adapt: Can it be used for something else?

M Minimize/Magnify: Make it larger or smaller.

P Put to other uses: Can you put it to another use? In this case, use it for another vegetable? If you make it larger, would it work for some other food?

E Eliminate/Elaborate: Remove some part or material, or make one section more detailed or refined.

R Reverse/Rearrange: Flip-flop some section of the item, move parts around.

Here are some improvements that can and have been made to water bottles. Can you think of any more improvements by using the SCAMPER technique?

2C: Design Improvements (continued)

SCAMPER	Questions to Ask	Water bottle Improvement	Benefit
Substitute	What could be used instead? What kind of alternate material can I use?	Different bottle material	Plastic bottle is unbreakable, unlike glass
Combine	What could be added? How can I combine purposes?	Add straw into top	Straw allows access to bottom of water bottle without lifting and tilting bottle
Adapt	How can it be adjusted to fit another purpose? What else is like this?	Use squirt top for watering plants	Directed stream gets water to the plant roots
Magnify	What happens if I exaggerate a component? How can it be made larger or stronger?	Larger bottle	More water for better hydration
Minimize	How can it be made smaller or shorter?	Smaller bottom of bottle	Can store in car's cup holders easily
Put to other uses	Who else might be able to use it? What else can it be used for other than its original purpose?	Turn upside down	Hand washing station
Eliminate	What can be removed or taken away from it?	Eliminate the handle	More volume for water storage
Elaborate	What can be expanded or developed more?	Larger base	Lower center of gravity helps keep water bottle from tipping
Rearrange	Can I interchange any components? How can the layout or pattern be changed?	Move handle from side to top	Better ergonomics for hauling large amounts of water
Reverse	What can be turned around or placed in an opposite direction?	Water spout at bottom	Easier to dispense water into cups

Session 2, Activity D

SCAMPER and Backpack

Goal
Apply the SCAMPER technique to the components of a backpack.

Outcome
Improve a backpack design using SCAMPER.

Description
Students look at the different components of a backpack and apply the SCAMPER technique to each component. They are introduced to sketching by enhancing an existing drawing with their improvements.

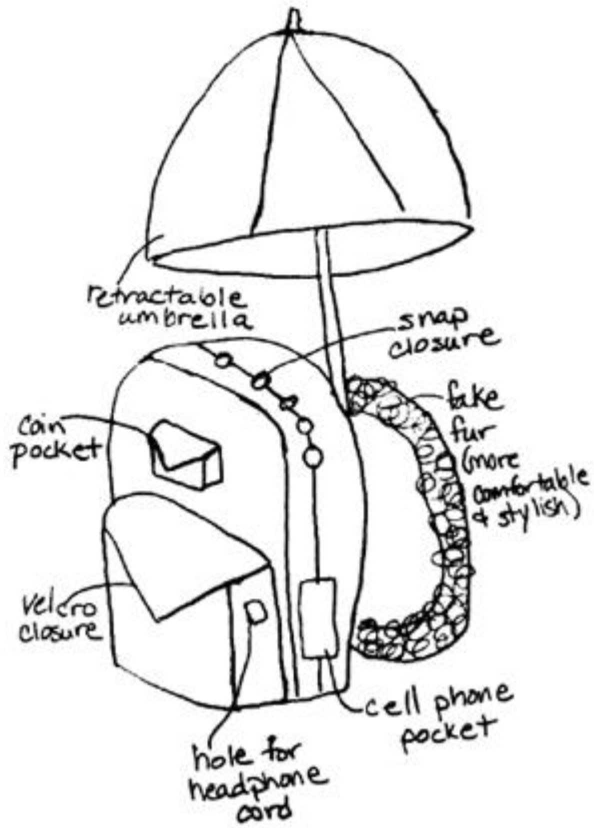
Supplies

- For each pair of students: 1 backpack (Have students bring in their own and then make comparisons with others.)
- Additional backpacks with other designs

Procedures

1. Distribute backpacks to students.
2. Ask the students to compare the backpack to the drawing on the handout.
3. Call attention to different components of the backpack. Notice how a product can be broken down into parts:
    - Large pocket
    - Small outside pocket
    - Shoulder straps
    - Zippers
4. Explain the task: Use SCAMPER to improve one part or all.
5. Walk through the first two letters of SCAMPER as a group, and then continue the process in teams.
6. As they work through the process, encourage students to sketch and make notes about possible improvements in their design notebooks.
7. Have them draw improvements in their notebooks or on the handout that shows a drawing of a backpack.

2D: SCAMPER and Backpack (continued)



8. Share improvement ideas for each SCAMPER letter and discuss:

- What component was improved or used differently?
- What idea comes to mind first?
- How many ways do you think this product could be changed?

Wrap Up
Introduce the Home Improvement activity, *Improvement of Everyday Things.*

Follow With
Session 3, *Materials for Design*, is the first of three sessions that provides engineering fundamentals needed for project development.

SCAMPER and Backpack

Handout: Session 2, Activity D

The Backpack, Improve It!

Apply SCAMPER to each of the backpack parts. Sketch and make notes about your improvement ideas. Make your drawings in your design notebook.

Improvement of Everyday Things

Home Improvement: Session 2

Goal
Know the difference between a superficial improvement and a functional improvement.

Description
Students study household objects with similar functions. They distinguish functional improvements from superficial improvements. A functional improvement is something that improves the performance of the product. A superficial improvement, such as a color change, does not affect the performance.

Directions Before Going Home

1. Review the list of objects on the Home Improvement handout.
2. Discuss and add to the list as a group. Agree on three to five items that students will bring in.
   - What else could be included here? (Remember, we are trying to find familiar, everyday items that can be found anywhere.)
   - Remind students that the task is to identify objects with functional improvements.

Next Day

1. Share the three things that best represent functional improvement.
2. Follow-up discussion could address the following questions:
   - What is more common, functional or superficial improvement?
   - What examples can you think of that we couldn't bring in, but could talk about?
     Example: different cars, stoves, lamps, chairs, etc.
   - Did anyone find a superficial improvement that reduced the object's function? (Form that messes up function.)

Improvement of Everyday Things

Handout: Session 2, Home Improvement

Where Do You See Improvement?

The following list represents common items found in most household kitchens, garages, or junk drawers. These items have been specifically designed to serve one need. In some cases, the variety of these items represents improvements in functionality; in others, the variety merely represents aesthetic appeal. Functionality is an engineer's job, and it is important to recognize the difference between "appeal" factor and meaningful improvement in functionality.

Bring three things from this list of items that best represent functional improvement:

- Cheese grater
- Cherry pitter
- Nail cutter
- Cup lids for hot liquids
- Candle holder
- Stapler
- Napkin ring
- Can opener
- Tooth floss container
- Eraser
- Key ring
- Lemon peeler
- Can opener
- Potato peeler
- Umbrella
- Toothpick dispenser

Be prepared to explain the functional improvement.