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 introduces the design process that guides the work of engineers and designers. In these sessions, you will engage in three hands-on activities that build understanding of the role of engineering and design in producing effective solutions to real-world problems.

In *1A: Build a Better Paper Clip* carefully examine the form and function of standard paper clips. Then with a set of wires and tools, 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 your own project, 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*, examine a designed solution to the problem of conventional screw-top toothpaste caps as you walk through the steps of the design process.

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.

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."

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."

1A Reading: The Perfect Paper Clip (continued)

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, 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.

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.

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

1B Handout: The Design Process (continued)

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.

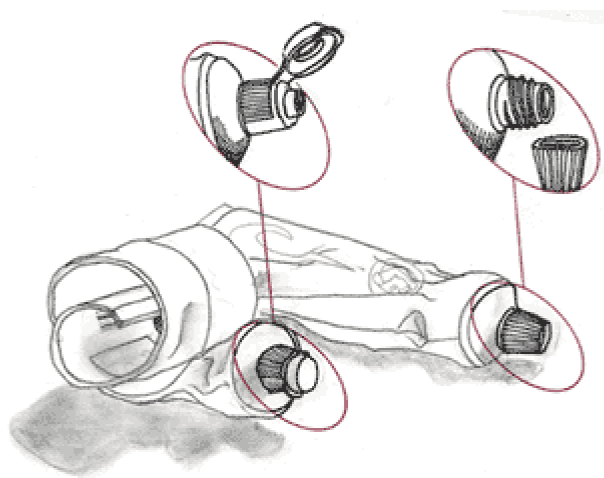
The work of designers and engineers overlaps as well. Both seek to develop solutions to specific and immediate problems and needs. While design is involved in the entire process, engineering is the more specific process of making the idea meet specifications and function. One is useless without the other.

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.

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?

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.

1C Handout: Toothpaste Cap Innovations (continued)

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?