HANDS-ON ACTIVITY

Design Steps 5 and 6: Create and Test a Prototype

Quick Look

Grade Level: 9 (9-12)

Time Required: 2 hours

The time required to complete this design process step is adjustable to as little or as long as the teacher desires. We suggest a minimum 120 minutes and a maximum dependant on the design difficulty and number of iterations.

Expendable Cost/Group: US $5.00

Cost is variable, depending on the materials required by teams to build their prototypes. Some example materials are suggested.

Group Size: 4

Activity Dependency:

Design Step 4: Select a Promising Solution Using Engineering Analysis

Subject Areas: Science and Technology

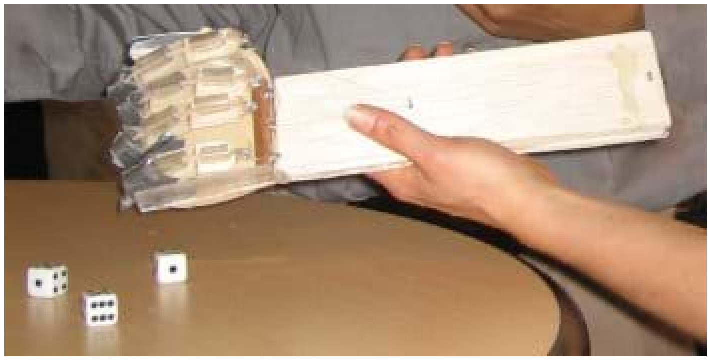
NGSS Performance Expectations:

HS-ETS1-2

Summary

Students learn about the importance of creating and testing prototypes during the engineering design process. They start by building prototypes, which is a special type of model used to test new design ideas. Students gain experience using a variety of simple building materials, such as foam core board, balsa wood, cardstock and hot glue. They present their prototypes to the class for user testing and in the following activity create prototype iterations based on feedback. (Note: Conduct this activity in the context of a design project that students are working on; this activity reflects Step 5 and Step 6 in a series of seven steps that guide students through the engineering design loop.)

This engineering curriculum aligns to Next Generation Science Standards (NGSS).



The purpose of creating prototypes is to test out new design ideas. In this case, can this student-made prosthetic roll dice?

Engineering Connection

Prototypes are routinely used as part of the product design process to give engineers and designers the ability to explore design alternatives, test theories and confirm performance prior to starting production of a new product. Almost every engineering discipline uses prototypes in some way, including aerospace, computer, mechanical, civil, environmental and electrical engineering.

Learning Objectives

After this activity, students should be able to:

- Explore design alternatives through the creation and testing of prototypes.
- Explain the difference between prototypes and models.
- Compare and contrast the use of different construction materials in the development of prototypes.

Educational Standards

- NGSS: Next Generation Science Standards - Science
- International Technology and Engineering Educators Association - Technology

Materials List

Prototyping materials and tools for the entire class to share may vary, depending on the project. Some suggested items include:

- foam core board
- balsa wood
- cardstock
- wooden or metal dowels
- craft utility knives

- rulers (if using utility knives, metal-edged rulers work best)
- cutting surface, such as a plastic board, kitchen cutting board or back of a newsprint pad
- hot glue and hot glue gun
- scrap materials (have students scavenge or ask for donations)
- Foam Core Tips Handout, one per team (if using foam core)

Worksheets and Attachments

Foam Core Tips Handout (docx)
Foam Core Tips Handout (pdf)

Visit [www.teachengineering.org/activities/view/cub_creative_activity5] to print or download.

Introduction/Motivation

How does a typical engineering design loop begin? (Take suggestions from the students.) That's right. The engineering design process begins by defining the engineering challenge, performing background research, brainstorming potential solutions, and evaluating several alternatives. And what is next? (Listen to suggestions from the students.) Next, an engineering team synthesizes this information to begin creating the product. Many times, something that works on paper proves to be very difficult to build. To help engineering teams assess the "buildability" of their project concept, they often create prototypes.

A prototype is a working model of a product that is used for testing before it is manufactured. Prototypes help designers learn about the manufacturing process of a product, how people will use the product, and how the product could fail or break. A prototype is not the same thing as a model. A model is used to demonstrate or explain how a product will look or function. A prototype is used to test different working aspects of a product before the design is finalized.

For example, a team of engineers designing a new cell phone might produce several cardboard and paper models to illustrate how the final product would look and feel. They may survey the general public to gain feedback about how the cell phone could look. The team might build a sturdier plastic prototype to test how easily the cell phone could break when dropped. If the prototype does not meet the team's design requirements, then they may complete an "iteration." Iteration is when engineers try again and re-design, re-build and re-test. Engineers often iterate many times before determining the final solution to a problem. Once a successful prototype has been developed, the engineering team can use it as a mock-up for full-scale manufacturing.

Your team will follow a similar process. By building a prototype, you should be able to determine if your chosen design solution is feasible and which aspects of your design needs special materials or further refinement. You will also ask other people to test your prototype to help you identify any problems a user might encounter. You will have time to complete iterations, or modifications, to your prototype in the next activity.

(Note: After conclusion of this activity, proceed to the next activity in the series, Design Step 7: Improve and Redesign/Manufacture a Product.)

Procedure

Background

New designs often have unexpected problems, and it is often difficult to determine whether a new design or product will perform as intended. Prior to large-scale manufacturing of a product, engineers often build prototypes. A prototype is a model of a product used to explore design alternatives, test theories, confirm performance and ensure the product is safe and user-friendly. Engineers use prototypes to figure out specific unknowns still present in the design.

For example, a student team designing a prosthetic hand that rolls dice could build a prototype using simple materials such as wood, rubber bands and string to test that the prosthetic hand performs the desired function of rolling and picking up dice. In most cases, an iterative series of prototypes is designed, constructed and tested as the final design emerges, is refined and becomes ready for production.

A philosophy often repeated and credited to Tom Kelley of IDEO, a successful worldwide engineering design and innovation consulting firm, is, "**Fail often to succeed sooner**." It might be helpful for students in the midst of prototyping iterations to see the value of this approach as expressed by professional designers. We learn more from failures than successes.

Rapid prototype machines can literally bring computer-aided engineering designs to life! Some examples of objects, tools and parts manufactured using a rapid prototype machine and CAD software.

Often, the term prototype is interchanged with the term "model," which can cause confusion. While several types of prototypes exist, for the purpose of this activity, we will make the following distinction: Whereas a model is used to demonstrate or explain how a product will look or function, a prototype is used to work out the kinks in a design or to try new ideas. Keep in mind that prototypes are unrefined versions of a future product. Most companies do not show prototypes to the general public to ensure that the public's opinion is based on the final product.

In some cases, engineers "rapid prototype" a part. Rapid prototyping is the automatic construction of physical objects using additive manufacturing technology and computer-aided design (CAD) software.

Basically, a virtual design from CAD software is "read" by a rapid prototyping machine that divides the design into thin horizontal slices. The machine then lays down successive horizontal layers of liquid or powder (such as ABS plastic material) and adhesive in the shape of the virtual design. The primary advantage of rapid prototyping is the ability to create almost any shape or feature, including assemblies with moving parts.

Before the Activity (Teacher Prep)

- Collect various materials and tools that students can use to construct prototypes.
- If using foam core board as a primary building material, review the tips outlined in the attached Foam Core Tips Handout, and make copies, one per team.
- Student teams should continue with the same 3-5 members each, as determined in the first activity of this unit, Design Step 1: Identify the Need.

With the Students

1. Explain to students the purpose of building prototypes. Mention that several types of prototypes exist, but we will focus on creating prototypes for the purpose of testing different working aspects of a product.

2. (optional) Ask students the Investigating Questions about creating and testing prototypes.

3. Show students the available building materials (or allow them to bring in their own if this was established in advance).

4. Review the Foam Core Tips Handout (if applies), or any other information on material use or tool safety.

5. Lead the pre-activity assessment (as described in the Assessment section) to give students a chance to sketch their ideas before constructing prototypes. Students are asked to complete a more detailed sketch of their design than in previous activities. Have them label materials and specify dimensions.

6. Give students "free time" to experiment with the materials and begin construction. Answer questions as they arise.

Students perform user testing to see if their prototypes function as intended.

7. Early in the construction process, briefly stop the class to lead a mini design review as described in the Assessment section (activity embedded assessment). Have each team show the class their initial prototype, explain its purpose, and describe any challenges they have encountered during the build process. Follow with a class discussion to collaborate in figuring out possible solutions.

8. Once teams have finished the build process, have them swap prototypes and engage in the user testing as described in the Assessment section (post-activity assessment).

9. Ask the design teams to reflect on the feedback received by summarizing the feedback and what changes they intend to make in the next iteration of their designs in the Design Step 7: Improve and Redesign/Manufacture a Product activity.

Vocabulary/Definitions

balsa wood: One of the lightest varieties of wood available with remarkable strength. Because it can be carved easily and bent into a number of shapes, balsa wood is often used to build models and prototypes.

foam core board: A lightweight and rigid material commonly used to produce architectural models, prototype small objects and produce patterns for casting. It consists of three layers—an inner foam layer (Styrofoam, polystyrene, etc.) with outer facings of slick, smooth paper in various colors.

iteration: Repeating a series of steps to get closer to a desired outcome (that is, re-design, re-test, re-build to get nearer to an optimal engineering solution to a specific problem). Also: A version of the final product or solution. For example: Our third iteration passed the strength test.

manufacturing: The use of machines, tools and labor to make things for use or sale. On a large scale, the transformation of raw materials into finished goods.

model: A plan, representation (often in miniature), or description designed to show the main object or workings of a product concept.

prototype: A model of a product that is used for testing before it is manufactured. Prototypes help designers learn about the manufacturing process of a product, how people might use it, and its durability.

rapid prototyping: The automatic construction of physical parts and prototypes using additive manufacturing technology directed by computer-aided design modeling software. In additive manufacturing, a material is laid down in layers to create an object.

Assessment

Pre-Activity Assessment

Sketch It! Have students use their initial sketches or outlines created in the Design Step 3 activity to generate more detailed sketches of their envisioned prototypes, labeling them with dimensions and materials. Now that they have seen the available materials, they should have a sense for the degree of the complexity achievable in this first prototype. Review the sketches with the students to check that they are designing prototypes, not models. If time allows, have them draw the prototype sketches to scale.

Activity-Embedded Assessment

Design Review: Briefly stop the prototype construction process to bring the class together as a group. Ask each team to show its initial prototype, explain its purpose (what the team is attempting to test) and describe any challenges encountered during the build process. Write these challenges on the board and lead a class brainstorming session so students may offer solutions to other teams' challenges. (Note: Alternative options for performing design reviews include: asking the team to present to a small "client focus group" that includes the teacher and a few others, having students rotate around the room and review for one other team, or asking another class to come in to listen and provide feedback to initial design descriptions.)

Post-Activity Assessment

User Testing: To simulate user testing, have each team swap prototypes with another team. Ask teams to give each other feedback:

- Is the prototype functional? What works? What does not work?
- Is the prototype used to explore several design alternatives?
- What improvements could be made?

Reflection: After user testing, ask the design teams to reflect on the feedback received. Have them write short documents for the teacher summarizing the feedback and what changes they intend to make in the next iteration of their designs.

Investigating Questions

Use the following discussion questions to help students gain understanding of an important aspect of engineering problem solving: **creating and testing prototypes**.

- **What is an advantage of building a prototype prior to full-scale manufacturing?** (Possible answer: Exploring design alternatives with a prototype saves resources [time, money and materials] required to manufacture a final product.)
- **Why might most engineering companies refrain from releasing a prototype to the general public?** (Possible answer: Because they want the public's opinions to be based on the final product, not on early versions and rudimentary prototypes.)

Safety Issues

- This is the first point in the design cycle in which safety issues are important. Remind students to be careful when using hot glue, utility knives, and construction materials and tools.

Troubleshooting Tips

If students become frustrated with the way their initial prototypes look, remind them that prototypes are used to test out new ideas and are not meant to look perfect!

Activity Extensions

Limitations to Prototypes: Have student teams brainstorm the limitations of prototypes and generat e lists of ideas. Engage the class in a discussion of these limitations and expand the discussion to t alk about what can be done to accurately determine these factors for final production. For example, limitations might include evaluating costs, time to build, material function and actual environmental impact.

References

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