Lesson 2 – Intro to Engineering Design Process

Lesson Focus
This lesson introduces students to the engineering design process (EDP)—the process engineers use to solve design challenges. Students work in teams to solve the challenge by designing both a product and a process to complete the engineering challenge.

Lesson Synopsis
Students learn about the engineering design process by doing an engineering design challenge called Tower Challenge where students need to work collaborative to design both a process and a product to build the tallest free-standing structure out of given materials and time given.

Objectives
During this lesson, students will:

- Apply the engineering design process to solve a design challenge.
- Build, test, and redesign a prototype.
- Employ teamwork and communication to successfully solve the challenge.

Anticipated Learner Outcomes
As a result of this activity, students will have:

- Applied the engineering design process to solve a design challenge
- Build, test, and redesign a prototype.
- Employ teamwork and communication to successfully solve the challenge.

Lesson Activities
Teams of students use the engineering design process to solve the Toxic Popcorn Challenge. The lesson closes with students sharing all they learned and discussing the answers to the many questions they had at the beginning of the lesson.

Resources / Materials

- Teacher Resource Documents (attached)
- Student Worksheets (attached)
- Student Resource Sheets (attached)

Alignment to Curriculum Frameworks
See attached curriculum alignment sheet.

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For Teachers: Teacher Resources

Lesson Goal:
The goal of this lesson is that teams of students use the engineering design process to solve the Tower Challenge. Students must work collaborative to design both a process and a product to build the tallest free-standing structure out of given materials and time given.

Lesson Objectives:
During this lesson, students will:

- Applied the engineering design process to solve a design challenge
- Build, test, and redesign a prototype.
- Employ teamwork and communication to successfully solve the challenge.

Materials:
One full set of material for each team

- 20 sticks of spaghetti
- 1 piece plain computer paper
- 2 paper clips
- 2 feet of string
- 5 toothpicks
- 1 yard of tape
- 1 large marshmallow
- EDP worksheet (per student/group)

Grade Level Modifications

- For ages 9 and younger you might consider limiting the materials, (reducing the materials by taking one or two things away completely).
- For ages 14 and older add additional, random materials to make the group think creatively together. Reduce a specific material.

Time Needed: One - Two, 60 minute sessions

- The lesson can be done in as little as 1 class period for older students. However, the class discussion and follow-up lesson may spill over to the next day.

Lesson 2 – Intro to Engineering Design Process

For Teachers (continued):

Challenge:
Build the tallest free-standing structure in 20 minutes, using no more than the materials given. The marshmallow MUST be on top and cannot be deformed to hold in place. The structure has to stand firmly on its own; it cannot be propped up, held, or suspended from the ceiling.

Teacher Prep:
Before the lesson, create "Tower Challenge" kits. Kits should contain all materials necessary for the challenge. Placing the kits in paper lunch bags will add and element of "surprise" to the challenge, as students do not know what they have to build the tower with until they get their bag.

Also, you will need the following to run the challenge successfully:

- **Measuring tape:** I suggest a measuring tape vs. a meter/yard stick. It will be easier to quickly measure the height of the delicate structures!
- **Stopwatch:** Use a projector if you can so students can see the time as they work. There are several online stopwatch sites that are great. I use: http://www.online-stopwatch.com/full-screen-stopwatch/
- **Music:** Students work well with music in the background. Music also serves as a volume control for students; setting the volume of the music, students understand their volume cannot go above a certain level to where the music cannot be heard. Additionally, for the challenge, a playlist can be created, allowing the music to get more intense as the time ticks down to zero!

Procedure:

1. **Divide students into teams of 3-4 students.**
2. **Go through the RULES.** You will want to go through the rules several times. Having students "repeat" back instructions and/or rules is a strategy to go over the rules again without you having to repeat them yourselves again. [After you go over a rule, then call on a random student to repeat back what the rule was in their own words] Also, posting the rules on the lab tables or on the screen for reference will be helpful and reinforce them for students throughout the challenge.

The RULES

- **Build the tallest free-standing structure**. The winning team is the one that has the tallest structure measured from the tabletop surface to the top of the marshmallow. That means the structure cannot be suspended from a higher structure, like a chair, ceiling, or chandelier.
- **The entire marshmallow must be on top.** The entire marshmallow needs to be on the top of the structure. Cutting or eating part of the marshmallow disqualifies the team.
- **Use as much or as little of the kit.** Team can use as many or as few of the 20 spaghetti sticks, as much or as little of the string or tape. *The team cannot use the paper bag as part of its structure.*
- **Break up the spaghetti, string or tape.** Teams are free to break the spaghetti and to cut up the tape and string to create new structures.
- **The Challenge lasts 20 minutes.** Teams cannot hold on to the structure when the time runs out. Those touching or supporting the structure at the end of the exercise will be disqualified. Teams cannot touch other team's structures or tables, disturbing their structure or the team will be disqualified.

3. **Pass out the Challenge Kits & Start the Challenge.**
    - Start the countdown clock and music with the start of the challenge.
    - **Walk around the Room**: Encourage teams, but do not help! Watch the teams create their structures and develop their process for using the different materials. Enjoy the innovation of each team and the patterns that emerge.
    - **Remind Teams of the Time:** Count down the time. Typically, the leader calls the time at12 minutes, 9 minutes (half-way through), 7 minutes, 5 minutes, 3 minutes, 2 minutes, 1 minute, 30 seconds and a ten-second countdown.
    - **Call Out How Teams Are Doing**: Let the entire class know how teams are progressing. Call out each time a team builds a standing structure. Build a friendly rivalry. Encourage people to look around. Don't be afraid to raise the energy and the stakes.
    - **Remind Teams that holding their Structures will disqualify them**: Several teams will have a powerful desire to hold onto their structure at the end — usually because the marshmallow, just installed at the apex, is causing it to buckle. The winning structure must be stable.
4. **Finish the Challenge**

    When the time runs out, ask everyone to sit down or move/stand at the edge of room. (Half or more of your teams should have free-standing structures).
    - **Measure the structures.** Measure from the shortest standing structure to the tallest and call out the heights. Have someone record the heights.
    - **Identify the winning team.** Ensure they get a standing ovation and a prize (if you've offered one).
    - **Wrap up the Tower Challenge lesson.** Have each team reflect on the following:
        - What building techniques make the tower stronger?
        - Does the placing of the marshmallows affect the strength of the tower?
        - Could you build a stronger tower with more of the same materials? What alternative materials would be better?
        - Does the size of the base alter the strength of the tower?
        - How do you think you worked as a group? Did you assume different roles? Did all groups work in the same way?
5. **Follow up Lesson.** This challenge is an introduction to the engineering design process (EDP). It allows students to have a problem, design prototypes, and present their solutions, while not formally following each step of the EDP. The challenge is structured to allow students to naturally work without too much interference; setting up the students up for a great class discussion of their challenge and the EDP!
    - **Distribute Engineering Design Process sheet to each student**. Copy the process on one side and the student EDP worksheet on the other.
    - **Review the EDP with students**. Using the Tower Challenge, review the EDP. Have students complete the sections they know/understand first. (Identify the Problem, Construct a Prototype).
    - **Complete the EDP worksheet**. Working as a class, review each part of the EDP, using the Tower Challenge as a reference to complete the worksheet. Students may not have known they completed each part of the EDP, but discuss as a class and talk about each step and how it was completed or could have been completed in this challenge.

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For Teachers (continued):
Alignment to Curriculum Frameworks

Next Generation Science Standards Grades 6-8 (Ages 11-14)

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should

- Communicate the process of technological design. Students should review and describe any completed piece of work and identify the stages of problem identification, solution design, implementation, and evaluation.
- Evaluate completed technological designs or products.
- Technological designs have constraints.

Standards for Technological Literacy - All Ages

Design

- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

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Student Resource: What is the Engineering Design Process?
In order to understand the Engineering Design Process you first need to understand technology and engineering.

Technology is all around us. It is any product (an object created by a person) or process (a series of steps that brings about a result) that is designed by people to solve a problem. Most of the things you are in contact with each day are technology. For example: paperclip, cup, glasses, stapler, bottle, and pencil etc. What technology do you use every day?

Engineering is the application of science and mathematics to design or redesign technology to solve problems and meet needs. Where scientists study the natural world, engineers design the human-made world. Engineers design everything from sandwich bags to submarines, robots to roller coasters and air bags to artificial hearts!

Can you name more technology that engineers have designed? Check out the Greatest Engineering Achievements of the 20th Century: (www.greatachievements.org) and see how engineers have made the world a better place. Engineering is a profession with a vast number of disciplines. For example: mechanical engineering, electrical engineering, civil engineering, biomedical engineering, systems engineering, ocean engineering, materials engineering, etc. Can you name more disciplines? To learn more about engineering and the different disciplines, visit www.tryengineering.org.

Engineering Design Process
All engineers have one thing in common and that is the process they use to solve problems -- it is called the engineering design process. The engineering design process is to engineering what the scientific method is to science.

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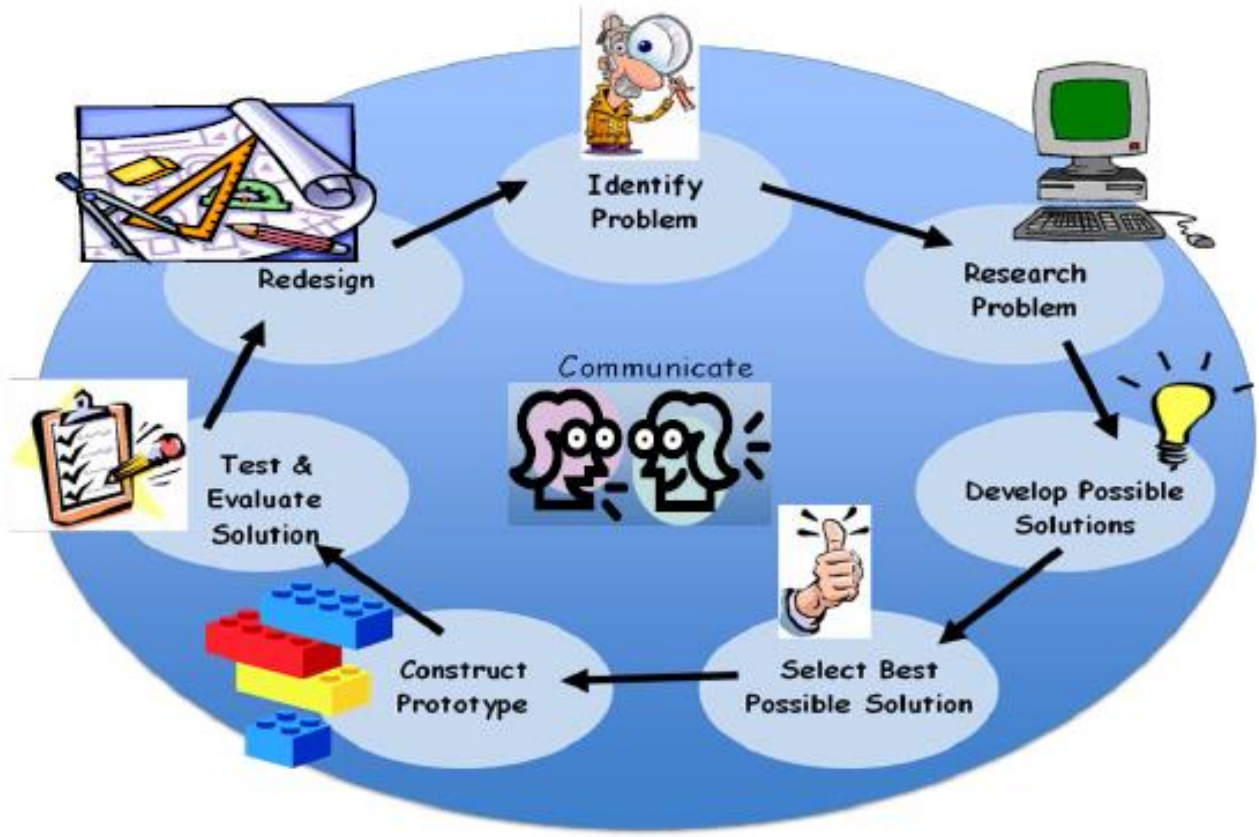
Student Resource:
The Engineering Design Process



Lesson created by Anne Lopez / Eastside Middle School STEM Teacher

Student Resource:
The Engineering Design Process

Engineering Design Process

	**Identify the Problem** • What is the problem you want to solve? • Write a problem statement. Your problem statement must answer these 3 questions: What is the problem or need? Who has the problem or need? Why is it important to solve? • The format for writing a problem statement uses your answers to the questions and follows these *guidelines*: WHO need(s) WHAT because WHY. Ex. _____ need(s) _____ because _____.
	**Research the Problem** • What do you know about the problem? • Find out as much about the problem as you can. • What are the criteria (conditions that the design must satisfy, overall size, weight, etc.) of the problem? • What are the constraints (limitations with material, time, size of the team, etc.) of the problem?
	**Construct Prototype** • Using the material given, build a prototype (a working model) of your design. • Don't forget about the criteria (conditions that the design must satisfy) and constraints (limitations that need to be designed around)
	**Test & Evaluate Solution** • Test and evaluate your design. • Did you satisfy the criteria and constraints? • Record data of your tests. • Analyze data to determine if your design solved the problem.
	**Redesign** • Did your design solve the problem? • Any changes/modifications that need to be made? • If not, brainstorm a new design, build and test it until you have successfully solved the problem.
	**Communicate** • Communication is at the core of the engineering design process • At each step in the process you must communicate with your team members. • You need to also communicate with others outside of your team to get feedback on your design. (Sometimes others see things you missed or just didn't see!) • You need to communicate verbally as well as by describing your design through writing and drawings. • Share your final design and results with the community, your client, other engineers – if you don't share, no one ever knows of the great work!

Student Resource:
The Engineering Design Process

Engineering Design Process

	**Identify the Problem** - Write the problem state of the challenge
	**Research the Problem** • Know: • Criteria: • Constraints:
	**Construct Prototype** – Draw your prototype(s) here
	**Test & Evaluate Solution** - Record test data here
	**Redesign** • Did your design solve the problem? • Changes/modifications: • New Ideas:
	**Communicate** • How did you communicate through the challenge?