Intro to Engineering Design: Hospital Gowns
Teacher version

In this lab you will be introduced to the Engineering Design Method. Similar to the way the Scientific Method guides scientists as they understand the world around us, the Engineering Design Method guides engineers as they solve everyday problems and create new solutions to those problems.

Next Generation Science Standards

- Middle School
    - 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 impact 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.
    - MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
    - MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
- High School
    - HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
    - HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
    - HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Prerequisites:

- Good for most students
- Students should have some familiarity with the Scientific Method for comparison
- More guidance and leading questions may be required for quieter students

Complete List of Materials:

- lots of Post-It Notes
- pencils and paper
- disposable hospital gowns
- example hospital gowns
- tape
- string
- paper clips
- scissors

***TEACHER NOTE**: This lab uses a re-design of the hospital gown to teach the concepts of engineering design. If you do not have access to materials required to prototype improved hospital gowns, you could substitute re-designing another item your students are familiar with. All of the principles set forth in this lab will still apply.*

Key concepts:

- Understanding the five major steps involved in the ***Engineering Design Process***, and how that process differs from the Scientific Method.
- Identifying problems and sorting them as ***system problems*** or ***design problems***
- Understanding the limitations of current designs and why they were created that way
- Distinguishing *'**must have**'* features of a design from *'**nice to have**'* features
- Using a ***Concept Scoring Matrix*** to evaluate and rank various designs prior to prototyping.

Optional Pre-Lab Activity: Working in Teams

***TEACHER NOTE**: Many students in the middle school and high school range have not spent much time working together in teams. As a result, they can have some difficulty compromising and building off of each other's ideas. Because teamwork is an integral part of this lab, we have included an optional activity to expose students to effective teamwork strategies. This exercise is used frequently in the Stanford d.school. None of this text appears in the student version of this lab.*

Scientists and engineers spend most of their time working in teams of people with very different experiences and skills. Each person brings unique ideas to the discussion, and learning to work together with all of these different people and build off of their ideas is a huge part of being a successful engineer. We are going to do a quick exercise to demonstrate how to work effectively as a team.

1. Split students up randomly into groups of 4-5 students
2. Tell students they will be deciding the rules for an all new planet as a group.
3. In the first round, students will go around in a circle and present ideas for the rules on their new planet. They will build off each other's ideas and must start each sentence with, "Yes, but…" Here is an example:

Student 1: On our planet, everyone will eat candy for every meal!
Student 2: Yes, but then their teeth will rot.
Student 3: Yes, but candy is delicious.
Student 4: Yes, but then people won't be well nourished.
Student 5: Yes, but people will be happy.
etc…

4. Stop students after 1-2 minutes of this and ask them what rules they decided on. If groups followed the "Yes, but…" format, they shouldn't have been able to agree on any rules. Explain to students that when you shut down every idea that another person has, a team will never get anywhere and won't be able to create a great new product.

5. Have students repeat the exercise, but this time as they build off each other's ideas, they must start each sentence with, "Yes, and…" Here is an example:

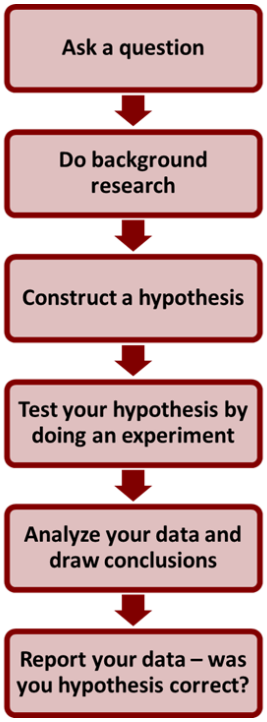
Student 1: On our planet, rocks will be money.
Student 2: Yes, and different size rocks will be worth different amounts.
Student 3: Yes, and people will store their rocks in cave banks.
Student 4: Yes, and the cave banks will guard the rock money will trolls.
Student 5: Yes, and the cave banks will provide lots of jobs.
etc…

6. Stop students after 1-2 minutes of this and ask them what rules they decided on. If groups followed the "Yes, and…" format, they should have developed at least one rule. Explain to students that when you work with other people's ideas and build upon them in a positive way, your teams move forward much more smoothly.

Introductory Mini-lecture:

We are all familiar with the Scientific Method which takes us from a scientific questions to results and conclusions in a linear fashion (draw the Scientific Method as a flow chart). Today we are going to talk about the ***Engineering Design Method*** which is an ***iterative***, or circular, process that guides engineers as they develop solutions to different problems. The Engineering Design Method has five major steps: Ask, Imagine, Plan, Create, & Improve (draw the Engineering Design Method as a flow chart). Today we will walk through all of these steps together and show you what it means for a process to be iterative.

Scientific Method



Engineering Design Method

Part I: Ask

The first step in the Engineering Design Method involves identifying a problem to solve. Sometimes engineers are given a problem to solve and other times they find a problem on their own. Today we are going to do a little bit of both.

TEACHER NOTE: Each student can do this part of the lab alone. If you have a large class, this can also be done in small groups of 3-4 students. At this point in the lab the hospital can be replaced with any other location (classroom, house, grocery store, etc) and achieve all the same goals.

Don't spend too much time on the Ask part of the lab. 10 minutes total should be enough.

1. Grab a stack of Post-It notes and write down any problems you can think of in the hospital. Put each problem on its own Post-It note.

   Students should not need more than 5 minutes to think of problems.

   Now that you have identified some of the problems in the hospital, we need to separate the problems based on whether or not they are system problems or design problems. **Design problems** are problems which can be solved by creating or improving a product. They are problems with how something works. Any easy way to identify design problems is to ask, "Can I create or improve a product to fix this problem?" If the answer is yes, it is a design problem. **System problems** relate to the way things are done and often involve actions and people.

2. Share the problems you identified with the class and sort them as either system or design problems.

***TEACHER NOTE**: It could be a good idea to have a board divided into two sections, system problems and design problems, for students to add their Post-It notes to.*

Example problems sorted by system vs. design problems (generated by our students in a beta test):

- System Problems
  - No consistent schedule
  - Some patient rooms aren't clean
  - Boring/bad TV channels
  - No place/activities for teens
  - Weird priorities in the Forever Young Zone
  - Nurses wake me up too much
  - Doctors don't explain things in a way I understand
- Design Problems
  - Beds are uncomfortable
  - Hospital food is bad
  - Call buttons don't work/are hard to find
  - O_2 finger reader falls off
  - Pumps are inconsistent
  - Monitor beeps too loudly/too much
  - Nurses mess up IVs (while this involves people, you could think of a product that would eliminate the nurses from the equation)
  - Better toilets/pee bottles
  - Not enough storage in rooms
  - Masks make it hard to breath/talk
  - Guest beds are awful
  - Shower heads don't work well

Part II: Imagine

Now that you have spent some time identifying problems, we are going to give you a problem to solve using the rest of the Engineering Design Method. Almost everyone agrees that hospital gowns are awful. We are going to re-design a hospital gown. Even though engineers often make completely new products. They also spend a lot of time re-designing products to make them better. That is what we are doing today.

***TEACHER NOTE**: This is most effective if done together as one group, but can be done individually if desired.*

15 minutes should be enough time for the Imagine section.

1. As a group, discuss the good and bad features of a hospital gown. (Having a few hospital gowns for students to look at can be helpful.)
2. Make a list of these good and bad features.
3. Why were these features implemented in the way they were?

Table 1: Good and Bad Features of a Hospital Gown

Feature	Good or Bad?	Why was it done this way?
open back	bad	give doctors access to your back
short sleeves	bad	port access
thin fabric	bad	cost
multiple patterns	good	give kids choices
few sizes	bad	cost, storage
tie back	bad	easy to dress yourself and easy access for doctors

A '**must have**' is a function or feature that your product must fulfill in order to be useful. A '**nice to have**' is a function or feature that would provide value to the user but isn't necessary for proper function of the product.

4. Based on, but not limited to, your feature list, make a list of 'must haves' and 'nice to haves' for a hospital gown. This is also a time that students can be creative and suggest new 'nice to haves' to incorporate novel features.

***TEACHER NOTE:** This section is a great place to discuss all of the different people who 'need' something from the hospital gown. For example, doctors need a certain functionality out of the gown. This is why the back is open: to provide doctors with access. The hospital administration needs to get lots of gowns at a reasonable price and needs to have places to store the gown. This leads to fewer designs both fashion-related and functionality-related (short and long sleeve or tie versus snaps). This can also lead to a limited size selection.*

Table 2: 'Must Haves' and 'Nice to Haves'

'Must Haves'	**'Nice to Haves'**
access to back for doctor	pockets
port access	long sleeve/short sleeve and size options
a way to clean between patients	fashionable patterns
full coverage of body	easy to fasten by yourself

Part III: Plan

Now you're ready to start designing a new and improved hospital gown. Before engineers start building their designs, they draw them on paper. We are going to start by planning our designs on paper as well.

TEACHER NOTE: *For this part of the lab, it is really important to ask the groups lots of questions about their solutions to help them decide if they make sense and are doable/reasonable. This is especially critical for quieter groups of students who may need more guidance to start drawing solutions. Remind students to think not only about their needs from the hospital gown, but also the needs of the doctor, the needs of the hospital administration, cost, and environmental impact.*

Split students up into groups of 3-4 students for the next two portions of the lab.

This sections should take 15-20 minutes.

1. Grab your Post-It notes and begin drawing solutions to the bad features or completely new features on your own. Make sure to put each solution or new feature on its own Post-It note.
2. Share your ideas for solutions or new features with your group.
3. As a group, categorize all of the features and solutions by their purpose or the problem they address.
4. As a group, come up with three full designs for a new and improved hospital gown.
5. Draw your design on a full sheet for paper using front and back views or close ups of certain areas if necessary.

In order to decide which designs to prototype, engineers often use a **Concept Scoring Matrix** to 'grade' their designs. This looks primarily at functionality and 'must haves' but also considers the cost and other essential factors. You will make a Concept Scoring Matrix to decide which design your group wants to prototype.

6. Use the following Concept Scoring Matrix to choose the design you will prototype. If a design does a great job of meeting a criteria, give it a 2. If it does an okay job of meeting a criteria, give it a 1. If the design does not meet the criteria, give it a 0. The design with the highest total score is the one you will prototype.

Table 3: Concept Scoring Matrix

Criteria	Design 1 Score	Design 2 Score	Design 3 Score
Reasonable Cost of Design	0	2	1
Feasibility to Build	1	2	1
Minimizes Environmental Impact	2	2	2
Must Have #1: access to back for doctors	0	2	2
Must Have #2: port access	1	1	0
Must Have #3: a way to clean between patients	2	2	2
Must Have #4: full coverage	2	2	2
Must Have #5:			
Total Score (add up all the boxes above)	8	13	10

This example group would prototype Design #2 because it had the highest score. In the case of a tie, students could either prototype both designs or combine aspects of both designs into a single design to give a higher score.

***TEACHER NOTE**: Make sure that students don't feel tied to their highest scoring design. If the Concept Scoring Matrix reveals a deficiency in the design, they should feel free to incorporate aspects from other designs or use new ideas.*

Part IV: Create

Once engineers have a design they feel good about on paper, they grab materials and start building a prototype. A **prototype** is a sample of their design that can be used for testing or to identify unanticipated problems. Now you are going to build and test your own prototype.

Give students 20-30 minutes for this section. Make sure you leave enough time for Part V.

1. Once you have completed your Concept Scoring Matrix from Part III, ask your teacher for prototyping materials.
2. Use the disposable gown, tape, string, paper clips, and scissors to make a prototype of your new and improved hospital gown. Your prototype should be based on your highest scoring design, but you should feel free to make changes and adjustments as you build.

Part V: Improve

Once engineers have built a prototype, they test it and present the results to many different people: fellow engineers, administration, businessmen, friends, and family.

1. Have someone in your group try on your design. They will be your prototype model when you present your design to the class.
2. Present your design to the class making note of how you addressed the 'must haves' and which 'nice to haves' you included. Don't forget to mention cost and feasibility to make.
3. Listen to other groups present their design and make notes about things you like about their designs.
4. After you are finished with the discussion, answer the following questions about your design.

Engineering Design Concept Questions:

Q1. What worked well in your design?

Q2. What were some flaws in your design?

Q3. What were some cool features from other groups?

Q4. How would your improve your design, so it would be even better next time?

Q5. How does cost factor into your design?

Q6. Can you think of ways to make your design more cost effective?

Q7. Draw a new design in the space below that incorporates things you liked from other teams and fixes any flaws you identified in your design. Score this design using the Concept Scoring Matrix and see how it compares to your previous design.