Berkeley Engineers and Mentors

A Handful of Fun!

Target Grade: Elementary/Middle School
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Please Read

In this lesson, we will be covering a concept (prostheses) that may be sensitive to some students. When you present this section at site, please be careful with the vocabulary you choose to use, be cognizant of how you frame your words.

Brief Overview

In this lesson, we will be introducing the field of bioengineering and the versatile applications of the field to people's everyday lives. We will be discussing what types of projects biomedical engineers work on, demonstrate the model-making and engineering process to students as we build a model arm, and then having students try it out themselves by creating a prosthetic hand.

Teaching Goals

- Familiarize students with the field of **bioengineering** and its applications.
- Introduce the concept of **prostheses** and their function. Have students consider the physical properties of different materials when choosing what to use in their designs.
- Practice the **engineering design process**!
  - Have students make multiple models as they test their model hand through different challenges. Ultimately, students should learn the importance of trial and error.
- There are many different ways you can design something! Engineering is not limited to one design.

Careers and Applications

As the name suggests, biomedical engineering is the intersection of biology, medicine, and engineering. Biomedical engineers use their engineering knowledge and apply it to solve issues in biology and medicine. This innovative field has resulted in many life-saving medical devices, such as pacemakers and insulin pumps.

Agenda

- Introduction to Biomedical Engineering (5 min)
- Introductory Guided Build: Arm Muscle (10 min)
- Engineering Challenge: I Gotta Hand it to You (40 min)
- Conclusion (5 min)

Introduction

In the first five minutes of site, you should introduce **biomedical engineering** and its applications.

Rather than lecturing the students about all of this, a useful tactic is asking students what they already know and building off from that! Here are some suggested questions you can use to start this lesson out:

- What is biomedical engineering?
- What do biomedical engineers do?
- What are some examples of biomedical devices and innovations?
- What must biomedical engineers consider when they design new devices?
- Why do we need biomedical engineers?

After introducing biomedical engineering, familiarize students with the **engineering design process**. The engineering design process can be split up into 5 main steps: **Ask, Imagine, Plan, Create, Improve**. This can be visualized in the following graphic. Discuss the different steps of this process with students. It is fine if they do not immediately grasp all of them, as they will observe it in the guided build and practice it in the engineering challenge!

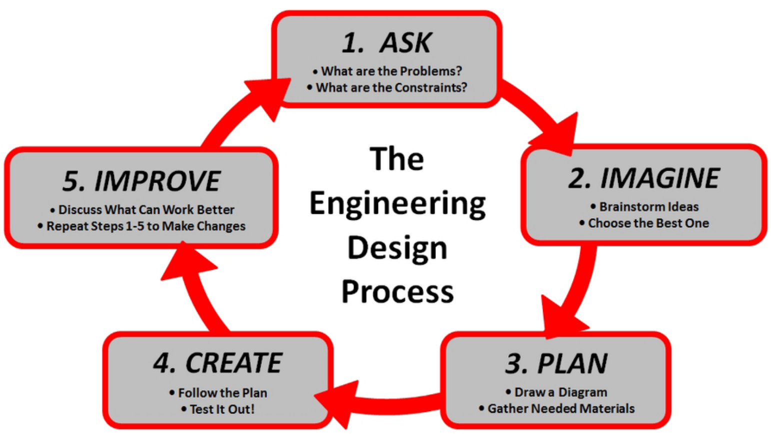


Figure 1: Engineering Design Process Mr. Fleming Science.

Introductory Guided Build: Arm Muscle

Introduction

In this guided build, we will act out the engineering and model-making process as we build a model arm for students so that students have a better understanding of both processes. We will also be introducing the muscles in the arm using this balloon and cardboard tube model. The idea is for students to be oriented to the thought process behind engineering and the part of the body that we will be focused on for the rest of the lesson (specifically, the hand).

Background for Mentors

The balloons will represent the various muscles in the arm, including the bicep and the tricep. You can demonstrate how when you bend the arm at the elbow, the bicep contracts and shortens as the tricep relaxes and lengthens.

Materials

(per site)

- 6 Cardboard tubes
- 4 Oblong Balloons (extras would be nice in case one pops)
- 2 Oblong Balloon Pumps
- 2 Scissors
- Straws
- Paper clips
- Rubber bands

Procedure

1. Line up the cardboard tubes such that two are in the same line and one is slightly below and in the middle of the two.

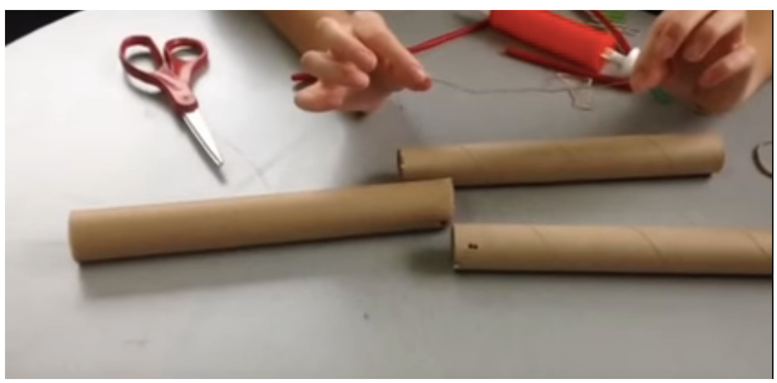


Figure 2: Lining Up of Tubes Youtube.

2. Unfold a paperclip and loop it through the cardboard tubes such that they are lined up.
3. Blow up a balloon. Tie one end to the middle of the two cardboard tubes, and the other in the middle of the single one.
4. Tie another balloon on the opposite side in the exact same way.
5. Bend the model arm where the cardboard tubes meet. You will observe that the balloon in the middle (the bicep), contracts, while the balloon on the back (the tricep) relaxes.

Figure 3: Model Arm Youtube.

Additional Notes for Mentors
Throughout this build, try to emphasize the different steps of the engineering design process. (For example, for Step 1 (Ask), give a reason why we need to make a model arm, perhaps Little Cynthia wants to have the coolest Halloween costume ever and become a 3-armed cyborg.) Also, try to have the students participate in the process as well by asking questions throughout the build.

As for the building of the model, a helpful video can be found here:
[https://www.youtube.com/watch?v=1phXt2Kumew]

Engineering Challenge: I Gotta Hand it to You

Introduction
In this challenge, students will be considering the physical properties of different materials as they engineer a functioning prosthetic hand that can successfully pass a series of tests. This challenge aims to demonstrate an example of biomedical engineering and show the considerations engineers must make when they design biomedical devices. This activity also reinforces the ideas of the **engineering design process** and **trial and error**.

Background for Mentors
A person may have lost an arm or a leg through trauma, sickness or a congenital condition. The most common reason for amputation occurs from a cardiovascular disease called peripheral arterial disease. This is when poor circulation caused by damaged or narrow arteries does not allow the tissue in the limb to get oxygen and it eventually starts to die or becomes infected. Prostheses can come in many different forms and their design depends on the patients lifestyle.

Prostheses are man-made devices created by biomedical engineers that are used to replace a missing body part. In the design of a real prosthetic, material science is critical to determine the structures strength and weight to make the device practical for the user. Biomedical engineers must consider the physical abilities, strength, weight, and functionality of different materials as they design a prosthetic. Currently, there are several types of prostheses available, which can be categorized into cosmetic (stationery), transradial (cable controlled) and myoelectric (electrode controlled) prostheses.

Here are some examples of real-life prostheses.

Figure 3: Prosthetic Hand The Scientist.

Prostheses aren't only designed for humans! Biomedical engineers have also created prostheses for our four-legged friends.

Figure 4: Prosthetic Legs for a Cute Dog! USA Today.

Important Notes

To help keep students engaged for the entire period, this challenge is designed to be a **competition among students as they try to complete different challenges.** Throughout this activity, students will practice the **engineering process** they observed in the previous module.

After performing the first four steps of the engineering design process Ask, Imagine, Plan, and Create, students will try to complete different challenges using their prostheses, modifying them as they go along (Step 5: Improve). It is very likely that a hand that initially works for one challenge will not work for the next challenge, so students will have to constantly change their design in order to make a ”super hand” that can past all of the tests!

If you are having trouble with getting an individual student engaged, one strategy is having them compete against a mentor and a pre-made design from decal.

Making a model hand will appear difficult to many students at first. However, with a push in the right direction, students will be able to make their own prosthetic hand. This challenge is structured to provide students that push, as you will first hold a discussion about designs and materials before students do the actual building.

In this activity we are prioritizing **functionality over appearance**! It is important to realize that the hands the kids will be building might not look like hands at all. Encourage kids to think outside the box! The challenge is to build something which will pick these items up. Now this is of course not always true for prostheses. Many prostheses are designed to look more like an actual limb. Dont be afraid to bring this up with the kids if they are held up on building something which looks like a hand. Different engineering applications require different designs.

Ultimately, the takeaway from this is **that there are many different ways you can design something!** In engineering, there is no set one answer, but rather a variety of different options and ideas engineers may explore. There is no end to your student's creativity, harness it to its true potential!

Materials
(per site)

- 30 Regular Straws (bend on straw is optional)
- 30 Boba/Milkshake Straws
- 30 Pipe Cleaners
- Tape (hella)
- Cardboard (hella)
- 5 Short PVC Pipes
- 16 Paper Cups
- 4 Eyeball Ping Pong Balls
- 40 Popsicle Sticks
- 15 Plastic Spoons
- Rubber Bands (hella)
- Rolls of String (one roll per group of 3-4)
- 3-4 Scissors
- 2-3 Hole Punchers
- 5 Binder Clips
- 2 Hot Glue Guns
- 5 Hot Glue Gun
- 2 Sheets of Paper

Procedure

1. Start with **Step 1 of the Engineering Process: Ask**. What is the problem?
   Sometimes, a person could have lost an arm or leg through trauma, sickness or a congenital condition. Have students imagine how their daily actions would change if they did not have an arm or a leg.
2. **Step 2 of the Engineering Process: Imagine**. Pull some ideas from students on how we can fix this problem. One of them might propose prostheses as a solution. Talk about these biomedical devices and explain their function to students.
3. **Step 3 of the Engineering Process: Plan**. Have a **discussion**! This will help students have a better sense of how they might build their hand. **Have the students brainstorm some possible design requirements:** Ask students what functions they think a prosthetic hand should be able to accomplish. What do we use our hands for? For example, the fingers of a hand should be able to bend but revert back to its original shape. Another example is picking and dropping items.
   After a brainstorm session, introduce all the materials and have the students consider each material's physical capabilities and then decide on what materials would work best (some will work better than others!).
4. Continue **Step 3 of the Engineering Process: Plan**. Based on your site: (1) Divide students into groups of 3-4 and have them come up with a initial design. OR (2) Have each student come up with their own design. Students will send a representative (or him/herself) up to retrieve materials from a mentor.
   (a) If your site is more advanced, you can give incentives for using less materials. Biomedical engineers aim to make practical designs that use the least amount of resources.
5. **Step 4 of the Engineering Process: Create**. Building time!
6. Once students finish, have them test out their hands with the first challenge.
7. **Step 5 of the Engineering Process: Improve**. After each challenge, give students 5-10 minutes to readjust their design.
8. Repeat with other challenges. Start out with a couple of the basic challenges that test out principal hand functions and then try out the HallowBEAM challenge!

Possible Challenges

Here are some general challenges we came up with. Of course, you may tweak these or add some of your own based on what you know of your site!

1. **Challenge #0:** Make a ”finger” that bends and reverts back to its original shape.
2. **Challenge #1:** High five a mentor.
   (a) ***Significance of this challenge:*** We use body language/gestures as a form of expression.
3. **Challenge #2:** Pick up a rubber bouncy ball.
   (a) ***Significance of this challenge:*** Bouncy balls are round items so students will have to be strategic in their design.
4. **Challenge #3:** Pick up a paper clip.
   (a) ***Significance of this challenge:*** Paper clips are small items so this will make them have to fine tune their design! Humans have particularly fine-tuned motor control when it comes to smaller objects.
5. **Challenge #4:** Pick up a ball and then drop it.

   (a) ***Significance of this challenge:*** Just like how our fingers not only bend but also straighten, our hands not only pick items up but also release items.
6. **Challenge #5:** Pick up a paper clip and then drop it.
   (a) ***Significance of this challenge:*** Just like how our fingers not only bend but also straighten, our hands not only pick items up but also release items. This makes students have to reconsider their design if they used a magnet in Challenge #3.
7. **Challenge #6:** Try to pick up as many paper clips as possible in 60 seconds without having magnets in your design. Bonus points if you can pick up multiple paper clips at once!
   (a) ***Significance of this challenge:*** When biomedical engineers design prostheses, they have to design models that not only accomplish everyday tasks, but do so in an efficient and still relatively quick manner.
8. **Challenge #7:** Try to pick up objects of different weights, such as a piece of paper vs a rock or marble.
   (a) ***Significance of this challenge:*** It is important to consider the strength of the muscles in the hand when designing. If there is decreased strength, people might not be able to pick up heavier objects.
9. **Super Extreme Difficult Challenge #1:** Open a door.
   (a) Students should automatically get hella candy for this, props to them.
10. **Super Extreme Difficult Challenge #2:** Tie a shoe (will probably need two hands for this).
    (a) If a student accomplishes this, I will buy them a cake.
11. **HALLOWBEAM CHALLENGE - SPOOKY PONG:** Boo! In the spirit of Halloween, you can spice it up by having students play a game of Spooky Pong!
    (a) Line up 6 cups in a pyramid fashion.
    (b) Give the student 3 spooky eyeballs (ping pong balls).
    (c) The student will try to use their prosthetic hand to throw the eyeballs into the cup. Each cup is worth one point.
    (d) The student(s) that get(s) the most points wins!

Additional Notes for Mentors

- Make sure to emphasize to the students how the different materials have different properties that make them more/less useful for the task.
  - Some Examples
    * The pipe cleaners can bend easily, but take effort reverting back to their original shape.
    * Can we use the tension from the rubber bands for anything?
- It may be a little difficult to come up with a design without looking at previous examples, but students should try to come up with their own design at first. If theyre struggling, try talking about the physical properties of the different materials and how they could benefit or prove harmful to the design.
- Emphasize the **engineering process**!
  - Students can try different designs and see which work best.

To help you out in case a student is stuck, attached to the end of this pdf are some designs we made! Note that some designs are better than others, and we will discuss the advantages/disadvantages of each in detail. You are of course not limited to these following designs, they are only a couple of the ones we came up with while lesson testing!

Conclusion

Biomedical engineering is an incredibly diverse field, and there are huge implications of creating devices that could potentially repair function in the human body. As we saw in this lesson, even a design built with materials you can find at home can mimic the function of a hand. With growing technologies and more resources, biomedical engineering is on the forefront of innovation in medicine.

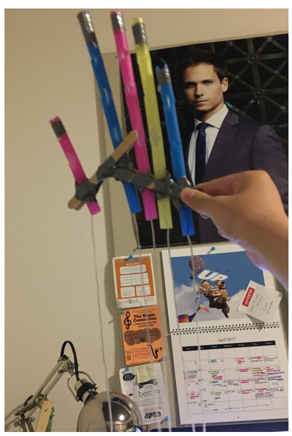
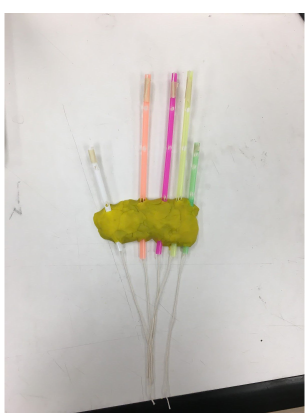
At site, ask students what they have learned about biomedical engineering is and ask for some examples of biomedical devices. What must biomedical engineers consider when they design these devices? What is the engineering design process like? How did the students practice the engineering design process today? Ultimately, what does the work of biomedical engineers accomplish? What is the purpose of biomedical engineering?

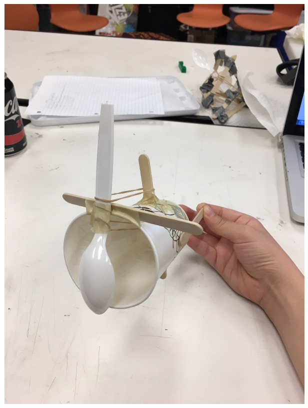
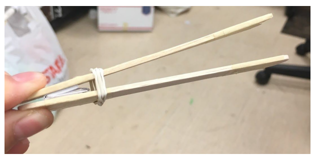
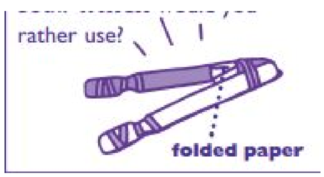
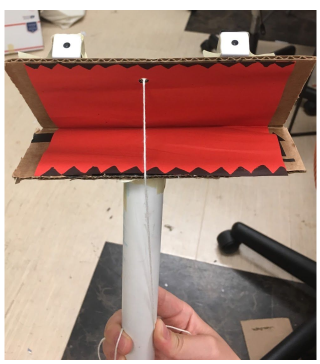
References

- Engineering Design Process, Mr. Fleming Science. *[http://www.mrflemingscience.com/engineering-design-process.html]*
- DIY Model of the Arm Craft, Youtube. *[https://www.youtube.com/watch?v=1phXt2Kumew]*
- Missing Touch, The Scientist. *[http://www.the-scientist.com/?articles.view/articleNo/32513/title/Missing-Touch/]*
- Pet Prosthetics: More Vets are Using Them, USA Today. *[https://www.usatoday.com/story/life/2014/04/21/pet-prosthetics/7979663/]*
- Build a Helping Hand, Science Buddies. *[http://www.sciencebuddies.org/science-fair-projects/project_ideas/HumBio_p042.shtml#summary]*
- Mechanical Grabber, PBS Kids. *[https://pbskids.org/zoom/printables/activities/pdfs/mechanicalgrabber.pdf]*
- How to Make a Robotic Arm out of Cardboard, Yuri Ostr, Youtube. *[https://www.youtube.com/watch?v=c9FuPdl3xCE]*

Summary Materials Table

Material	Amount per Group	Expected $$	Vendor (or online link)
Regular Straws	30 per site		
Boba/Milkshake Straws	20 per site		
Plastic Spoons	15 per site		
Popsicle Sticks	40 per site		
Paper Clips	35 per site		
Rubber Bouncy Balls	2 per site		
6 inch PVC pipes	5 per site		
Rubber Bands	30 per site		
Paper Cups	16 per site		
Tape	Hella		
Hot Glue Gun	2 per site		
Hot Glue Sticks	5? per site		
Cardboard	hella		
String	2 Spools per site		
Scissors	3-4 per site		
Hole Punchers	2-3 per site		
Binder clips	5 per site		
Paper towel cardboard tubes (like the ones from this video: https://www.youtube.com/watch?v=1phXt2Kumew)	6 per site		
Latex gloves or plastic gloves	5 per site		
Oblong balloons	4 per site		Inventory from last semester
Balloon Pumps	1 per site		
Paper	2 sheets per site		
Eyeball Ping Pong Balls	4 per site		

Design Name (materials)	Picture	+	Δ
Thin Straws (popsicle sticks, drinking straws, tape, string)		-*appearance*: looks cool and resembles a hand -can control individual fingers using the string	-*functionality*: holes must be cut perfectly in alignment with each other and be of the same size in order to result in the best functioning hand (using a hole puncher kind of helps but this hand is still hard to use) -straws are weak and don't pick up objects well
Thicc Straws (similar to previous design except with thicker straws)		-*appearance*: looks cool and resembles a hand -can control individual fingers using the string -more structurally strong because the straws are more likely to pick up objects without collapsing	-*functionality*: holes must be cut perfectly in alignment with each other and be of the same size in order to result in the best functioning hand -for making perfect holes, hole puncher is more difficult than in previous because harder to cut through the thick straws
Thin Straws + Play-Doh (thin straws, string, play-doh, tape)		-*appearance:* Looks cool! The play-doh adds a smoothness to the design.	-lacks the structural integrity the popsicle sticks gave -the straws slip through the play-doh easily, design collapses easily -would not recommend this design at all

The Scooper (spoon, popsicle sticks, rubber bands, cup, and tape)		-*functionality:* pretty good at picking normal size objects (like the ball)! Way better than the straws in this sense. Tension in the rubber band helps keep the spoon in place.	-might be difficult to pick up smaller objects like the paper clip -could add a magnet to help, still have the issue of releasing the paper clip after it's picked up
The Tongs/Pincher (popsicle sticks, rubber band, folded paper)	  	-*building:* easier design, good for younger students -*functionality:* easy to use -*further extensions:* mimics crab pinchers and demonstrates a new concept of **biomimicry**	-*functionality:* you have to exert more effort to use this design
The Monster (pvc pipe, string, cardboard, dice, origami paper)		-*building:* easier design, good for younger students -*functionality:* easy to use -*appearance:* looks cool haha -*further extensions:* mimics mouth of a crocodile and demonstrates a new concept of **biomimicry**	-*functionality:* doesn't pick things up super quickly -*functionality:* doesn't do much other than picking up/dropping items

The Really Cool One (cardboard, straws, string, hot glue) Youtube link: https://www.youtube.com/watch?v=c9FuPdl3xCE		-combines both *functionality* and *appearance*! -*functionality:* fairly decent at picking objects up and making hand gestures -*appearance:* looks like a hand, and has joints	-*build time:* takes more time to build, one of the more complex designs -probably better suited for middle school sites -*functionality:* can't pick up small items