HandGineering: Design, Create, Iterate

Students design and create prosthetic hands using common classroom materials, then test their designs to find areas for improvement. This guide brings together a number of activities into a sequence that: (1) introduces user-centered design, (2) explores hand anatomy, and (3) guides students through the design, testing, and revision cycle while highlighting the importance of failure and iteration in the engineering process.

Learning Objectives

- When designing a solution, user needs must be considered.
- In engineering, failure is a critical part of the process and not something to be avoided.
- Engineering requires iterating repeatedly until a workable solution is found.

Class Time

90-180 minutes (the more students iterate, the better!)

Materials

- An internet-capable device per student or student group
- Student sheets, print or use fillable PDF for a digital option
- A "doodle space" such as blank paper, mini-whiteboards, or digital drawing program
- Inexpensive materials to build a prosthetic hand. Suggestions:

rubber bands	paper
fishing line	aluminum foil
straws or drink stirrers	paper plates
yarn, string, or twine	cardboard
penne or elbow pasta	card stock
pipe cleaners	felt
popsicle sticks	foam
lab gloves	rulers
paper clips	scissors
brads	labels
beads	hot glue gun/sticks
tape (masking, duct, mailing)	

Note from the developers

One "constraint" we had in creating this activity was keeping it low cost. And it's completely possible to build a hand out of just paper and masking tape. On the flip side, feel free to clean out your cabinets! Either way, we hope this activity encourages creative thinking for students.

Background Information

Below are some resources for you to learn a bit more about prosthetics and the anatomy of the hand. Feel free to adapt for use with your students.

Timeline of prosthetic limbs plus a couple of videos of prosthetic users https://share.upmc.com/2015/03/timeline-prosthetic-limbs-years/

A short history of prosthetics https://synergypo.com/blog/a-short-history-of-prosthetics/

Hand anatomy in brief https://www.ncbi.nlm.nih.gov/books/NBK279362/

(1) Introduce User-Centered Design

Living with Limb Loss <link>

Students apply reading comprehension skills to tease out what people with limb loss really need from an engineered solution. Can be done individually, in small groups, or as a jigsaw.

(2) Explore Hand Anatomy

Manipulations! <link>

Students learn the elements and functions of hand anatomy systems (bones, muscles, tendons and nerves).

Students play a web-based mini-game to practice coordinating the movements of a simulated robotic hand. These range in difficulty and may be too hard for some students to master. Decide how much class time you want to devote to playing with the robot hand.

Used as a resource throughout the HandGineering activity.

(3) Design, Create, Iterate

The HandGineering Student Sheet guides students through the design, building, and testing phases to build a prosthetic hand. Begin with page 1.

- Share any relevant background info that wasn't covered in the Student Sheet introduction or in ***Living with Limb Loss.***
- Discussion – How is designing an engineering project different from doing a science experiment? How is it similar?
- Briefly discuss the engineering cycle
- Divide the class into groups of 2-4 students for the project

Step 1: Design

Page 2 of the Student Sheets will guide this step. Before beginning, share the following with your students:

- The constraints, in terms of materials and time. Set time limits on each section (design and build).
- The criteria (if you're providing), or background resources (like ***Living with Limb Loss***) if the students will determine criteria on their own
- Decide if each group will work on unique user needs, or if you'll work on 1-2 needs as a class.
- For unique needs, consider chatting with groups after completing questions 1 and 2, to ensure projects are workable.
- As a class, have a group discussion and steer them toward 1 or 2 that you think are appropriate.

Notes:

Allow students to use ***Manipulations!*** as a resource throughout the activity in case they need to know more about hand anatomy and how things work together.

There is a basic outline of a hand on the last page of this document if you would like to print that out for students to use for brainstorming or designing their prototype.

Students may need help here narrowing down ideas that also fit into the criteria and constraints.

Encourage students to be very detailed in their drawings and to include measurements.

Work with students to facilitate materials needs.

Step 2: Create

Move on to pages 3-4 of the student sheets.

Notes:

You may wish to look over student work from Part 1 before beginning.

Build phase:

- Remind students of time constraints.
- Encourage them to divide tasks if they can in order to maximize their time.

Testing:

- If students will be completing the gesture test in the first iteration and the grasping test in the second, then hold on to page 4 until Part 3.
- Feel free to have students design their own tests. Instruct them to skip the printed instructions and data table and write out their own.

- Ensure students know how to fill out the data tables, calculate averages, and graph the results.
- Consider encouraging students to film the attempts so that they can go back later during the iteration phase to see what went wrong.
- If groups are able to easily do the grasping tests, suggest adding extra force (someone pulls on the object).
- Have all students stop at the end of Step 2 (page 4). Groups that finish early can explore famous "engineering design fails" such as: the sinking of the Titanic, the Tacoma Narrows Bridge collapse, hoverboards, or the Space Shuttle Challenger disaster.

Video and Discussion: Failure

Watch the [video name] as a class. In this video, a student does xyz and an engineer shares abc. After watching the video discuss:

- What factors most likely caused the failure?
- How could this failure be prevented?
- What can we learn from this failure?

Step 3 – Iterate

Spend as much time as you can in this part. The longer your students spend iterating, the more satisfying this project will be for them and the better they will grasp what engineering is like.

- **What does it mean to iterate?** Hopefully they have gathered enough from the activity, the video, and the design cycle to be able to answer this, but if you think they can't come up with anything, feel free to include a definition for them.
- Read through the first paragraph together. Emphasize that engineers aren't looking for the perfect design, just something that works well enough and meets the criteria. Small, incremental progress toward that end is the goal.
- **Analyze your prototype.** Give your students some thoughtful time to reflect and brainstorm some things they can improve. Then they will need small group time (maybe jigsaw with other groups) to get peer feedback on the things they chose to improve on. This should help keep them within the bounds set, instead of covering the hand with glitter or adding a sixth finger just because they can.

  Students may want to continue to address gestures or grasping tests, or they may have something totally different to try. One suggestion is to add a thumb that rotates like ours does.

- **Define.** Give them any new constraints (like a time estimate or limited or new materials).

- Let them finish the cycle of drawing, building, and testing the new prototype at least once. They may edit the original drawings and prototypes in this step or start fresh. Set up checkpoints or time limits as desired. Feel free to use the outline we have provided or create your own.
- Allow time to complete self-reflection questions 9 and 10. Consider having each student do this on their own instead of with their group. Question 10 is a good option if you'd like an exit ticket.
- **Share.** At any point (or at multiple points) in the process, you could have groups share their work with the class. One strategy for this is a Gallery Walk.

Supplemental Materials

Below are a couple of resources about cool prosthetics. To avoid discouraging students or building up false expectation, wait to show these until after they have done their projects.

- https://unews.utah.edu/star-wars-inspired-arm/
- https://spectrum.ieee.org/dean-kamen-luke-arm-prosthesis-receives-fda-approval#toggle-gdpr

Following are some incredible teen inventors, along with that they invented. Many have TED talks or YouTube videos that might inspire your students.

- Jack Andraka: improved pancreatic cancer test
- Gitanjali Rao: device to detect lead in drinking water
- Deepika Kurup: easier, cheaper method to remove toxins from drinking water
- William Kamkwamba: improvised electrical generator using windmill in Malawi
- Austen Veseliza: digital display glove to aid people with speech impairment
- Cristian Arcega, Lorenzo Santillan, Oscar Vasquez, Luis Aranda: underwater robot
- Heman Bekele: fighting skin cancer with soap