Summary

Student teams investigate biomedical engineering and the technology of prosthetics. Students create a model prosthetic lower leg using various materials. Each team demonstrate its prosthesis' strength and consider its pros and cons, giving insight into the characteristics and materials biomedical engineers consider in designing artificial limbs.

Engineering Connection

Category 3. Engineering design In everyday life, many people require replacement body parts. Those who need an artificial leg must have a structurally stable one to replace a critical part of their skeletal system. One aspect of biomedical engineering is designing and researching new and better prostheses (replacement body parts). Biomedical engineers are continually improving the strength, durability, longevity and lifelikeness so amputees can lead full lives.

Contents

Grade Level: 7 (4-7) **Group Size:** 4

Time Required: 120 minutes Activity Dependency :None

Expendable Cost Per Group : US$ 5

Keywords: amputee, body, bone, bioengineering, biomedical, biomedical engineering, design, design process, engineering design process, human, human body, leg, prosthetic, prototype, skeletal system, skeleton, strength, structure

Related Curriculum :

subject areas	Science and Technology
	Biology
	Life Science
curricular units	Biomedical Engineering and the Human Body
lessons	Engineering Bones

Educational Standards

- Colorado Science
- b. Develop, communicate, and justify an evidence-based scientific explanation regarding the functions and interactions of the human body (Grade 7) [2009]
- c. Gather, analyze, and interpret data and models on the functions and interactions of the human body (Grade 7) [2009]
- International Technology Education Association-ITEA STL Standards Technology
- H. Apply a design process to solve problems in and beyond the laboratory-classroom. (Grades 6 - 8) [2000]
- K. Test and evaluate the design in relation to pre-established requirements, such as criteria and constraints, and refine as needed. (Grades 6 - 8) [2000]
- G. Advances and innovations in medical technologies are used to improve healthcare. (Grades 6 - 8) [2000]

Pre-Req Knowledge (Return to Contents)

Familiarity with the idea of bones providing a body's structure, as described in the Engineering Bones lesson.

Learning Objectives (Return to Contents)

After this activity, students should be able to:

- Describe the engineering design considerations that go into developing quality prostheses.
- List characteristics and features that are important for a prosthetic leg.
- Analyze a prototype prosthetic leg and make suggestions for design improvements.

Materials List

Each group needs:

- A yardstick, ruler or tape measure, for measuring
- Scissors
- One type of prosthetic structural material with which to create a prototype (see suggestions below); note: The number of groups depends on how many different prosthetic resource materials are collected.
- Prosthetic Party Worksheet, one per person

For the entire class to share:

- 1 roll duct tape

Provide a variety of prosthesis structural material resources. Suggestions:

- For leg structure: toilet plungers (unused), plastic pipes, metal pipes, metal strips, cardboard tube (from wrapping paper roll), wooden "2 x 4," thin metal duct material (to be rolled and taped into a tube shape), all generally 1.5 ft (or .46 m) long
- For comfort: Large sponges, scrap bubble wrap, scrap cardboard, etc.
- For lifelikeness: bath towels, pairs of pants, shoes (use students')
- For body attachment: String, rope, twine (about 30 ft [or 10 m])

Introduction/Motivation (Return to Contents)

What is a *prosthesis*? (Answer: An artificial body part that replaces a missing body part.) Who might need a prosthesis? Many people are in need of various types of prostheses, including injured soldiers, people who live in war zones, or people who have been in accidents. Biomedical engineers design prostheses for these *amputees* so that they can live as easily as others.

A student-made prosthetic lower leg.

What are some important features required for a good prosthetic leg? The most important characteristics are strength, durability, longevity, shock absorption, lifelikeness and comfort. Biomedical engineers research and design new ways to create prosthetic legs that have all of these characteristics.

Today, we will be biomedical engineers, and design and create our own prosthetic lower legs! Then we will test our *prototypes* by bending a knee and resting it on the prosthesis. Our goal is to provide all the important features that we talked about. Then, we'll figure out some way to connect our prostheses to a body. Since we do not have real manufacturing equipment, we will use some everyday, around-the-house materials.

Vocabulary/Definitions (Return to Contents)

amputee:	A person who has had a limb removed.
bioengineering:	The use of artificial tissues, organs or organ components to replace damaged or absent parts of the body, such as artificial limbs and heart pacemakers. Source: The Oxford Pocket Dictionary of Current English, http://encyclopedia.com/doc/1O999-bioengineering.html
biomedical engineer:	An occupation that includes designing artificial body parts.
engineer:	A person who applies his/her understanding of science and math to creating things for the benefit of humanity and our world.
prosthesis:	An artificial body part to replace a missing one. Plural: prostheses.
prosthetics:	A specialty of medicine and engineering that designs, constructs and fits artificial limbs and body parts (prostheses).
prototype:	An original, full-scale, and usually working model of a new product, or new version of an existing product. Source: American Heritage Dictionary: http://dictionary.reference.com/browse/Prototype

Procedure

Before the Activity

- Gather materials and make copies of the Prosthetic Party Worksheet, one per person.
- Review the attached, three-page Images of Example Prototype Prostheses, for how students might create their own prostheses, and ideas to address comfort and lifelikeness.

With the Students

1. Divide the class into enough teams so each has a different structural prosthetic material.
2. Lead a pre-activity discussion and brainstorming session (as described in the Assessment section) so students have a good understanding of the various prosthetic requirements and material resources to meet these needs.
3. Explain to the students that when engineers design a new or improved product, they work in groups and follow the steps of the *engineering design process*: 1) understand the problem or need, 2) come up with creative ideas, 3) select the most promising idea, 4) communicate and make a plan to describe the idea, 5) create or build a prototype or model of the design, and 6) evaluate what you have made.
4. Assign teams different material resources with which to construct their prostheses. Make available other materials for the students to consider incorporating into their design.
5. Hand out worksheets and have students follow along with its questions throughout the activity.
6. Have students discuss ideas within their groups, while completing the first page of the worksheet.
7. Have each group choose one teammate for whom to make the prosthesis. So that the prosthesis fits him/her, measure that student's lower leg from where it bends at the knee.



Students design and create their own prosthetic lower legs, choosing and combining materials to achieve structural, stability, comfort and lifelikeness requirements.

8. Have students collect other materials, such as tape and string, and begin creating their prototypes, creatively addressing the requirements of strength, stability, durability, longevity, shock absorption, lifelikeness, comfort, etc.

Get creative to find ways to make your prosthesis comfortable and lifelike.

9. After all teams are finished, have each group present their prosthesis to the rest of the class, explaining their design concepts and choice of materials, as well as demonstrating the prototype's strength by having their teammate use it to walk (while bending his/her knee and wearing the prosthesis). See post-activity presentation suggestions in the Assessment section.
10. Conclude with a class discussion using the questions provided in the Assessment section.

Attachments (Return to Contents)

- Prosthetic Party Worksheet (pdf)
- Prosthetic Party Worksheet (doc)
- Images of Example Prototype Prostheses (pdf)
- Images of Example Prototype Prostheses (doc)

Safety Issues

- Be careful when testing prostheses. Have student "spotters" positioned around their teammate who is testing the prosthesis to catch him/her if s/he falls.

Troubleshooting Tips

If the prostheses are not strong enough to hold the body weight, test them with heavy objects (such as books) while students hold the prosthetic steady.

Since students may be unable to cut certain materials to the correct length, advise groups with these materials to choose their "amputee" teammate by finding the person who has a lower leg length closest to the material length. Or, if the material is too long, they could adjust by elevating the opposite foot (perhaps by standing on a book or strapping an object to the foot). Engineers realize that all materials have pros and cons; if a material is difficult to work with, it is a disadvantage to ultimately choosing it to make prostheses.

Assessment (Return to Contents)

Pre-Activity Assessment

Discussion/Brainstorming: As a class, have students engage in open discussion. Solicit, integrate and summarize student responses. Give prompts as necessary. Remind students that in brainstorming, no idea or suggestion is "silly." All ideas should be respectfully heard. Take an uncritical position, encourage wild ideas and discourage criticism of ideas. Have students raise their hands to respond. Record their ideas on the board. Ask the students:

- What features would make a useful prosthetic lower leg? (Possible answers: Strength, stability, durability, longevity, shock absorption, lifelikeness, comfort.)
- How can you achieve some of these qualities, using the provided resources? (Possible answers: Use the plunger head for a comfortable knee support, use rope or duct tape for connection to the body, use tube or pipe or wood for strong and sturdy support.)

Activity Embedded Assessment

Worksheet: Have students complete the activity worksheet; review their answers to gauge their mastery of the subject.

Post-Activity Assessment

Conference Presentation: Have each group present their prosthetic lower leg as if they were presenting it at an engineering conference. They should include in their presentation:

- List of materials and purpose of each
- How they came up with the design
- Important design features
- Estimated cost
- Demonstration of use

Concluding Discussion Questions: Conclude with a class discussion to gauge students' comprehension of the subject matter covered. Ask the students:

- What improvements would you make to your prototype prosthesis?
- What other materials and fasteners would help improve your design?
- What would be different if you had to make the whole leg, including the knee?
- What design constraints or limitations might be different for biomedical engineers developing real prostheses?

Activity Extensions (Return to Contents)

Expand the design challenge to have teams make a functional prosthetic arm. For an artificial arm, the primary purpose shifts from being structural to enabling movement. Have students brainstorm ways to make the prosthetic arm move. A bonus challenge is to create a prosthetic arm and/or hand that can pick up an object.

See if your local hospital, rehab center, veteran's hospital or medical center can loan you real prostheses to show to students. Or, find images of the latest designs on the Internet.

Have students research gait analysis and how engineers help measure a person's gait. How would this analysis be helpful in designing a prosthetic limb?

Activity Scaling

- For lower grades, instead of testing the prosthetic with the weight of an entire body, test it with heavy objects (such as books) while students hold the prosthetic steady. This way, the prosthetic need not be as strong or dependant on a secure attachment to the leg.
- For upper grades, have students draw more than one design. Have them predict and explain why one of their designs would be best, and construct a prototype of that one.

Additional Multimedia Support

As featured in Copper-Hewitt National Design Museum's *Design for the Other 90%* exhibit (http://other90.copperhewitt.org/Design/jaipur-foot-and-below-knee-prosthesis), have students investigate the Jaipur prosthesis at http://www.jaipurfoot.org/.

References (Return to Contents)

The American Heritage® Dictionary of the English Language, Fourth Edition. Accessed October 9, 2008. Dictionary.com. http://dictionary.reference.com/browse/prototype

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Supporting Program (Return to Contents)

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