Designer Bones

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Description:
The purpose of this lesson is to introduce students to the concept of orthopedic implants and materials testing.

Prerequisites:
No significant prerequisites required. If students know about forces, compression, and tension, then certain aspects of the lesson will go by more quickly

Instruction Time:
Approx. 90 minutes of instruction

Audience:
Middle school science class

Lesson Objective:
By the end of the lesson, students will be able to make decisions about which materials would be suited for particular tasks.

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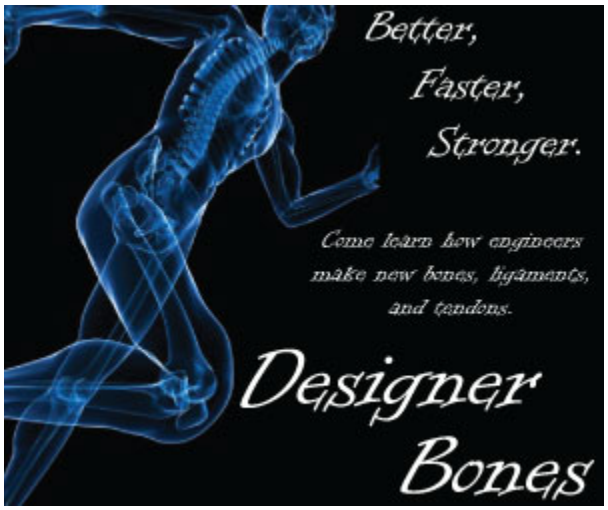

Lesson Overview:

The purpose of this lesson is to introduce students to the concept of orthopedic implants and materials testing. The engineering aspect of this lesson is in getting the students to design tests for what they think are desired properties of potential implant materials.. This was originally designed as a 3 day lesson, with an allocated 35 minutes on each day for a 6th to 8th grade audience.

Background Information:

- The musculoskeletal system consists primarily of many types of tissue including bones, muscles, cartilage, tendons, and ligaments
- The main load bearing components that we will focus on are: bones, ligaments, and tendons
- **Bones** are rigid organs that constitute part of the endoskeleton of vertebrates. They support and protect the various organs of the body, produce red and white blood cells and store minerals. Bone tissue is a type of dense connective tissue. Bones come in a variety of shapes and have a complex internal and external structure, are lightweight yet strong and hard, and serve multiple functions.
- **Tendons** (or sinew) are a tough band of fibrous connective tissue that usually connects muscle to bone[1] and is capable of withstanding tension. Tendons are similar to ligaments and fasciae as they are all made of collagen except that ligaments join one bone to another bone, and fasciae connect muscles to other muscles. Tendons and muscles work together.
- **Ligaments** are the fibrous tissue that connects bones to other bones.
- In physics, **tension** is the pulling force exerted by a string, cable, chain, or similar solid object on another object.
- In physics, **compression** is the application of balanced inward ("pushing") forces to different points a material or structure, that is, forces with no net sum or torque directed so as to reduce its size in one or more directions.

Learning Objectives & Assessment:

After this lesson, students will be able to:	Assessment for this objective:
1. Make decisions about the desired properties in materials for bone/ligament replacements	Checking both the oral (from class discussion) and written down (from Worksheet 1) brainstorm ideas for good implant materials properties.
2. Design and perform tests for various materials properties	Checking validity of proposed testing ideas and tests that are performed
3.Collect both quantitative and qualitative data from materials tests	Checking what type of data the students are collecting during class and written down test results (from Worksheet 2).
4. Make decisions about which materials would be best for given tasks based on the data they collected & give reasoning for the decisions	Checking both the oral (from group discussions) and written down (from Worksheet 2) materials decisions and reasoning.

Alignment to NRC Framework:

Scientific & Engineering Practices

Planning and Carrying Out Investigations, 6-8 grade level:

- *Design an investigation individually and collaboratively, and in the design: identify independent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how much data are needed to support their claim* – The entire process of deciding what material properties will be tested and how to balance the varying strengths and weaknesses of the different properties revolves around designing an investigation and determining what data to collect.
- *Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions* –The qualitative and quantitative data that the students collect from the tests they design will be used as evidence to justify the decisions that are made about which materials to use.

Crosscutting Concepts

Structure and Function, 6-8 grade level:

- *Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used* – The materials testing and evaluation portion of the lesson focus on the very idea of material properties. Also, the tie in to anatomy and how different bodily structures bear loads in different ways also emphasizes the relationship of structure and function.

Disciplinary Core Ideas

Engineering, Technology, and Applications of Science, 3-5 grade levels (ETS2.B)

- *Engineers improve existing technologies or develop new ones to increase their benefits (e.g. better artificial limbs), to decrease known risks (e.g. seatbelts in cars), and to meet societal demands (e.g. cell phones)* –The premise of the design problem is that there is some shortcoming with the way current artificial limbs are designed and that biomedical engineers can work to improve them by finding more optimal materials for the task.

Vocabulary:

Bone – hard, load bearing parts of the skeletal system made of minerals like calcium, phosphorus, etc.

Ligament – fibrous tissue that connects bone to bone

Tendon - fibrous tissue that connects bone to muscle

Force – a push or a pull that causes an object to accelerate

(Material) Property – a quality, attribute, or distinctive feature of a material

Tension – a pulling force that stretches apart

Compression – a pushing force that presses together

Materials:

Paper Resources	**Technology & Multimedia Resources**	**Physical Resources**
2 worksheets (included) - 1 of each worksheet per student.	Computer, projector, audio support for included PowerPoint presentations and embedded videos.	Materials testing "toolkit" Mass balance (electronic or triple-beam), meter sticks/rulers, spring scales Materials to test: *(these are just suggested material that can be substituted; just make sure that the samples that they are testing vary in properties and that they are of roughly the same size/length)* Hemp cord, styrofoam (e.g. floral foam), balsa wood, metal bars (e.g. iron/steel), aluminum wire (18 gauge/22 gauge) *(most of these items can be found at a local craft/hobby store like Hobby Lobby)*

Lesson plan:

Engage (5 min)	<u>What is Bioengineering?</u> Ask the students if they know what bioengineering is. Correct misconceptions and present definition using provided PowerPoint. Make sure to explain the visuals (left to right: prosthetic leg, MRI machine, fluorescent microscopy of cells).
Explain (6-8 min)	<u>Anatomy 101</u> (make sure all students have the Day 1 Worksheet in order to take notes) *Bone* – show first picture and ask students what they think the definition of a bone is; show the definition on the next slide; add to understanding by having students feel their own bones in order to differentiate from tendons, ligaments, etc. Emphasize the fact that bones bear compressive loads. *Ligament* – show the pictures of the various athletes who have suffered ACL/knee injuries. See if any of the students recognize any of the athletes and perhaps know what body part they injured. Some might even know the term 'ACL' from these pictures or from their own/friends injuries. Use this as a way to introduce the word 'ligament'. Show the diagram of the knee and point out the ACL and other ligaments. Show the next slide with the definition of a ligament. *Tendon* – Show the definition of a tendon. Have the students feel their own Achilles' tendon for a tactile addition. Emphasize the fact that tendons and ligaments bear tensile loads.
Engage (6-8 min)	<u>Amazing Bone Facts!</u> Show each 'Amazing Bone Fact' and ask the students as a group/ in pairs to decide whether or not they think that that fact is true and why they think so. After, hearing a few explanations, reveal the answer and explain why. Repeat for each fact. <u>"The Strength of the Knee" video clip</u> Show the included video clip on the next slide. Ask the students what interesting facts they picked up about the human knee from the clip. <u>Design Problems</u> Present the 2 design challenges via the pictures: **(1)** Picking a material for an **artificial ligament**. Motivation: Currently, ACL repair surgery requires harvesting a tendon/ligament from the patient's own body, which weakens the knee to an extent and increase recovery times. **(2)** Choosing a material for a **bone replacement**. Motivation: Currently, the materials for such replacements are expensive, heavy, and don't last long enough.
Explore (5 min)	<u>Brainstorm Design Criteria</u> Ask the students to brainstorm (individually, then in pairs) what they think good properties would be for an implant material. They should write down the ideas + reasoning on their worksheets.
Evaluate	Have different pairs present their ideas for good implant materials to either other pairs or

(< 5 min)	the class as a whole.
Engage (<5 min)	Recall Design Challenges Show the design problem slide. Make sure that the students recall what we are working towards.
Explain (8-10 min)	Introduce the tools in the 'toolkit'. Briefly explain about how they work. Picking Design Criteria Use their brainstorm answers to make a 'word cloud' slide (use the site http://tagcrowd.com/ to do this). Show the students this slide, and explain that these are their answers with the most popular ones being the largest. Have them rule out (as a group) what design goals are not practical to test. Pick the three properties that you want to test as a class. Show them the testing materials. Allow them to play with the materials as this discussion ensues.
Explore (10 -15 min)	Testing Materials "Jigsaw" group assignment: Assign every student a **color** and a **number** (the number of colors & numbers should be equal to the number of desired small discussion/testing groups). *(Worksheet 2 should facilitate this entire process.)* Have the students get into groups by **number** and assign each of these groups a property to test. The students will use tools from the toolkit and general qualitative observations to rank each material for their group's assigned property.
Explain (5-8 min)	Share data with "jigsawed" groups & evaluate design problems Have the students get into groups by **color** and assign alternating groups either design problem **(1)** or design problem **(2)**. Students should explain what properties they tested, how they tested them, and what their results were and use this information to make a decision together to as to which material is best suited for their task.
Elaborate (5-10 min)	Presenting Decisions Have the students share their decisions and reasoning with either the class as a whole or with groups with different design problems. Emphasize the importance of providing **evidence and reasoning** for their decisions. The Science Behind Materials Introduce concepts of tension, and compression and how they relate to the materials they tested. Now that the students have experience with the materials and testing them, they should be able to identify which materials and anatomical body parts are strong under tension/compression and apply this to their design problems.