Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
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Repair and Regeneration of the Human Musculo-Skeletal and Cardiovascular Systems

Curriculum Unit 14.04.10
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Introduction

One of the things I love most about being a teacher is that each day I get to see the direct impact of the work I do. I imagine that doctors feel the same gratification, from their patients, that I feel from my students. Teachers, like doctors, must also often attend to urgent matters. Over the past three years, I have seen just how high the stakes are for my students. But every skill or life-lesson I teach them can open the door for opportunities and put them on a different life path. Similarly, advancements in biomedical technology, like prosthetics, are enhancing the capabilities and quality of life of individuals with physical impairments.

I believe creating a curriculum unit focused on engineering in biology, health, and medicine, will allow me to change the minds of my students, while sharing ways engineers and doctors are changing the lives of patients. This unit will foster transformational change by impacting all areas of my students' lives, from academic growth to problem solving and career development. Academically, my students will gain exposure to real world scientific connections. They will engage in cutting edge work of the discipline, through topics such as prosthetics, joint replacement, and rehabilitation. Also, this unit will focus on problem solving. My students, like engineers and doctors, will practice thinking critically and creatively to solve problems that relate to the world around them and other fields of science and mathematics. And finally, this unit will provide my students with a deeper understanding of careers in science, technology, engineering, and mathematic (STEM) and hopefully spark their interest in pursuing a STEM degree.

The New Haven 7 th and 8 th Grade General Science Curriculums focus heavily on the biological sciences. The 7 th grade curriculum includes units on cells, genetics and reproduction, and life systems (musculo-skeletal and cardiovascular). Through this unit you will be able to: (1) gain an understanding of key ideas and techniques of engineering, (2) learn about advancements that have been made in biology, health, and medicine, as a result of engineering practices, (3) grow as a professional by gaining valuable teaching strategies to help your students use higher order thinking skills to seek their own answers to real world problems using engineering, and (4) instill in your students a desire to pursue a career in the field of STEM by researching careers in engineering.

This curriculum unit addresses engineering related particularly to advancements in orthopedic technology.

Orthopedic bioengineering is a way for students to deepen and expand their thinking about the musculo-skeletal and cardiovascular systems. In addition to gaining a deeper understanding of the function of bones, joints, muscles, and the heart, students will also see first-hand how scientists and engineers work together to repair injury and wear and tear through the design of artificial joint replacements, prosthetics, and stem cells. Students will also practice using their inquiry skills through a problem based learning activity. By analyzing, through their own experimental design, how types of materials used for these techniques affect factors such as friction, lubrication, and wear characteristics students will propose their own engineering ideas. [3]

Biomedical Engineering

Why Teach Middle School Students about Biomedical Engineering?

Middle school students in New Haven take a general science course during their 7 th and 8 th grade years. These general science courses cover a wide variety of topics and disciples including, scientific inquiry, physical science, life science, earth and space science, and science, technology, and society. Under the scope of science, technology, and society the following topics are discussed: water resources, how humans affect water, protecting water resources, bacteria and food preservation, and bridges. It is this section of the curriculum that is missing a huge component of today's science, technology, and society and that is engineering related to engineer in biology, health, and medicine.

Teaching students about biomedical engineering provides a platform for students to gain real-world examples of how technological advances, influenced by scientific knowledge, affect the quality of life. Students are also provided, with this unit, a space to explore the design process. By designing a prosthetic or cast prototype students design a solution (product) to meet a human need and take into account needs and constraints (cost, time, properties of materials, safety, and aesthetic qualities). [3]

Biomedical Repair and Regeneration

Each and everyday people encounter trauma, disease, or injury that repairs the repair and regeneration of body parts. These body parts can range from cells within one chamber of the heart to an entire limb like the leg. Biomedical engineers and doctors use a variety of technology and techniques to help their patients maintain the highest quality of life possible. [3] Bioengineering is a field in which artificial tissues, organs, or organ components are used to replace damaged or completely absent parts of the body. [3] This type of engineering includes items such as artificial limbs, heart pacemakers, stem cell therapy, balloon angioplasty, and stenting among many others. [3]

While many prosthetics are found outside of the body, another job of engineers is to test and develop new materials that can safely be implanted into the body. [3] This includes artificial organs or engineered cells. Doctors have worked on repairing the human body for many decades now, but regenerative medicine is an emerging health filed that seeks to go beyond treatment to fully heal damaged tissue and organs. The use of stem cells is a very hot topic in medicine right now. And lots of time, money, and resources are being put towards researching potential uses of stem cells (See Figure 1). This unit focuses on the use of stem cells for heart repair after a myocardial infarction, or heart attack. [1]

images/2014/4/14.04.10.01.jpg

Figure 1. Diseases and conditions where stem cell treatment is currently being investigated. Illustration: "Stem cell treatments" by Mikael Häggström. [7]

Musculo-Skeletal System

The musculo-skeletal system provides shape and support, protects internal organs, allows for movement, stores important minerals (calcium), and produces red blood cells. Overall, the system serves as our body's structure. [5] It is this system that allows us to stand up, sit down, and move around. The skeletal system contains 206 bones and each bone and muscle has a different functions. Often the size, shape, and location of the bone determine its use. For example, the ribs and scull protect important organs like the heart, lungs, and brain. Bones in the hand, on the other hand, are small and capable of holding things and making small movements. While bones in the leg, hip, and back support the weight of the entire body. [5]

And with the help of the muscular system the bones provide movement. The site of movement is called a joint. [5] Joints allow bones to connect to each other and there are several main types: ball and socket, hinge, pivot, gliding, and immovable joints. The ball and socket joint allows for a free range of movement and can be found in the shoulder and hip. Hinge joins provide a 180-degree of motion and form the elbow and knee. The pivot joint provides rotation and is found in the neck. Gliding joints in the vertebrae allow for small movements. And finally immovable joints, found in the skill, do not allow for any movement. When a part of the skeletal system is compromised, such as the legs, technology can even be used to help repair the support system. [5]

Repair and Regeneration of Bones and Muscles

Biomedical engineers apply engineering techniques using their understanding of body systems to develop technologies and devices to meet the needs of humans. [12] One field of biomedical engineering is prosthetics, or artificial body parts. When an entire leg, arm, or hip needs to be replaced doctors often look to prosthetics. [12] A prosthetic can either replace an entire or part of a missing/damaged body part. Prosthetics are designed to look as much as possible like the original body part and must be made with the characteristics of strength, durability, longevity, and comfort, in mind (See Figure 2). [12] Common prosthetic procedures include surgery of the joints, at the knees, and hips. [3,5]

Several different materials are currently used for prosthetics such as willow wood, laminated fibers, plastics, metallic alloys and carbon-fiber composites. [5] Ceramic, while strong, is very brittle making it a problem. The main concern with new materials is a lack of knowledge of how long they will last inside the body. [5] Currently knee and hip prosthetics last anywhere from 10 to 15 years. [5] This number is not favorable for young patients, and researchers are looking to add things to prosthetics to help promote bone growth. [5]

In addition to the material, biomedical engineers also focus on the sensors, joints, and connections that the

prosthesis has to the body. [12] While it is easy to harness the shoulder or upper these sites of attachment do not offer the widest range of movement for the patient. New technology is being developed to use small sensors, implanted in the body, that detect minute electoral changes in nearby muscles and nerves. [5] This data is then transmitted to the prosthesis and movement is produced. This new wave of sensors is more lifelike and one artificial knee recently designed to adjust to a person's walking based on the speed and surface they are on. [5]

The body has a natural tendency to heal itself, but tissue engineering goes beyond that. We cannot replace organs yet, but biomaterials are being used to provide structural scaffolding future endeavors that may yield even more promising results. Skeletal muscle tissue engineering could help reconstruct muscle loss caused by trauma, disease, or tumors. Since there are so many issues with donor tissue being rejected when grafting, tissue engineering could tackle a problem from a new angle. Engineered tissue is new, functional muscle tissue derived form stem cells. Currently research is going on to simulate muscle myoblast cells using stem cells, use scaffolds to build muscle tissue, and also vascularizing tissue in vitro. [1]

Commonly Used Knee Prosthetics Overview

Cruciate-Retaining Mobile or Fixed Bearing Knee

The cruciate-retaining mobile or fixed bearing knee is a total knee replacement system. This type of prosthetic is used for patients how have a fully function Posterior Cruciate Ligament (PCL), as it is left intact during surgery. The Anterior Cruciate Ligament (ACL) is no longer functional after surgery and the prosthetic takes over for the movement of this ligament. [4]

Cruciate-Substituting Mobile or Fixed Bearing Knee

During this total knee replacement surgery both the ACL and PCL are lost and the prosthetic compensates for their loss. This surgery is often used for patients that have damage or a lack of function in their PCL already. [4]

Hinged Knee

The hinged knee is used in a patient that has already had a total knee replacement prosthetic and is in need of further repair. This surgery is therefore only used in old prosthetic patients, but longer stems of the components are used to hold the new prosthetic parts in place. [4]

Knee Fusion

In a knee fusion surgery the ends of the femur and tibia bones are cut off, ligaments and the menisci are removed, and the two bones are fused together. The benefit to this is a secure and pain-less joint. But the leg is often several inches shorter than before. This procedure is often performed on patients who suffer from joint infection or bone tumors. Sometimes this fusion can eventually be replaced with a bendable knee later, which allows the patient to experience some movement in the knee again. [4]

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Figure 2. Model of a total knee replacement prosthetic.

Uni-Compartmental Knee

This type of prosthetic is also referred to as a partial knee replacement because only one

compartment of the knee is replaced. One of three joints is replaced: the inner joint (medial), outer joint (lateral), or joint under the kneecap. This surgery is used for patients who suffer from osteoarthritis that is found in one part of the knee. Since other joints are capable of being weight only one joint needs to be replaced. [4]

Cardiovascular System

The cardiovascular system is composed of the heart, blood, arteries, veins, and capillaries in the body. This network of blood vessels can be thought of as a roadmap. There are two major networks of highway systems, arteries and veins. [6] The arteries are red and they carry oxygen rich blood away from the heart, while veins are blue and they take de-oxygenated blood back to the heart. Capillaries are small blood vessels that allow for blood to exchange important resources with cells throughout the body. Blood serves as the body's liquid messenger and it carries oxygen, food, and waste. [6]

The heart is the main organ of the cardiovascular system and it is responsible for pumping or pushing blood throughout the entire body. A child's heart is about the size of a fist and an adult heart is about the size of two fists. [6] It is broken down into four distant chambers or compartments. The two upper chambers are called atria and the two lower chambers are called ventricles. There is a left and right side to the heart. Oxygen poor blood is pumped from the right atrium through a valve to the right ventricle and then through another valve into the pulmonary vein. The pulmonary vein is connected to the lungs, which provide blood with oxygen. Once oxygenated, blood is pumped back into the heart through the pulmonary arteries into the left atrium. A valve opens and blood is sent into the left ventricle. From there, blood is sent to the aorta. The aorta offers a network of branches that are responsible for sending oxygenated blood to the rest of the body. [6]

The heart can be listened to using a stethoscope. And the lub dub sound it makes is caused by the opening and closing of the valves discussed above. The lub can be heart when blood is pushed out of the heart and into the body. The dub is the sound of the heart reloading with blood. [6] This vital organ beats about 100,000 times a day, which is equal to about 35 million times each year. [6] In an average lifetime a human heart will be almost 2.5 billion times. [6] This engine-like wonder never stops, even at rest, the muscles of the heart work twice as hard as leg muscles running at a sprint. [6]

Heart Health

With all the heart does for the body, it is imperative that the heart remains healthy. There are a variety of problems that can occur with the heart or blood vessels that feed into and out of it. Some major heart problems include cholesterol and plague build up. [6] The liver produces cholesterol; it is also found in the meet and dairy products we consume. Too high of cholesterol can lead to endothelial tissue dysfunction, fatty streak

build-up, and eventually advanced lesions, also known as atherosclerosis. [6] This plaque builds up in the coronary arteries can block blood flow and oxygen to the heart. It can be diagnosed with non-invasive imaging or measuring body fat content. Basic interventions include a healthy diet, exercise, plenty of sleep, and a low stress environment. [6] When this does not work stenting is the best option. Doctors often use a balloon angioplasty and stenting to repair this. One of the main issues with this procedure is stenosis and re-stenosis. Stenosis is the natural build up of cells on the stent. [6] Engineers are currently working on solutions to this problem. Some possible solutions are making biodegradable stents, coating stents with polymer drugs that release anti-inflammatory drugs, magnetic stents that attract magnetized stem cells to make endothelial cells, and finally tissue engineered blood vessels. [6]

Cardiologists, or physicians that treat problems within the cardiovascular system, are also extremely interested in helping people recover from heart attacks. [4] Heart failure affects more than 5.8 million people in the United States. [13] And according to the World Health Organization cardiovascular disease is the leading cause of death worldwide. [13] Hundreds of thousands of people suffer from heart attacks each year, also known as a myocardial infarction. [13] A heart attack can occur when one or more of the coronary arteries become blocked and blood is thus unable to pass to the necessary heart tissue. [4] When this happens, muscle of the heart either dies or is damaged. [4] If too much muscle dies, people can develop congestive heart failure. [4] Patients with this condition have a difficult time supplying blood to their body, making it extremely difficult to exercise or perform physical labor. [4] Physical activity causes people with congestive heart failure to feel symptoms such as, fatigue, swelling of the hands, feet, and abdomen, and shortness of breathe. [4] It is extremely important that the left ventricle of the heart work properly because it is this chamber that supplies blood to the entire body. [4] Patients with blockages or damages to the left ventricle are often most in need of repair or regeneration therapy. [4]

Repair and Regeneration of the Heart

Scientists and doctors have had great success in helping patients prevent heart attacks from happening in the first place, but repairing the muscle itself after a heart attack has occurred is a difficult task. [4] Recently have observed stem cells at the site of tissue damage after a heart attack. [4] These stem cells appear to help the heart repair, but they only last for a few days and are unable to offer more than minor repairs. [4] Scientists then became interested in increasing stem cell numbers at the location of tissue damage. Their hope was that these stem cells could help patients' hearts recover after a heart attack. [4]

And in fact they were right in their hypothesis! Initial trials have shows that stem cells can increase vascularization in the heart, or the number blood vessels in the heart tissue. [4,14] Stem cells also possess the ability to differentiate or become new heart muscle cells. [14] And finally stem cells can prevent other heart cells from being damaged and assist in overall recovery. [4,14]

The question now becomes how do doctors get stem cells into the heart after a heart attack. Two clinical trials are currently underway to answer just that. [4] Both trials are in phase 1, which means researchers are just in the second step of five-step process for getting approval from the FDA for a new therapy or prescription drug. [4] There are still two more sets of clinical trials that would need to be conducted before patients could have access to either of these therapies. [4] The drug development stages include: Pre-clinical development – invention of the drug, Phase I – initial safety test, Phase II – tests efficacy in humans using small trials, Phase

III - further tests in efficacy in humans using large trials, and Phase IV – post-marketing safety and efficacy studies. All together this process can take anywhere from 9-17 years. [6]

One therapy involves removing stem cells from the patient's bonne marrow and injecting them directly into the heart. [4,14] Once in the heart, these stem cells can repair heart tissue just like the ones naturally found there after a heart attack. [14] On the other hand, the second therapy seeks to use the body's natural repair system and signals, but increase the time and strength of the signals so more stem cells are recruited to the hear to assist in repair. [11]

Injecting Bone Marrow Stem Cells

Stem cells for this therapy are collected through a bone marrow aspiration or bone marrow transplant. [4] The bone marrow is harvested from the hip using a thin needle. [4] After the bone marrow is sent to the lab where the bone marrow is centrifuged, separated out, and cleaned. [4] The stem cells that are sent back are ready to be injected back into the patient through catheterization. [4] Catheters are tubes that are inserted into arteries. [6] In this procedure the right femoral artery in the upper thigh is often used to get the stem cells back up into the aorta, across the aortic valve, and then into the left ventricle. [4] It is imperative that no arterial wall is punctured; otherwise the patient could suffer internal bleeding. [4] Doctors use contrast dye to determine the damaged heart tissue and carefully inject the stem cells to the site. [4] Finally, doctors use an echocardiogram to see if any small holes, or perforations were caused during surgery. [4] An echocardiogram uses sound wave to produce an image of the heart. Patients who undergo this procedure are carefully monitored for four months to measure results. [4]

Increasing SDF-1 Signals

The second therapy uses the body's immune system, or built in repair system, to fix the heart. [4] As noted above, the heart already sends stem cells to the site of muscle tissue damaged by a heart attack, but too few are sent and they remain for too short of a time. [4,11] Now doctors are seeking to increase the number of stem cells that are sent to the site in need of repair and increase the time they remain there. [4,11] The body sends out this same type of signal when any damage occurs including cuts, bruises, or sprains. This signal called a stromal cell derived factor 1 or SDF-1 signal recruits adult stem cells (stromal cells) to a site in need of repair. [11] The problem lies in the fact that the body only produces SDF-1s for a few days after a heart attack and if SDF-1 was injected into the heart it would still only last a short period of time. Scientists therefore needed to figure out a way to get the heart cells to produce more SDF-1 on its own. [11]

Research has shown though that by injecting a plasmid, or ring of DNA, with specific instructions to produce SDF-1, heart cells can make more SDF-1 themselves. [4,11] Initial research on mouse hearts shows that SDF-1 plasmids injected into cells can cause the to continue to release the signal for up to 20 days after the original injection. [4,11] In this procedure the right femoral artery in the upper leg is again used to inject the plasmids up into the aorta, across the aortic valve, and then into the left ventricle using catheterization. [4] The same precautions are used to make sure the arterial walls are not punctured, contrast dye is also used to find damaged heart tissue, and an echocardiogram again checks for perforations or tears. [4] Patients that undergo either procedure require careful monitoring for four months. [4]

Aortic Aneurysm Repair

An aneurysm is a balloon-like bulge in an artery. [17] Arteries are blood vessels that carry oxygen-rich blood to the body and they therefore have generally thick walls. [6] However, extreme pressure can weaken the walls and cause and aneurysm. When an aneurysm grows large enough it can rupture and cause dangerous internal bleeding. [17]

images/2014/4/14.04.10.03.jpg

Figure 3. Diagram of an aortic aneurysm. Section A shows a normal aorta. Section B shows a thoracic aortic aneurysm (located behind the heart). Section C shows an abdominal aortic aneurysm located below the arteries that supply blood to the kidneys. Based on public domain photo courtesy of the National Institute of Health, 2010.

Most aneurysms occur in the aorta, the main artery that carries blood from the art to

the rest of the body. [17] An aneurysm that occurs in the chest portion of the aorta is called an thoracic aortic aneurysm, while an aneurysm found in the abdominal cavity is called an abdominal aortic aneurysm (See Figure 3). [17] About 13,000 Americans die each year from aortic aneurysms. [17] When found in time, doctors can often treat aneurysms with medicine or surgery. During surgery, weakened or damaged parts of the artery are replaced (open abdominal or open chest repair) or reinforced (endovascular repair). [17] During open abdominal or open chest repair the aneurysm is removed and that section of the aorta is replaced with a graft (stent) made of material such as Dacron or Teflon. [17] During endovascular repair the aneurism is not removed. [17] Instead, a catheter is used to insert a graft into the aorta to provide strength. [17] Once the stent reaches the site of the aneurysm it is expanded and fixed in place. This graft helps to reinforce the weak section of the aorta and hopefully prevent it from breaking. This endovascular procedure does not work for all aneurysms though, it depends on their location and size. [17]

Teaching Strategies

Cool STEM Careers [8,16]

One of the things that drew me most to a unit focused on engineering in the fields of biology, health, and medicine is the ability to expose my students to even more opportunities available to them through STEM careers. My students are knowledgeable about many careers in science and mathematics, but often don't gain as much exposure to careers in technology and engineering. My female students in particular often shy away from showing interest in STEM careers. I found two websites to meet this problem called Engineer Your Life (http://www.engineeryourlife.org) and Engineer Girl (http://www.engineergirl.org). [8,16]

Edheads [4]

What is Edheads?

Edheads is a non-profit organization that provides free high-quality Internet activities educational activities for teachers and students. I've already found that this innovative and unique learning experience was highly motivating for my students. It makes hard-to-teach and difficult science, technology, engineering, and math concepts understandable and exciting for students. And by promoting exploration beyond the classroom we, as teachers, can increase life-long interest in science and science careers. This site is growing rapidly as more funding becomes available, so continue to check it regularly for brand new activities. [4]

Bringing Edheads into the Classroom

All the activities at the Edheads site also have connections to National and State standards under each of the activities teacher section. You can look for these standards under the heading "Teacher's Guide" for each activity. The Teacher's Guide also contains recommended grade levels, tips for using the site with students, student handouts, quiz questions and answers, class discussion questions, and wonderful follow-up activities. This is also a glossary available for each activity to build student vocabulary. [4]

Students can complete these activities by working individually or in groups of two o three. Please note: These activities do depict real surgeries and several contain graphic photographs and procedures. Some students may feel queasy during these activities. As a result, students should be closely monitored while experiencing these activities, especially when experiencing this site for the first time. Below you will find a variety of recommended activities for students to try out using a computer lab or mobile computer lab in your classroom. You might also find it helpful to assign some of these activities as extension activities for students to try at home. [4]

Musculo-Skeletal System Repair and Regeneration Activities

Each of the following activities will allow students to play the role of surgeon. Students will learn about a variety of procedures patients undergo each and everyday. At the same time they will gain an understanding of medical technology, and health risks and benefits to each surgery. [4]

Choose the Prosthetic – Students become orthopedic surgeons as they assist a doctor in selecting the appropriate knee replacement and perform surgery on five patients. [4]

Virtual Hip Replacement Surgery – Students take on the role of a surgeon and complete a hip replacement surgery. [4]

Virtual Hip Resurfacing Surgery – Students again act as a surgeon and perform a hip resurfacing surgery. [4]

Virtual Knee Replacement Surgery – Students become surgeons and aid in a total knee replacement surgery. [4]

Cardiovascular System Repair and Regeneration Activities

Aortic Aneurysm Surgery – In this activity, students help Dr. Dixon repair a weakened aorta using grafts by performing an abdominal aortic aneurysm surgery. [4]

Stem Cell Heart Repair – Student compare two different stem cell medical therapies to see if they can be used to repair the human heart. This research is currently in clinical trials to be approved for further use by the Food and Drug Administration (FDA). Students help determine which therapy will produces the best result for

patients. [4]

The below Create a Stem Cell Line activity is a great way for students to gain background knowledge on stem cells if you do not cover this topic in your classroom. If you do cover stem cells then it is a great re-teaching or refresher activity. I highly suggest having students complete it if you plan to use the Stem Cell Heart Repair activities in your classroom. The other activity Stem Cell Transplant is a great extension activity and has student see how stem cells are currently being used to treat leukemia. These three stem cell activities can be used together or individual as you see best to meet the needs and interests of your students. Each activity provides students with examples of how stem cells are currently being used and it also sheds light on future areas of impact for stem cells in human medicine. [4]

Create a Stem Cell Line – This activity is an introduction to stem cells. It explains what they can do and teaches students the vocabulary used by stem cell biologists. [4]

Stem Cell Transplant – Students apply their knowledge of stem cells to help scientists perform a stem cell transplants. [4]

Other Edhead Activities Related to Engineering in Biology, Health and Medicine

The following activities relate to the field of engineering in biology, health, and medicine, and would serve as extensions or expansions of my current unit topic, which focuses specifically on the human musculo-skeletal and cardiovascular system. [4]

Deep Brain Simulation – Students perform brain surgery and help Dr. Mei cut, probe, and drill into the brain in order to help her patient cope with Parkinson's Disease. [4]

Nanoparticles and Brain Tumors – Students help develop nanoparticles with Dr. Winter. By using these extremely small particles Dr. Winter hopes to find a way to mark brain tumors so doctors can better see them during diagnosis and surgery. Therefore this nanoparticle must be magnetic, florescent, and small enough to pass the blood brain barrier. [4]

Sickle Cell DNA – Students can help a family determine if they might be a genetic carrier for sickle cell anemia, which is a genetic mutation of blood cells. [4]

COSI Surgical Suite: Total Knee Replacement Video Conference Program [15]

Columbus, Ohio's Center of Science and Industry (COSI) seeks to inspire future scientists, inventors, and dreamers. They offer an amazing opportunity for students to experience a real surgery in real time through the COSI Surgical Suite: Total Knee Replacement Video Conference Program. Students can watch a surgery through videoconference equipment and then ask questions to the surgeon and other medical personnel throughout the surgery. More information is available at this URL: http://www.cosi.org/educators/educator-ivc/item/total-knee-replacement#. There is a cost associated with the video conference of anywhere from $285-$325, but this cost does include a kit of materials so students can conduct both pre- and post-activities such as building a knee joint, diagnostic x-rays, treatment options, and suture knot tying. [15]

NY Med [9,10]

The program *NY Med* has become a hit primetime show on the ABC television network. This unique reality show gives an in-depth look at medicine through the eyes of some of New York's top surgeons and their patients. The show offers a mix of scheduled procedures and ER cases from the straight from the streets of one of America's most violent cities. ABC posts full episodes for viewing on the NY Med section of their website (http://abc.go.com/shows/ny-med). [9,10]

The episode "Doctors Work to Save the Lives of Their Patients" offers direct connections to this unit on repair and regeneration of the human musculo-skeletal and cardiovascular system. [9] For example, one of the patients was told by a previous surgeon that she was inoperable due to the large tumor on her heart. Dr. Girari attempts surgery that others say is impossible and uses new medical techniques while doing so. Another patient suffered from a sudden stroke while on vacation with his family and Dr. Oz performs surgery to repair a hole in his patient's heart. [9] Another episode, "The Frontlines of Life Saving," shows how innovative surgery is used to repair a ruptured aorta. Viewers also see a kidney transplant and discover how donors are often found. [10] Either of these episodes would serve as great real-world connections for students. Students often get fixated on the soap-opera medical shows and don't see the real drama in medicine itself. I believe NY Med will allow some students to really connect with biology, medicine, and health. [9,10]

Prosthetic Party [12]

Through this activity students have the ability to put there own biomedical engineering ideas to the test. Students can work together in small teams of two or three students to create models of prosthetic lower legs. Each team should seek to create the best proshetic leg possible using household materials. [12]

Materials

Students should have access to a yardstick, scissors, duct tape. For the leg structure students could use: plastic pipes, metal pipes, cardboard tubes. For comfort students could add: sponges, bubble wrap, cardboard. For life-likeness: bath towels, pans, shoes (students can use their own). And for attachment: string, rope, or twine. [12]

Procedure

1. Divide students into groups of two or three.
2. Conduct a pre-activity discussion, in which students brainstorm prosthetic materials and qualities of a good prosthetic.
3. Compare and contrast the engineering design process to the scientific method.
4. Give students time to brainstorm the design of their lower leg prosthetic.
5. Groups should decide which teammate the prosthetic will be made for and materials should fit to where the student's knee bends. 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.
6. Allow students to use materials to design a strong, stable, comfortable, and life-like lower leg

prosthetic.
7. Once all groups are finished designing their prototype they should present their prosthesis to the rest of the class. During their presentation, students should explain their design process, the relational behind their materials, and demonstrate its strength by having the student walk with it. [12]

Broken Bones and Biomedical Materials [2]

Another activity to get students involved and using the engineering design process is having them design a cast. The problem for this activity is a fellow 7 th grade student has broken his fibula. The cast he has is extremely itchy and he still has five more weeks before the bone in his leg heals. He would like the class of engineers to help him design a new cast to fix the problem. A fun way to get the students excited about this hands-on project is to actually create a hand written letter from a make believe student asking for help from the Engineers at "Casts R Us." Another key feature to this activity is creativity. Students will be given everyday materials, but they can use the materials to represent any material they want, even materials that have not yet been developed. As long as students defend and describe the properties of the materials they choose they should get credit. [2]

Materials

This project can be completed with Play-Doh, Popsicle sticks, recyclable materials (fabric, cotton, egg cartons, toilet paper or paper towel roles, toothpicks, plastic bottles, milk cartons, rubber bands, straws, plastic tubing), poster board, markers, and a scale. [2]

Procedure

1. Review with students the job of biomedical engineers and introduce the problem for the engineers at "Casts R Us."

2. Explain to students that they will have to construct a prototype of cast that is less than 300 grams, be stable enough to hold a "broken bone," and must seek to solve the initial problem of itchiness. Students can have the freedom to bring in their own materials from home if they wish. Remind students they can use materials to represent other materials they invasion or brainstorm, but they must explain their rationnel.

3. Give students time to brainstorm their cast, provide paper for sketches to be made, and allow students to begin constructing their prototypes.

4. Since prototypes can be designed with materials students create in their heads the project should be physically evaluated simply for meeting the mass requirements and stability.

5. The final portion of the evaluation comes from their ability to communicate their solution to the rest of the co-workers and their boss (you) at "Casts R Us." Explain to students how important it is for engineers to be able to share their ideas with others. Students should create a poster presentation and 3-5 minute sales pitch of their cast prototype. [2]

Poster Project

To share their cast prototype with the class students should create a poster to explain their design. The following topics could be included on the poster: engineering design process, problem the group was trying to solve, sketches of the design, description of the prototype, list of materials, description of materials (mass, flexibility, strength), evaluation and analysis describing how cast solves original problem, and possible improvements. [2]

Appendix A. Implementing District Standards

Current Connecticut Standards

Content Standards

Structure and Function – How are organisms structured to ensure efficiency, stability, and survival?

Standard 7.2 Many organisms, including humans have specialized organ systems that interact with each other to maintain dynamic internal balance.

> 7.2.a – All organisms are composed of one or more cells, each cell caries on life-sustaining functions.
> 7.2.b – Multicellular organisms need specialized structures and systems to perform basic life functions.

This unit addresses the Connecticut Content Standards related to Structure and Function. More specifically it seeks to answer the question: How are organisms structured to ensure efficiency, stability, and survival? It addresses Connecticut Science Standard 7.2.a and 7.2.b. Some additional core science curriculum frameworks standards that could also be added include the idea that multicellular organisms need specialized structures that match their function. These specialized structures work together cooperatively to achieve the basic life functions. And a change in these structures at the basic level can impact function and a change in the network of structures can also compromise form and function. As such, I aim to connect these various components and use ideas from engineering to show how the system stabilizes and performs various tasks.

CMT Expected Performances

C INQ.9 Provide explanations to investigated problems or questions.

C INQ.10 Communicate about science in different formats, using relevant science vocabulary, supporting evidence, and clear logic.

C 15. Describe the basic structures of an animal cell, including nucleus, cytoplasm, mitochondria and cell membrane, and how they function to support life.

C 16. Describe the structures of the human digestive, respiratory and circulatory systems, and explain how they function to bring oxygen and nutrients to the cells and expel waste materials.

C 17. Explain how the human musculo-skeletal system supports the body and allows movement.

Current New Haven Curriculum Standards

Grade-Level Expectations

Students should be able to:

1. Compare and contrast living organisms that are single celled with multicellular organisms.

2. Illustrate and describe in writing the structure and the function of the cell membrane, cytoplasm, mitochondria and nucleus in an animal cell.

3. Explain how the structure and function of multicellular organisms (animals) is dependent on the interaction of cells, tissues, organs and organ systems.

4. Investigate and explain in writing the basic structure and function of the human skeletal system.

5. Differentiate between the structures and range of motion associated with ball, socket and hinge joints and relate human joints to simple machines.

6. Demonstrate how the muscles, tendons, ligaments and bones interact to support the human body and allow movement.

7. Label the major parts of the human respiratory system and explain in writing the function of each part (nasal cavity, trachea, bronchi, lungs and diaphragm).

8. Label the major parts of the human circulatory system and explain in writing the function of each part (heart, veins, arteries and capillaries).

9. Design and conduct controlled variable experiments to analyze the interaction between the circulatory and respiratory systems as the demand for oxygen changes.

10. Label the major parts of the human digestive system and explain in writing the function of each part in the

chemical and physical breakdown of food (mouth, esophagus, stomach, small intestine, large intestine and rectum).

Bibliography

[1] "Advances in Skeletal Muscle Tissue Engineering." New Harvest Journal Club, last modified December 12, 2013, http://www.new-harvest.org/2013/12/advances-in-skeletal-muscle-tissue-engineering-in-vivo/. A summary of current advances in skeletal muscle tissue engineering.

[2] "Broken Bones and Biomedical Materials," Center for Engineering Educational Outreach, Tufts University, last modified July 21, 2014, http://www.teachengineering.org/view_activity.php?url=collection/wpi_/activities/wpi_broken_bones/bones_sue.xml. Students become part of the engineering design process as biomedical engineers charged with the task of designing a cast for a broken arm.

[3] "Curriculum Unit: Biomedical Engineering and the Human Body," Integrated Teaching and Learning Program, College of Engineering, University of Colorado, last modified July 21, 2014, http://www.teachengineering.org/view_curricularunit.php?url=collection/cub_/curricular_units/cub_biomed/cub_biomed_curricularunit.xml. This unit focuses on a series of hands-on activities relating to seven of the human body systems.

[4] Edheads. (Edheads.org, 2014), http://www.edheads.org (accessed May 21, 2014). An interactive website that allows students to engage in science activities that promote critical thinking skills through virtual exploration. Some activities include Virtual Knee Surgery, Stem Cell Heart Repair, and Sickle Cell DNA tests, among many others.

[5] "Engineering Bones," Integrated Teaching and Learning Program, College of Engineering, University of Colorado, last modified July 21, 2014, http://www.teachengineering.org/view_lesson.php?url=collection/cub_/lessons/cub_biomed/cub_biomed_lesson01.xml. This resource provides an overview of the skeletal system and biomedical engineering design.

[6] Fahmy, T. "Seminar 4: Blood and Circulation." Presentation at the Yale New Haven Teachers Institute Engineering in Biology, Health, and Medicine Seminar, New Haven, CT, June 3, 2014. In this seminar Tarek Fahmy discusses basic biology of blood and circulation and explains current engineering techniques used for intervention and diagnosis.

[7] Häggström, Mikael. "Medical gallery of Mikael Häggström 2014". *Wikiversity Journal of Medicine* 1, no. 2 (2009). http://commons.wikimedia.org/wiki/File:Stem_cell_treatments.svg#mediaviewer/File:Stem_cell_treatments.svg. (accessed July 1, 2014). This image shows areas that are currently being researched in the field of stem cell therapy. This image is in public domain and licensed under Public domain via Wikimedia Commons.

[8] Miller, J. "Meeting Inspiring Women," Engineering Your Life, http://www.engineeryourlife.org/cms/6167/6194.aspx?eylprofile=Video (accessed July 2, 2014). This video highlights Jessica Miller who designs life-saving medical devices for the heart.

[9] NY Med. "Doctors Work to Save the Lives of Their Patients." ABC's NY Med video, 42:28. July 10, 2014. http://abc.go.com/shows/ny-med/episode-guide/season-02/203-ny-med-710-doctors-work-to-save-the-lives-of-their-patients. In this episode of NY Med surgeons work to save the lives of patients suffering from a plane crash, bladder cancer, a tumor on the heart, and an aneurysm.

[10] NY Med. "The Frontlines of Life Saving." ABC's NY Med video, 40:52. July 25, 2014.

http://abc.go.com/shows/ny-med/episode-guide/season-02/205-ny-med-724. In this episode of NY Med surgeons work to save the lives of a patient who is about to have her aorta rupture and a woman who needs a kidney transplant.

[11] Penn, M.S., Pastore, J., Miller, T., and Aras, R. "SDF-1 in Myocardial Repair." *Gene Therapy* 19 (2012): 583-587. This article explains the SDF-1 stem cell therapy techniques currently being used to induce cardiac repair.

[12] "Prosthetic Party," Integrated Teaching and Learning Program, College of Engineering, University of Colorado, last modified July 21, 2014, http://www.teachengineering.org/view_activity.php?url=collection/cub_/activities/cub_biomed/cub_biomed_lesson01_activity1.xml. Students investigate biomedical engineering by creating their own prosthetic of the lower leg using a variety of materials.

[13] "Regenerating Heart Tissue Through Stem Cell Therapy," *Discovery's Edge* , Mayo Clinic's Online Research Magazine 9, no. 1 (2011). http://www.mayo.edu/research/discoverys-edge/regenerating-heart-tissue-stem-cell-therapy (accessed July 12, 2014). This article describes a new stem cell therapy that aims to repair damaged heart tissue using a patient's bone marrow.

[14] "Stem Cell Therapy for Heart Disease," Diseases & Conditions, The Cleveland Clinic, last modified January 1, 2014, http://my.clevelandclinic.org/heart/disorders/heartfailure/stemcells.aspx. This article discusses how stem cell therapy is currently being used in clinical trials to see if a patient's own stem cells found in their bone marrow can be used to a help damaged heart heal itself.

[15] "Surgical Suite: Total Knee Replacement," *Center of Science and Industry* (COSI, 2013), http://www.cosi.org/educators/educator-ivc/item/total-knee-replacement# (accessed July 20, 2014). Through this 90 minute experience student have the ability to participate in a live total knee replacement surgery through an interactive platform with the surgeons and other medical personnel in a hospital operating. Students have the ability to watch the surgery in real time and ask questions.

[16] "Try on a Career." EngineerGirl, last modified January 1, 2014, http://www.engineergirl.org/33.aspx. Students have he opportunity to explore careers in engineering and learn about the education, life style, skills, and salary to see which match their individual interest and talents.

[17] "What Is an Aneurysm?" The National Heart, Lung, and Blood Institute, last modified April 1, 2011, http://www.nhlbi.nih.gov/health/health-topics/topics/arm/. This article provides and overview of aneurysms and also describes types, causes, risks, signs and symptoms, treatments, and prevention.