Abstract

This Robots in Healthcare: From Science Fiction to Reality seminar introduced many facets of medial robotics rehabilitative care. This curriculum unit utilizes hands-on explorations of prosthetics and math to create new body part prototypes for medical rehabilitation. The curriculum unit from this seminar will bring real-life mathematics into the classroom and teach students the engineering design process, Students will create a prosthetic finger, hand and lower arm; experiment with different materials and mapping movement using math. The new knowledge that students gain from the lessons will enable them to relate the subject matter to math in new and exciting ways.

Keywords: medical robotics, mathematics, algebra, word problems, linear equations, movement, engineering design, prosthetic

Gearing Up for Prosthetics

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Rationale

The seminar “Robots in Healthcare: From Science Fiction to Reality” considered robots in the medical field. Many of the topics were science fiction ideas in the past but today are a reality in medical rehabilitation. Whether the task was to replace a missing limb or restore a motor skill lost due to injury or to assist the therapeutic needs of seniors or autistic children, robot designs are inspired by the biology and function of humans and animals. The goal of the seminar was to explore the design and function of robots in medicine and healthcare. It explored how robots work; what animal, human part or function inspired them; how they enhance human function; and how they shed light on human frailties. The activities were designed to show how robot designers use biomimicry to create their robots, how robots sense, think and act on their environment, and how they are being used to advance the healthcare field.

Robots are used to increase a human’s power, improve their precision, and extend their capabilities. The seminar incorporated STEM (Science Technology Engineering and Math) knowledge as it relates to the design, evaluation and use of robots in industry. There are many reasons why a curriculum unit focused on robotics and medical robotics would be beneficial to students.

Learning engineering and math will increase student interest in attending my school and improving retention of their learning. I am an appointed mathematics teacher at the Philadelphia High School for Girls, a magnet, high school within the School District of Philadelphia. Students apply and are admitted from all Philadelphia neighborhoods and ethnicities of the city having matriculated at private, parochial, magnet, and neighborhood middle schools and charter schools. The Philadelphia High School for Girls has a rich history of academic excellence and a tradition of sisterhood and extra-curricular athletic and scholastic programs. Founded in 1848 to "prepare teachers for the common schools of Philadelphia,” Girls’ High, as it is affectionately known, was the first municipally supported secondary school for girls in the United States and was called the Girls' Normal School. In 1893, the Philadelphia High School for Girls separated from the Girls' Normal School, and the foundation for today's college preparatory curriculum was laid. The school continues to exist as a school for the academically talented, providing young women with outstanding opportunities for scholarship, leadership, and service. Its' motto, "Vincit qui se vincit" (He conquers who conquers himself), is embodied in the Code of Honor and Courtesy written by students early in this century. (Cutler, 2013). Prior to Central High School, another Philadelphia magnet high school, becoming co-ed, Girls' High was the only magnet high school for high achieving female students. Today, with more choices for high school matriculation, the programs and experiences we provide effect the students we can attract. Expanding our offerings using medical robotics will make us more attractive to potential students.

Robotics and medical robotics will help expand the types of course offerings students encounter: The Philadelphia High School for Girls offers programs which attract students across all grades. In addition to an extensive group of AP courses and a vibrant IB curriculum, the school established a STEM program in the early 2000's to broaden partnerships with nearby universities and businesses. This program serves as a collection of STEM initiatives championed by Girls' High mathematics and science teachers. These programs include in-school presentations, summer collegiate opportunities, after school clubs and competitions. The robotics team falls under the STEM umbrella. It is a competition program restarted in September 2016 which allows students to learn engineering principles, computer programming and computer aided design, while building a robot of their own design to meets competition guidelines established yearly by the competition sponsor. The Robots in Healthcare seminar was rich in robotics material and will enhance both my classroom and after school robotics students. Robotics will be woven into my classroom through the curriculum unit and in the robotics team through computer programming, 3-D modeling and enrichment using the Arduino microprocessor.

This curriculum unit will bring the knowledge of medical robots to my students. In the unit students will create robots that mimic real life functions. I am fascinated with robotics. Since 2004, I have been involved in after school competition robotics programs. This seminar focusses on a very human issue, robots in medicine and healthcare and provides formal content on engineering design and applying it to real life situations. The unit will teach students the engineering design process, create body replacement parts and use math to determine how it moves. The new knowledge that students gain from the lessons will enable them to relate the subject matter to math in new and exciting ways.

Real world investigations help my students see math in everyday situations and relate engineering to biology and the human body. This curriculum unit explores three subjects: the engineering design process in the classroom, the mathematics of robot movement, and medical design: robotic arms, hand and/or fingers. The engineering design process, like the scientific process used in science fair projects, provides the basis for organizing thoughts and design ideas. The mathematics of robot movement provides the link between math and engineering as students explain how and why their creation works. The reflection on medical design relates the real-life application their design achieves. Using math and science together, students will see themselves having fun using math and science increasing the possibility they will seek STEM careers.

Background

This seminar, Robots in Healthcare: From Science Fiction to Reality seminar curriculum unit teaches not only math but also introduces how math is used in engineering to create new parts for medical purposes. Students' learning experiences will be enriched by engaging in real life engineering work. The unit brings math to light in a real-world sense by considering movement as it relates to robotics. The curriculum unit from this seminar will bring real-life mathematics into the classroom using the medical rehabilitation concept: prosthetics.

The importance of authentic educational experiences and STEM education is evident in High school students' questioning how school and the material they are learning relate to the real world. Math with its abstract reasoning and unique language, seem irrelevant to the future goals of students. Science and math, the language of science, are two subjects with the lowest achievement indicators particularly when measured by standardized tests. These low success indicators effect the number of students pursuing college degrees and careers in Science, Technology, Engineering and Mathematics (STEM). As a nation a new emphasis has been established to increase the number of STEM professionals. This general emphasis also extends aggressively to racial minorities and other under-represented populations in the STEM fields. (Berube, 2014)

Robotics in Healthcare

The Robots in Healthcare: From Science Fiction to Reality" seminar provided an overview of robots in healthcare in three applications areas; assistive devices, rehabilitation technology, and medical devices. These areas were further divided into: Robots Fundamentals: Sensors, Motors, Microprocessors; Robots in education – robot and design toolkits; Robot Inspirations: Humans to Humanoids and Animals to Animaloids; Rehabilitation Robots Areas: prosthetics/orthotics, wheelchairs, technology-mediated exercise, and design for special populations (pediatric and elderly), exoskeletons; Medical Robot Areas: Surgery, Simulation, and Devices (e.g., heart). The focus of this curriculum unit is medical robotics and prosthetics.

When society discusses health and healthcare they frequently focus on diet and wellness and their effects on disease and wellness rather than injury and rehabilitation.

This is for good reason as non-communicable diseases accounted for 68% of all deaths globally in 2012 and is expected to increase to 73% by 2020.

Non-Communicable Diseases (NCDs)

- The four main NCDs are cardiovascular diseases, cancers, diabetes and chronic lung diseases.
- Communicable, maternal, neonatal and nutritional conditions collectively were responsible for 23% of global deaths and injuries caused 9% of all deaths.

Source: World Health Organization

Four Non-communicable Diseases

The four main non-communicable diseases, (NCDs), are cardiovascular diseases, cancers, diabetes and chronic lung diseases, contribute to other debilitating conditions for which rehabilitation needs can be high. Debilitating conditions caused by diseases such as stroke (ambulatory issues, speech, quality of life) and amputations due to diabetes, create a need for higher levels of rehabilitative services. The US population, particularly the boomer generation is aging while life expectancy is increasing.

Age and the prevalence of disability show a positive correlation therefore as the population ages, their need for assistive devices due to disability also increases.

Rehabilitation medicine provides physical medicine and rehabilitation to serve the disabled. Physical medicine provides diagnosis and treatment using medicine, exercise and procedures to treat musculoskeletal disorders while physical therapists, doctors and engineering development provide supports to make the disabled person “maximally able” again. The treatment plan today involves a patient -centered, multi-disciplinary team for treatment. Rehabilitation engineering and medical device design require a personal fit to the patient and the places they live work and play. It relies on the social and political regulations and can be successful when all stakeholders work together.

Rehabilitation Classifications

People needing rehabilitation are classified in five target groups: traumatic injuries (amputation/limb loss, brain injury (due to falls, motor vehicle accident etc.), and spinal cord injury); non-traumatic injuries sustained from cardio-vascular disease and cardio-vascular accidents (strokes); pediatric injuries and diseases such as vertebral palsy and autism; degenerative diseases such as multiple sclerosis and Parkinson’s disease; and diseases from aging such as dementia and Alzheimer’s disease.

The rehabilitation needs, and the millions of dollars needed to create the supports create fertile ground for medical rehabilitative and robotic devices. Robotic devices such as that interact with patients as well as those that assist patients or even replace missing limbs are all used to make life better for those in need.

Prosthetics

Prosthetics whether simple or robotic are defined as artificial devices used to replace a missing body part, such as a limb. It must attach to an existing human stump of shoulder, must be light weight and will perform a function that the patient cannot accomplish without assistance. (Wikipedia, 2013).

Bodily needs that can ultimately result in needs for prosthetics range in diagnosis to include upper extremity and lower extremity diagnoses. Upper extremity diagnoses include the hand through complete the arm and the upper body. The cause of the diagnosis can be fractures, dislocations, crush injuries, joint replacements, over use injuries such as trigger fingers, tendon and/or ligament tears/repairs, pain, nerve and neuropathies, arthritis and rheumatic diseases and congenital anomalies.

Assessment of upper extremity diagnoses can include occupational therapy, physical therapy, rehabilitation (message, stretching) physical agent modalities (wax treatments, ultrasound), isolation of upper body therapies, and activities to strengthen the ability to perform daily living activities. Physical remedies can also include splints and orthoses.

Lower body diagnoses include the lower extremity of the body from the hip through the feet including the toes. The cause of the diagnoses is the same as upper extremities and can be fractures, dislocations, crush injuries, joint replacements, overuse injuries such as trigger fingers, tendon and/or ligament tears/repairs, pain, nerve and neuropathies, arthritis and rheumatic diseases and congenital anomalies. Assessment and treatment of lower extremity diagnoses typically fall in the physical therapy domain and include a treatment program of strengthening on treadmills, stairs, exercises for gait and stride, motor coordination, balance and paresis.

Lower Extremity solutions are very complex. Walking is a very complex event involving the coordination of center of gravity (balance), vision, soles of the feet, weight, gait and ankle movement. As the diagram below shows forward progression involves many factors.

Body relationships: Walking forward	Walking forward requires interaction of selective postures, muscular force and tendon elasticity. Once a person begins to walk forward the foot must pivot to provide forward movement and balance.

Amputations

The public frequently calls the loss of a limb by cutting amputation. In the medical profession amputation has a very specific definition. Cutting of an extremity whether whole or partial, through the bone is an amputation. Cutting the extremity in whole or part through the joint is considered disarticulation. There are many reasons for amputations: vascular disease, malignant tumors, trauma, congenital. The most common is peripheral vascular disease (90%) while congenital is the lowest (3%). The location of amputations is very strategic. Efforts are made to leave a lever whether upper or lower for increased movement and ability to accomplish normal tasks.

Customizing Prostheses

When amputations are necessary, the replacement with a prosthetic is customized for the patient. For the artificial limb to fit precise measurements are taken, the weight and size are calculated to be consistent with the patient. Prostheses designers consider ease of use and the degrees of freedom which is important for accomplishing everyday tasks.

Robotics Devices.

There are almost five million amputees in the United State and Europe alone. (Raspopovic, 2016). The introduction of robotic protheses has improved the quality of life for many patients. These newer devices such as the 6-DOF prosthetic arm increase the degrees of freedom, are sophisticated enough to do some of the lifting and rotating of extremities such as the wrist. Disadvantages are primarily weight since the new features increase the weight and resulting in fewer hours a person can wear it. Some patients have multiple prostheses each dedicated to tasks or situations: one aesthetic and one functional (Piazza, 2017).

New areas of prothesis research include technology allowing sensory feedback (touch, temperature and pressure), special sensors to power joints and provide movement and muscle reinnervation, (surgical procedures to redirect amputated nerves to healthy muscle) (Ahmadizadeh, 2017). Wearable exoskeleton also provides better materials for movement for lower extremity prostheses (Garate, 2016). Upper-limb prosthetics technology such as the reverb arm (partial hand technology) and i-LIMB fully articulating prosthetic hand give hope to patients for better products to meet their needs. (Fairley, 2009). Innovative prosthetic hand designs are rare given they lower demand versus lower extremities ((Cipriani, 2011).

The Engineering Design Process

New prosthetic designs are created by engineers using the engineering design process. This prescribed process is a series of steps that guides engineering teams as they solve problems. The design process is iterative, meaning that the steps are repeated as many times as needed, making improvements along the way as we learn from failure and uncover new design possibilities to arrive at great solutions.

1. Define /State the Problem: An engineer's job is to develop solutions to problems so there are a lot of detailed discussions until a complete definition of the task is clearly articulated. Before students start to build the project the first step is to state the problem. This requires a complete understanding of the assignment. The teacher's instructions are an important part of information gathering for the assignment. Students should consider questions such as: What is the problem we are asked to solve? What do we want to design? Who is it for? What do we want to accomplish? What are the project requirements? What are the limitations? What is our goal? In this step research to understand the category or industry is recommended. Student research might include, talking to people working in the field, reading articles finding examples of products or solutions already exist, or learning about what technologies are related to the problem.

2. Generate Ideas: Before building the prototype, the team must generate ideas. This portion of the process involves ideation using brainstorming. The objective of this creative process is to gather as many ideas as possible without judgement or analysis. The team works to brainstorm ideas and develop as many solutions as possible. Ideas that the group might normally consider "wild" or impractical" are encouraged. Building on others' ideas often create even better ones.

3. Select a Solution: This step is the first toward refining the ideas generated to meet the goal. The result of this step requires comparing the best ideas, selecting one solution and devising a plan to move forward. To select a solution, the group must consider the needs outlined in step one, the research from step two and determine specific criteria to guide selecting the idea. It is helpful to break down and prioritize design criteria finely enough so that ideas can be ranked to from most appropriate to least. Frequently the solution selected combines one or more of the original ideas into one solution.

4. Build One Idea: Now the team can begin building one idea. This item built is called the prototype. Now the idea begins to come to life, to become real. This is the first step to determine whether the idea will meet the objectives of the original task assigned. The team will determine the materials needed and the process for putting everything together.

5. Test and Evaluate: Step five requires the team to ask questions, test and evaluate the answers. Typical questions include: Will the prototype complete the tasks identified in step one? Is it an appropriate size? Do the materials hold up under the weight of the task? Can we build it with better materials? Does it work? Does it solve the need?

Engineers will communicate the results by getting feedback, analyzing the results focusing on what works, what doesn't and what could be improved.

6. Revise, Redesign, Repeat: The team will discuss how to improve the prototype considering the testing and recommendations from step five and make revisions. It may be necessary to draw new designs, consider characteristics of a design not originally selected of reevaluate some assumptions. This step and step five continue indefinitely to create design iterations and the best product possible Iterate your design to make your product the best it can be.

Objectives & Strategies

Objectives: Students will be able to apply math that they learn in class to relate math to real world problems. This unit will emphasize the importance of education across both science and math as a vehicle to improve STEM knowledge using a cross curricular approach involving science and math.

Strategies:
1) Students will use the engineering design process to develop a human prosthesis.
2) Students will compare and contrast the engineering design process to the scientific method. The relate the mental process to word problems
3) Students will be able to apply mathematics to human body part movement;
4) Students will study real world examples of math in action in medical robotics and solve a situation mathematically.

Lesson Plan Desired result:

1. Students should know - how mathematics is used to model real life situations for the medical technology industry
2. Students should understand - – why medical technology and the application of mathematics is important to society
3. Students should be able to - apply mathematics (at their respective levels: Algebra 1 and AP Calculus) to kinematics and medical robotics

<u>Ultimate transfer desired:</u>

Students will be able to apply mathematical knowledge, skill and reasoning to solve real life problems concerning kinematics related to prosthetics and medical technology.

Classroom Activities

Lesson 1: Soft Robotics – Finger Movement Story

Lesson Objectives: Students will create soft robot finger prostheses using molds;

Students will us soft finger prosthesis to model linear equations; Students will write story graphs consistent with their liner model and their own imagination

Pacing: Day 1, 45 minutes Creating mold (steps 1-8)
Day 2, 45 minutes Finishing the mole (steps 9-16)
Day 3, 45 minutes Making the finger (steps 17-20)
Day 4, 20 45 minutes Removing finger, creating the model (step 21-23)
Day 5, 45 minutes Group reports

Essential Learning Objectives:

Part 1: Students will have experience making a mold and dividing the mold into subsections to create the sections that give the finger the ability to move. Students will create a two-part cast by pouring and curing two different materials into the same mold to achieve a specific prosthetic finger that moves.

Part 2: Using the finger they have created students will count the number of bends their finger makes in one to 2 minutes. Based on this data they will create a chart, graph and write the mathematical model for the relationships.

Previous Learning: Students have prior knowledge of (x,y) coordinates, slope (rate of change) inverse operations
Soft Robotics Materials for teacher: (See appendix for buying guide)
Materials for students: Silicone elastomer, Kevlar cord, Cardboard, Hot glue, hot glue, gun, Tubing

Introduction (5 minutes): Have students find the equation of a line using two points and create a scenario for their answer (a story) and a graph.

Exploration: SDM Finger Fabrication Guide (40 minutes per day for 4 days)

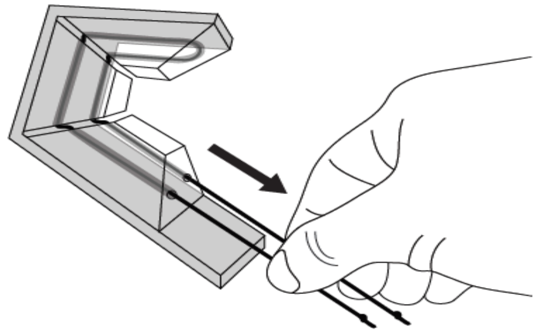
Closure (as time permits): Writing prompt to write the equation of a line I…

Homework: Write the equation of a line given 2 points; write a story and graph the line

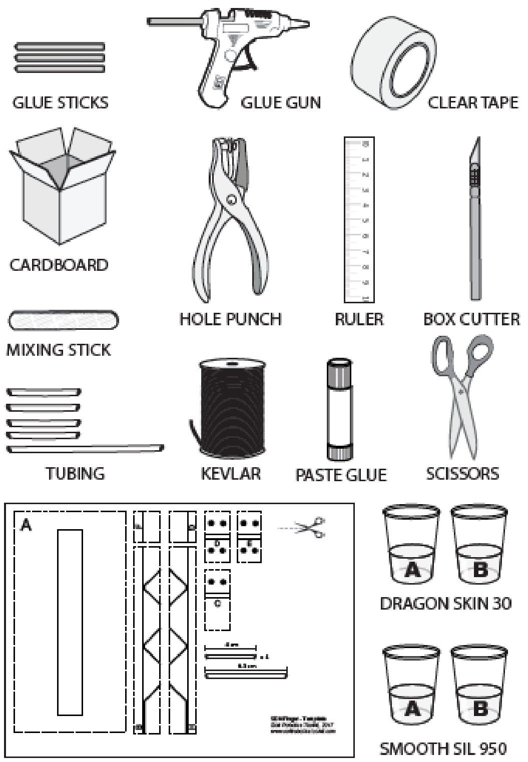
The following instructions are available for public use from An Educators Guide, Soft Robotics Toolkit 2017, www.softroboticstoolkit.com

SDM FINGER

An Educator's Guide
Soft Robotics Toolkit, 2017
www.softroboticstoolkit.com



SUPPLIES



A more detailed supply list for this activity is located in the Bill of Materials document that was within the fabrication guide package. Please be advised that if the supply list calls for box cutters, irons or scissors it is under the discretion of the educator to decide if their group is able to use these tools as part of the activity or substitute as needed.

Glue Sticks: 2-3 per mold is recommended.

Glue Gun: Helps to assemble and seal the cardboard mold.

Clear Tape: Used to seal the inside of the mold from the elastomer. For best results use clear packing tape.

Cardboard: For constructing the mold. You may use any recycled cardboard for this.

Mixing Stick: For mixing the two part silicone together.

Ruler: Helps to guide students using box cutters when cutting template pieces.

Box Cutter: For inflating the gripper upon completion. You may also use a bike or hand pump.

Tubing: Allows a channel for the kevlar to be established when molding.

Kevlar: Kevlar cord to control the movement of the finger.

Paste Glue: Glue to allow the paper templates to be pasted onto the cardboard.

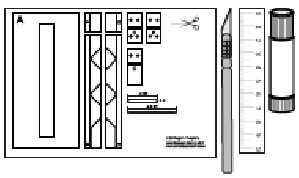
Scissors: For cutting the paper template, tubing and kevlar cords.

Template: Includes parts for the walls of the mold, the interior sections and the sizes of tubing needed.

Dragon Skin 30: For casting the first portion of the finger's construction.

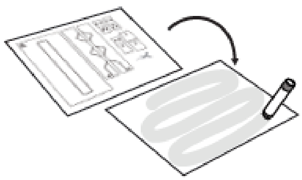
Smooth-Sil 950: For casting the second portion of the finger's construction.

01



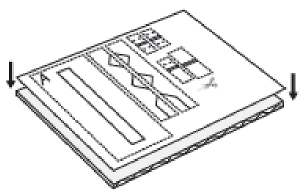
Gather the paper template, a box cutter, ruler and paste glue for the construction of the mold.

02



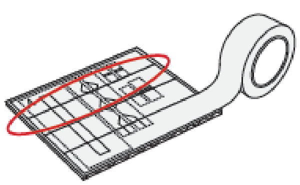
Spread paste glue across the back of the entire template.

03



Paste the template onto a piece of cardboard large enough to fit the whole template.

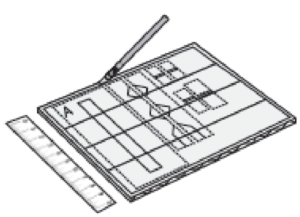
04



Use the clear packing tape to laminate the entire front side of the template.

NOTE: Overlap the edges of the tape to ensure that there are no gaps between the lengths of tape. The cardboard must be completely sealed to prevent the leaking of the Ecoflex in later steps.

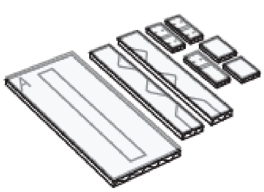
05



Use an box cutter to cut along the dotted lines, separating parts A-F.

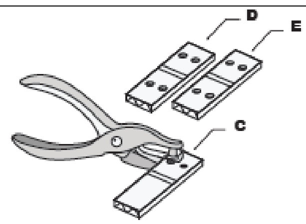
NOTE: Students may need close supervision at this step. Some students may struggle to use the box cutter, in which case they may use scissors. You can also score the template for the student to make it easier for them to cut.

06



Students should have parts A-F as individual pieces. A is the base with an outline for the finger mold. B and H are the long sides of the mold. F and G are the short sides of the mold. C, D and E are the sections added within the mold to shape the finger.

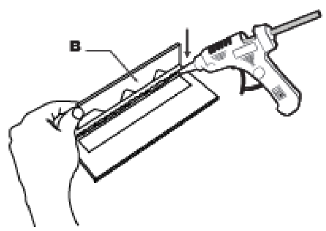
07



Use a hole puncher to punch holes through the black circles on parts C, D, and E. Tubing will run through these holes to provide a channel for the vv cord.

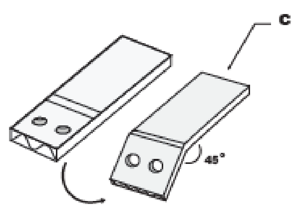
NOTE: Have students punch these holes carefully and accurately. When these pieces are folded up in the mold, the holes need to align as closely as possible.

08



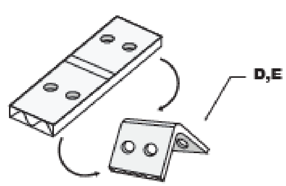
Use a hot glue gun to assemble part B onto the mold outline of part A. Ensure that the laminated side of B is facing the interior of the mold to protect the mold from silicone. “B” should be right side up. You will later assemble parts C, D and E inside the mold, using the solid lines on piece B as a guide.

09



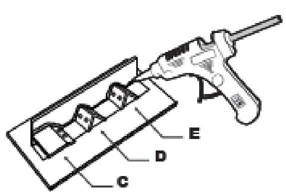
Fold part C along the lines printed to a 45° angle. The fold should be bent towards the non-laminated side of these pieces.

10



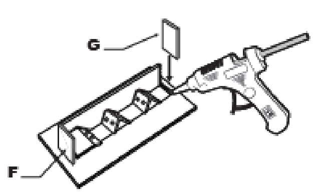
Fold parts D and E in half along their lines. The laminated side should be on the outside of the fold.

11



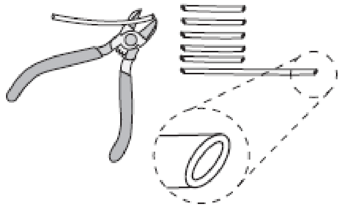
Use a hot glue gun to assemble parts C, D and E onto the mold outline of part A. Align C, D and E along the solid lines on part B. Secure the pieces in place by outlining the entire structure in hot glue. Make sure to line all of the areas where the parts meet, both inside and outside of the mold.

12



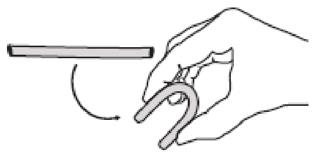
Use a hot glue gun to assemble parts F and G onto the short ends of the finger outline on part A. Ensure that the laminated sides are facing the interior of the finger mold to protect the mold from silicone. “F” and “G” should also be facing right side up.

13



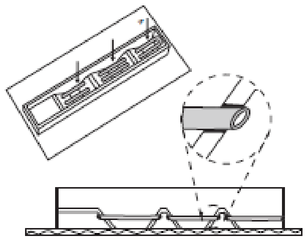
Use wire-cutters to cut 5 pieces of plastic tubing. 4 of the pieces should be 4 cm in length and 1 piece should be 6.5 cm in length. Refer to the template for a guide on tube lengths.

14



Bend the 6.5 cm tube in half but DO NOT crease it. The tubing will act as a guide later for the Kevlar cord. If students crease the tubing, the Kevlar will get stuck and will not be able to make it all the way through the tube.

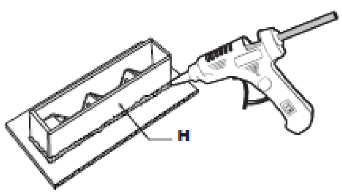
15



Insert the tubes into the holes of the mold. The 4 cm pieces of tubing are placed between C-D, and D-E. Both ends of the 6.5 cm tubing are placed in E, creating a loop for the cord.

NOTE: If the tubes are too long and are interfering with one another, trim them shorter. If the tubing loop at the end sticks up too much, you can secure it level against part G with a dot of hot glue.

16



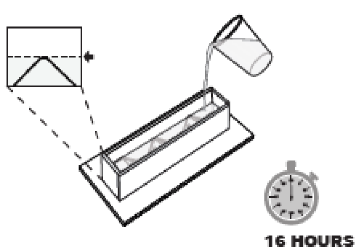
Use a hot glue gun to assemble part H onto the remaining edge of the mold outline. Ensure that the laminated side of H with the solid lines is facing the interior of the mold to protect the mold from silicone. "H" should be right side up. The solid lines should align with parts C, D and E inside the mold.

NOTE: Secure all of the pieces and corners with the hot glue gun, both inside and outside of the mold. Be sure to seal C, D and D to the side of H.

17

Using a mass scale, measure out a 1:1 ratio of parts A and B of Dragon Skin 30. 20 g of part A and 20 g of part B is recommended. Mix the silicon completely with mixing sticks for 30 seconds, or until completely mixed.

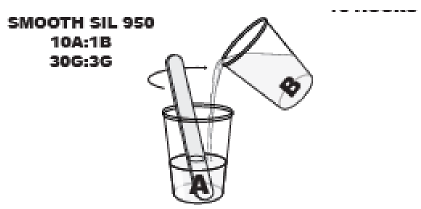
18



Fill the mold with the Dragon Skin 30 to the fill line on the mold's interior. The silicone will just barely submerge parts C, D and E. Let the silicone cure for 16 hours in the open air. Touch the silicone with a finger to test whether or not it has cured completely. If the silicone still feels "greasy" or "tacky", let it cure longer. If it feels "rubbery", then the silicone is ready.

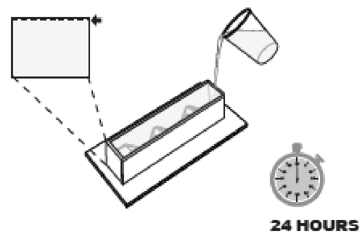
NOTE: If you have access to an oven, you can cure the silicone much more quickly. Turn the oven to 70°C (140°F) and let it cure for 20 minutes.

19



Using a mass scale, measure out a 1:1 ratio of parts A and B of Smooth Sil 950. 30 g of part A and 3 g of part B is recommended. Mix the silicone completely with mixing sticks for 30 seconds, or until completely mixed.

20



Fill the rest of the mold up with the Smooth Sil 950 to the top of the mold's interior. Let the silicone cure for 24 hours in the open air.

NOTE: If you have access to an oven, you can cure the silicone much more quickly. Turn the oven to 70°C (140°F) and let it cure for 20 minutes.

Lesson 2: Designing a Lower Extremity Prosthetic

Lesson Objectives: To create a lower extremity prosthetic and model its articulation in x-y and x-y-z space.

Pacing: Day 1, 45 minutes Measuring and creating the form
Day 2, 45 minutes Finishing the arm; graphing in 2 and 3 D
Day 3, 45 minutes Group reports

Essential Learning Objectives: Students will have experience making an upper extremity prosthetic lower arm from any material they desire.

Previous Learning: Students have prior knowledge with angles in the x-y coordinate system; students have explored prothesis and understand the degrees of freedom, limitations/issues based on where a limb is attached

Materials for teacher: Tag board of different colors (for students without materials)

Materials for students: Tag/poster board (material of their choice), tape, graph paper; chart paper (groups will report out 1 design; each student will have their own design)

Introduction: (5 minutes) What is the ideal lower arm length? How do you define ideal?

Exploration: In groups of 2 -4, using your "ideal" arm length, create a lower arm prosthesis. Where will your arm attach (i.e. what is the nature of your "stump"). For your situation, map out the motion in x-y space and x-y-z space that your arm can accomplish.

What is your quality of life? Should you modify your design? IF so, what would you change?

Closure: (as time permits) Exit ticket – You are the Inquirer reporter who visited our class today write a short review

Homework: You design is a big hit. Design fabric covers for your arm. How much fabric will you need if each arm in of identical size to our prototype? Select the fabric you would like and (find a fabric store on line print off your selection). Describe the cost and your design.

Lesson 3: The Hand Knows - Designing a prosthetic hand to pick up arcade toys (modeling quadratic motion)

Overall Objective: To create hand prosthetic and model its articulation in a case at an arcade. Using the lower arm prosthetic how will you attach the hand to reach into the glass case and get a prize.

Pacing: Day 1, 45 minutes Understanding the problem; brainstorming
Day 2, 45 minutes Finishing the mole (steps 9-16)
Day 3, 45 minutes Making the finger (steps 17-20)
Day 4, 20 minutes Removing finger, creating the model (step 21-23)
Day 5, 45 minutes Group reports

Essential Learning Objectives: Students will make a hand prosthetic using the engineering design process.

Previous Learning: Students created a fictitious cellphone case suing the engineering design process. They can work effectively in groups.

Materials for teacher: See materials list in Appendix

Materials for students: Thick rubber bands, jumbo wooden craft sticks, industrial strength duct tape, flexible straws, cardboard, Playtex glove tips, thick string, hot glue, scissors, ruler. Engineering design process list and report paper

Introductions: (5 minutes) Describe how your hand is designed. How does it work?

Exploration: In groups of 2 -4 students design a prosthetic hand using the materials given. You do not have to use all the materials, but you may not add any. After you build the hand it hand will have to reach inside a box and pick up arcade toys. Describe the function the motion the hand makes from the top of the box to the toys.

Closure: (as time permits) Did you have enough material? Why or why not?

Homework: Find pictures of real life prosthetic hands

Appendix/Content Standards

Anchor Descriptor	**Core Standard**
A1.1.2.1 Write, solve and /or graph equations using various methods	CC.2.1.HS.F3Apply quantitative reasoning to choose and interpret units and scales in formulas, graphs and data displays CC.2.2.8.B.3 Analyze and solve equations CC.2.2.8.C.2 Use concepts of functions to model relationships between quantities. CC.2.2.HS.C.3 Write functions or sequences that model relationships between two quantities. CC.2.2.HS.D.7 Create and graph equations …to describe numbers or relationships.
A1.2.1.1 Analyze and/or use patterns or relations.	CC.2.2.HS.C.3 Write functions or sequences that model relationships between two quantities.
A1.2.2.1 Describe, compute, and/or use models to describe functions	CC.2.2.HS.C.6 Interpret functions in terms of the situations they model.

SCIENCE

Anchor Descriptor	**Core Standard**
Science & Technology	Conduct multiple step experiments
	Apply appropriate tools, materials and processes to solve complex problems

Next Generation Science Standards		
Students who demonstrate understanding can: **HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.**		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Science and Engineering Practices *Asking Questions and Defining Problems* Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Analyze complex real-world problems by specifying criteria and constraints for successful solutions.	Disciplinary Core Ideas *ETS1.A: Defining and Delimiting Engineering Problems* • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.	Crosscutting Concepts Connections to Engineering, Technology, and Applications of Science *Influence of Science, Engineering, and Technology on Society and the Natural World* • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.
Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include: **Physical Science**: HS-PS2-3, HS-PS3-3		
Articulation of DCIs across grade-levels: **MS.ETS1.A**		

* The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

The section entitled "Disciplinary Core Ideas" is reproduced verbatim from *A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas*. Integrated and reprinted with permission from the National Academy of Sciences.

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Teacher Resources

Teach Engineering STEM Curriculum for K-12
https://www.teachengineering.org/k12engineering/designprocess

Mathematics Content Rubric			
Advanced Understanding 4	Meets the Standard 3	Approaching 2	Does Not Meet 1
• The student uses appropriate mathematical concepts and skills to solve application problems in both familiar and	• The student uses appropriate mathematical concepts and skills to solve application problems in familiar situations	• The student uses appropriate mathematical concepts and skills to solve routine problems but is unsuccessful with	• The student demonstrates limited success in the use of appropriate mathematical concepts and skills

Mathematics Content Rubric			
Advanced Understanding 4	Meets the Standard 3	Approaching 2	Does Not Meet 1
unfamiliar situations with limited scaffolds & supports. and/or • The student solves problems that require connections among multiple concepts without scaffolded prompts	with scaffolds & support. and/or • The student solves problems that require connections among multiple concepts with scaffolded prompts.	applications to real life contexts. and/or • The student solves problems involving concepts in isolation.	to solve routine problems and applications to real life contexts. and/or • The student has limited success solving problems with concepts in isolation.

COMPARISON	
The Scientific Method	The Engineering Design Process
1. State your question & Do background research	1. Define the problem & Do background research
2. Formulate your hypothesis, identify variables	2. Generate ideas/brainstorm
3. Design experiment and establish procedure	3. Create alternative solutions, choose the best one and develop it
4. Test your hypothesis by doing an experiment	4. Build a prototype
5. Analyze your results and draw conclusions	5. Test prototype and evaluate

COMPARISON	
The Scientific Method	The Engineering Design Process
6. Communicate results	6. Revise, redesign, repeat

Student Worksheet

Engineering Design Process **Group Summary Sheet**	
Design Step	Outcome of Group Process
1. State the Problem:	
2. Generate Ideas: (All drawings should be attached)	
3. Select a Solution:	
4. Build One Idea:	
5. Test and Evaluate:	
6. Revise and Redesign Repeat:	

Lesson 1 - SDM Finger Bill of Materials	
CONSUMABLES	**Part #/ SUPPLIER**

Box cutter/ X-acto	B00TXVJA8K Amazon.com
Clear Packing Tape	B003W0P2SA Amazon.com
Coffee sticks (x1 box)	B01A1FI0KA Amazon.com
Cups	B00HKH0N5I Amazon.com
Glue gun (One per team)	B00IA8WLQA Amazon.com
Glue sticks (For glue gun)	B003JZII34 Amazon.com
Hole Punch	B0001DT3ZE Amazon.com
Mass scale	B00ME8VI34 Amazon.com
Paste glue	B001E69WBW Amazon.com
Scissors/ Wire cutters	B005P58CYG Amazon.com
Syringe for pressurizing actuator *A bike pump or any other air source will work as well	B06XFPZMRC Amazon.com
Cardboard (Lots of Cardboard)	20585T22 Recycling
Crack-Resistant Polyethylene Tubing, 1/16" ID, 1/8" OD, 1/32" Wall Thickness, White (x25 feet) (1 ft per student)	5181K15
Kevlar thread (2 ft per student)	8800K44 McMaster Carr
Lightweight Aluminum Ruler, 12"/30 cm Length (x3)	1971A42 McMaster Carr
Dragon Skin 30 (.088 lb. total needed per student)	Smooth-on.com
Smooth Sil 950 (.07 lb. total needed per student)	Smooth-on.com

Lesson 3 Materials (per student)	
10 thick rubber bands*	10 flexible straws
5 Jumbo wooden craft sticks (6”x3/4”x1/16”	Industrial strength duct tape
1 piece of cardboard for palm	Playtex dishwashing gloves (textured tip)

Thick String (5x20" per student)	1 Magnet or a thick round washer
Hot glue gun and glue sticks (extension cord)	Scissors
1 small funnel (to attach hand & arm if needed)	Ruler
Prosthetic arm (lesson 2)	

* Staples carries thick rubber bands on line (#105 rubber band)