Exploring Soft Robotics Through the Movie *Big Hero 6*

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Abstract

This curriculum unit will explore the field of soft robotics and will include four multi-day lessons as well as one optional hands-on lesson. The movie Big Hero 6 will be used to introduce the concept of soft robots since many students will already be familiar with one of the main characters, Baymax, who is a soft robot. Students will have many opportunities to produce digital projects to showcase what they have learned. Lesson 1 will learn about what makes a robot a "soft" robot. Students will create a Venn diagram using Google Drawings and then use that diagram to compare soft robots to traditional robots. In Lesson 2, students will explore the many types of soft robots and will create a Google Slides presentation to share this information. Lesson 3 will introduce the applications of soft robots and students will produce a Google Doc to share their information. Finally, in lesson 4, students will discuss the advantages of using soft robots and will produce a Google Site that displays all the information they have learned in this unit.

Keywords: soft robots, soft robotics, robotics, technology, *Big Hero 6*, digital literacy, English Language Arts, Google suite

Content Objectives

One of the greatest responsibilities of an educator is to introduce students to topics that will challenge and stretch them to explore areas of study that may be completely foreign to them. My students that come to me from other countries all around the world are challenged to do this every day. Sometimes these topics become areas that they are greatly intrigued by and desire to pursue further study, sometimes on their own. When asking students what they would like to be or do when they grow up, they are limited to fields of study of which they are aware. How can they desire to be something that they do not even know exists? There are currently fields to explore, especially in the areas of science and technology, that did not even exist when I was child, and there will be new technologies and areas of study that will exist when they are ready to begin their careers. As educators, we must prepare our students for this ever-changing terrain.

In some respects, our students are already hardwired to meet these new challenges. They have never known a time when there were not smart phones, SMART boards and smart televisions, the Internet and social media platforms, computers and laptops, and our two-years old can operate them better than we can. It seems that they were born knowing how, and yet, advances in this technological age are occurring seemingly at the speed of

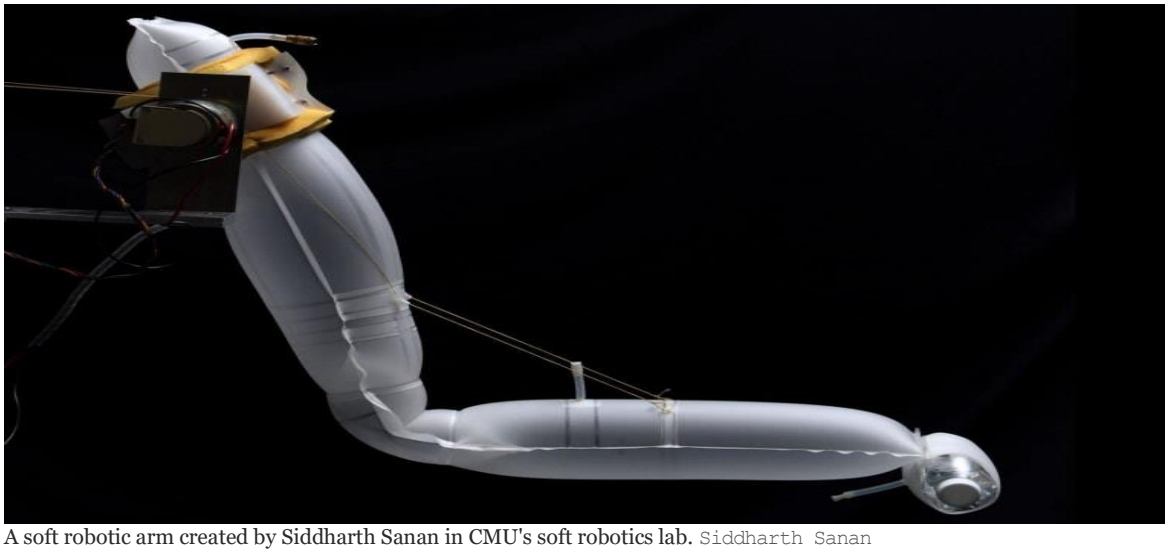
light. So, we must prepare ourselves to prepare our students to embrace and engage in these 21st century technologies, even when they may seem daunting and challenging for us.

Students are more likely to engage with material to which they can relate. When educators find ways to make learning accessible and relevant, they can teach students any subject, no matter how challenging that topic may be. One of these ways is to use media and entertainment to make these connections. I was simply delighted to learn that I could use one of my favorite animated movies, *Big Hero 6*, to teach my students about soft robots. I recently realized that one of the main characters, Baymax, is a soft robot. Baymax is a soft, cuddly "personal healthcare companion," able to perform 10,000 medical procedures. I have seen the movie many times but did not make the connection to the course work that I am currently studying until very recently. I suddenly realized that the movie can be used to introduce elementary and middle school students to the concept and applications of soft robots in a way that they can access. It has also occurred to me that many of the functions that Baymax was able to perform in the movie that were futuristic in 2014 when the movie was first released, may now be possible in 2022, or at least closer to possible. This unit will explore many of these possibilities.

https://www.cbc.ca/news/entertainment/big-hero-6-actor-scott-adsit-on-becoming-baymax-1.2827752

The concept of Baymax was inspired by an inflatable robotic arm at Carnegie Mellon University's Robotics Institute. This robotic arm was created by Siddarth Sanan, a post-doctoral fellow at Harvard's Wyss Institute. ('Big Hero 6': The Science Behind Baymax, Disney's Big, Soft Robot 2014)

Figure 1



A soft robotic arm created by Siddharth Sanan in CMU's soft robotics lab. Siddharth Sanan

Analyzing the movie with a scientific and technological mindset will allow my students to engage with material that was created primarily for entertainment and view the concepts with a different set of eyes. It is important for students to develop critical thinking skills that will stretch them beyond the environments in which they find themselves and show them that there is a great big world out there, waiting for them to explore and with which they can interact. Many of my students in Southwest Philadelphia have a limited view of the world. Unless they have come to us from outside the country, they sometimes have tunnel vision and do not see the rest of the world or even realize that there is new territory to explore. I have found this to be true for many students who grow up in urban areas.

In this curriculum unit, I will address the following concepts/topics/questions:

What is the field of softs robotics and what are soft robots?

What are some types of soft robots?

What are some of the applications of soft robots?

What are the advantages of developing and using soft robots?

What is Soft Robotics? What are Soft Robots?

The field of soft robotics has emerged out of a need to develop robots that were able to interact with humans safely. The earlier robots that were mostly metal could work on

assembly lines quite efficiently but were actually very dangerous to humans. They were unable to sense that humans were near and adjust so as not to harm them. They were only able to perform the functions that they were programmed to perform. They were also very expensive to make. There was a need to develop robots that were less expensive to make, able to interact with humans, and able to adapt to changing environments in real time. Here are some of the ways that the field of soft robotics has been defined:

"The field of soft robotics is the side of robotics that draws the most inspiration from nature. Unlike traditional robotics, soft robots are designed with highly malleable and compliant materials such as silicone elastomers and hydraulic fluidics. This allows soft robots to accomplish many humanoid tasks that were originally impossible through traditional robotics." (Applications of Soft Robotics 2021)

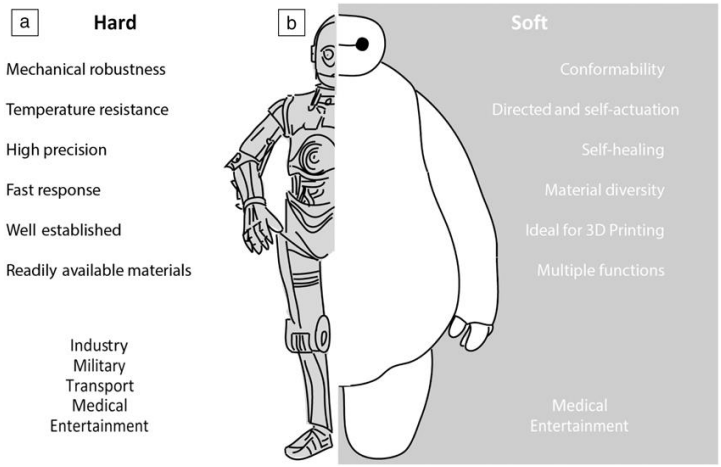
"Soft robotics is a growing field which relies on mimicking locomotion mechanisms of soft bodies existing in nature to achieve smooth and complex motion." (Soft Robots: A Review 2021) "A soft robot encases in a soft body all the subsystems of a conventional robot: an actuation system, a perception system, driving electronics, and a computation system, with corresponding power sources." (D.Rus 2015)

"Soft robotics can be considered as a means of making biocompatible artificial objects, for example, prosthetics actuated by artificial muscles, and artificial organs produced by 3D bioprinter." (Open Machines 2018)

Soft robots are made of soft, malleable, compliant materials. They are made to mimic the motion of animals in nature (biomimetic). They often have shape-shifting properties so that they can fit into tight spaces. They can be actuated pneumatically or hydraulically, and they integrate sensors, actuators, and computation. This design offers many advantages over traditional robots.

An article that explored whether soft robots like Baymax featured in the movie "Big Hero 6 could actually exist stated this, "Soft robots are robots that mirror the biological movements and makeup of living creatures, known as biomimicry. They have synthetic skin, allowing their shape to change easily, like the muscles within animals and humans. Soft robotics utilizes electronics and microsystems to move parts of the robot with the ease that living organisms use." (Baymax in Real Life? How Soft Robotics Might Change the Future 2022)

Figure 2-Hard Robots vs. Soft Robots



https://www.cambridge.org/core/journals/mrs-bulletin/article/robotics-science-preceding-science-fiction/E8975B55336F3EA240576E4503B238BA

The Whitesides Research Group is developing soft robots. "Using biomimetic principles… we are developing partially or entirely "soft" robots, fabricated in materials (predominantly elastomeric polymers) that do not use a rigid skeleton to provide mechanical strength, and are actuated pneumatically. Soft robots are simpler to make and less expensive than conventional hard robots, and may, in some respects, be more capable of complex motions and "cooperative function" (that is, safe operation around humans)." (Soft Robotics n.d.)

Types of Soft Robots

There are many different types of soft robots. Depending on the function that needs to be performed, soft robots can be designed to perform a variety of tasks.

Gripping Robots

Gripping robots are designed to operate like a hand that can pick up fragile items like eggs or fruit without damaging them. They have finger-like appendages and can perform tasks that traditional robots are unable to perform because they are able to sense and respond to their environment. This allows them to be gentler and more effective.

Video: Soft Robotic Gripper https://youtu.be/csFR52Z3T0I

Jamming Robots

Jamming robots can also pick up items, but they do not have "fingers" like gripping robots. "Individual fingers are replaced by a single mass of granular material that, when pressed onto a target object, flows around it and conforms to its shape. Upon application of a vacuum, the granular material contracts and hardens quickly to pinch and hold the

object without requiring sensory feedback." (Brown 2010) These robots are more sensitive and can pick up objects that are too small for gripping robots to grasp.

Video: Presenting the Universal Jamming Gripper https://youtu.be/Rna03IlJjf8

Wearable Robots

One type of wearable robot can function like a prosthetic hand, arm, or leg. They can assist with physical impairments or physical rehabilitation. Other types can be woven into fabric and made into an exoskeleton with sensors.

Video: Wearable Assistive Robotics with Integrated Sensing
https://youtu.be/Itt8bTHXvYs

Origami Robots

Origami robots are inspired by the folding nature of origami and the other things in nature that operate by the same principles.

> "Many things in nature, such as proteins and enzymes, are actuated through a complex folding motion. This type of actuation provides tremendous power which allows them to lift enormous weights and propel them through the dense medium of human tissue. This is what origami robots aspire to do. Fundamentally, origami robots are just plain sheets of metal or plastic that fold into certain shapes, allowing them to walk, throw, or even swim. What makes these robots so desirable is that they can fold into impossibly tight spaces and expand as required, all without losing the power of pneumatics." (Applications of Soft Robots 2021)

Video: Origami-Inspired Soft Robot https://youtu.be/ngL2m0G3OME

Climbing Robots

> "One version of soft climbing robots has a bendy design, much like a caterpillar, that allows it to climb up and down large structures." (5 Innovative Applications 2018)

> "The tendril-like soft robot created by researchers at IIT-Istituto Italiano di Tecnologia, can move around different structures, like a pipe or a branch. Researchers at IIT-Istituto Italiano di Tecnologia created the first soft robot mimicking plant tendrils. It is able to curl and climb using the same physical principles determining water transport in plants. The research team is led by Barbara Mazzolai, and results have been published in *Nature Communications*. In the future, this tendril-like soft robot could inspire the development of wearable

> devices such as soft braces that actively morph their shape." (Why Do We Need Soft Robotics? 2019)

Video: Flippy: A Soft Autonomous Climbing Robot https://youtu.be/AQcBEuOAlWE

Crawling Robots

Watch these video clips to see crawling robots in action!

Video: Watch This Robot Crawl Up Walls https://youtu.be/eGeIi_GY4W0

Video: Stanford Engineers Develop Crawling and Transforming Soft Robots https://youtu.be/XqgbLb8m77U

Video: Octopus-Inspired Robots Can Grasp, Crawl, and Swim https://youtu.be/L7FEJJsvHRQ

Robot Swarms

"Robot swarms allow simpler, less expensive modular units to reconfigured into a team, depending on the task that needs to be performed, while being as effective as a larger, task-specific, monolithic robot." (Yang 2018) This is the principle behind the microbots in *Big Hero 6*, which seemed to be purely science fiction at the time I first watched the movie. However, the University of Pennsylvania's GRASP lab has created flying nano quadrotors, which are small robots that can fly in synchronized swarms with incredible accuracy. These robots remind me of drones in the way they operate.

Video: A Swarm of Nano Quadrotors https://youtu.be/YQIMGV5vtd4

Edible Robots

Edible robots were invented by a team of high school students at Haverford School in Philadelphia. They can deliver medicine to specific parts of the body. Researchers in Switzerland have designed gelatin-based robots that animals and humans can ingest. (Why Do We Need Soft Robotics? 2019)

These are just a few examples of the types of soft robots that currently exist. The field is changing so rapidly that there will likely be new technologies by the time this curriculum unit is published.

Applications of Soft Robots

Surgery (laparoscopic or endoscopic)

> "In January of 2019, Assistant Professor Ellen Mazumdar arrived in the Woodruff School of Mechanical Engineering (Sensing Technologies Lab) with the intention of building a robotic actuator without a single hard component. The field of soft robotics has powerful implications for the medical field. Flexible robots could be used to navigate catheters or endoscopes to the right places in the body, while minimizing stress and damage to tissues." (The Incredible Potential of Soft Robotics 2020)

Search and Rescue, disaster relief

> "If you have a disaster scenario, and you need to go through a small hole and re-expand on the opposite side, soft robots can potentially be used, said Mazumdar. In the future, small robotic components could be passed through small holes like a liquid and reformed on the other side into shapes that allow them to start doing work." (The Incredible Potential of Soft Robotics 2020)

> "Isuru Godage, assistant professor in DePaul University's College of Computing and Digital Media is working on finding a solution that can help first responders during a crisis. His solution involves the deployment of dozens of transformable, soft robots into any opening found around the perimeter of a collapsed building. The adaptable robots could change into snake or legged robot forms, so they can navigate a staircase, small sewer lines, or a pool of water. These robots will safely alert first responders to survivors along their pathway and provide a blueprint for where rescue should begin." (Soft Robotics: Bend Them, Shape Them, Any Way You Want Them n.d.)

Space and deep-sea exploration

The possibilities for the use of soft robots in space exploration and deep-sea exploration are limitless. Soft robots are able "to go where no man has gone before" and survive elements that are unsuitable for humans. They do not need oxygen because they do not need to breathe. They are unaffected by toxic fumes and extremes in temperature. They can fit into small spaces and expand when needed.

Prosthetics, artificial muscles (origami muscle robots), and rehabilitation (exosuits)

> "Inflatable suits are being developed for rehabilitation to fit around damaged limbs and joints, and through inflation and deflation help patients build up

> strength and flexibility." (Inflatable Soft Robots Like Baymax May Be Used in Hospitals n.d.)
>
> "Soft robotics makes it possible for us to create fully functional body parts that can not only adjust to human motion, but also mimic it. This is done through the use of highly flexible materials such as thermoplastic polyurethane (TPU)." (Applications of Soft Robots 2021)
>
> "Robotic Muscles- One of the most promising draws inspiration from origami. Its folded-up structure can lift 1000 times its own weight and is scalable from a few millimeters to a meter long." (5 Innovative Applications of Soft Robotics 2018)

Technology can be used to create grippers at the end of a prosthetic arm for more delicate grasping of objects.

Wearable technology

> "These biomimetic devices can be applied to a person undergoing physical rehabilitation. The soft robot mimics the natural movement of the body, wherever it is placed, helping the patient restore normal motor functions." (5 Innovative Applications of Soft Robots 2018)

Advantages of Soft Robots

More life-like: They are designed to mimic the behavior of living organisms.

Soft robots are designed using the principles of biomimicry, so they look and move like living organisms. Scientists study the way animal move and design soft robots to mimic their movements. "Octobot," the first autonomous soft robot, resembles an octopus in the way it moves through the water and grasps objects.

Increased flexibility and adaptability, "able to face unexpected situations in the real world"

Soft robots are able to conform, deform, and adapt themselves into environments that would be impossible for traditional hard robots. They can fit into tight spaces, wrap themselves around objects to grasp them, slide under or climb over objects to navigate obstacles. This makes it possible for them to respond to novel situations, which makes them perfect for search and rescue.

Gentle manipulation

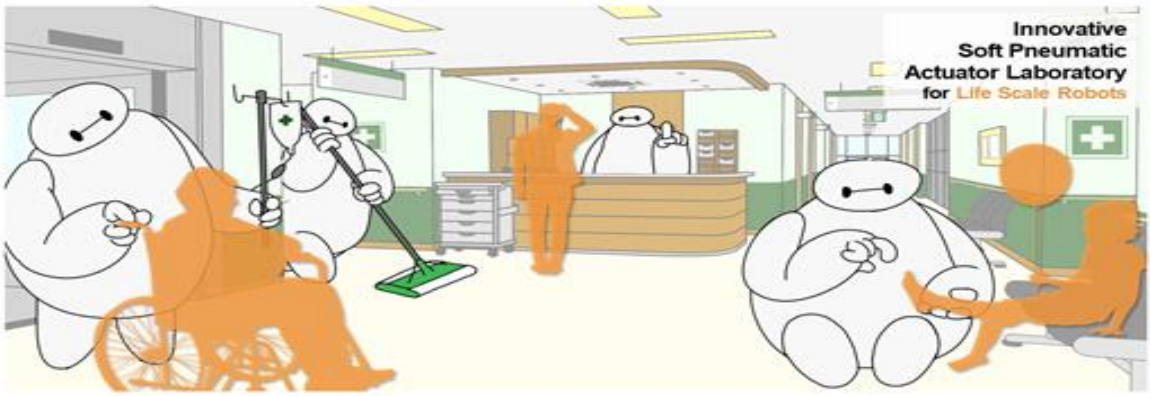
“George Whitesides’ research group at Harvard have shown these mechanical principles (inflation and deflation) beautifully with their work designing soft robot gripper arms that can delicately pick up fruit and eggs without the need for any mechanically moving parts.” (Inflatable Soft Robots Like Baymax May Be Used in Hospitals n.d.)

Safer for human interaction

One of the advantages of soft robots over traditional robots is that they can interact safely with humans. This increases the applications for which soft robots can be used. “Chris Atkeson, robotics expert at Carnegie Mellon University (2011), is trying to develop robots that could be used to help people in nursing homes. The robots would do things like feed them and dress them and comb their hair and wipe their face.” (The Challenge of Big hero 6: How to Make a Huggable Robot 2014)

While some people might be concerned about soft robots taking jobs from human workers, during the coronavirus pandemic, these types of soft robots could have provided invaluable service without concern for contracting or spreading an infectious disease.

Figure 3



https://rise.skku.edu/research/2020/222/

Simple, inexpensive

Soft robots can be made with very simple materials, such as fabric, balloons, and tape. The article, “SDM Finger: Teaching Engineering Design Through Soft Robotics,” is a complete lesson on how to make a simple, soft robot. They can also be engineered through 3D printing, which makes them very cost-effective. “In 2016, Harvard scientists used liquid silicone rubber to develop the Octobot, the first ever soft, autonomous robot.

The Octobot is cheaper to make than a latte, and it only costs 5 cents to fill with fuel. One can imagine hundreds of cheap, soft robots being sent in to investigate a scene, wriggle through obstacles, and navigate tight quarters to assist in a rescue mission." (Why Soft Robots Have NASA, Doctors, and Tech Whizzes So Excited 2021)

This curriculum unit will be appropriate for use with elementary or middle school students, but it will also be appropriate for anyone wanting to introduce soft robots their students. It is designed to be used in a middle school digital literacy class, so it will make extensive use digital platforms, especially the Google suite, including Google Docs, Google Slides, and Google Drawings. The unit will consist of four multi-day lessons that will challenge students to think critically and work collaboratively to create projects.

Teaching Strategies

1. **SWBAT** identify the characteristics of a robot IOT recognize what is and what is not a robot.
2. **SWBAT** analyze the movie *Big Hero 6* IOT determine at least 5 ways the character Baymax fits the criteria for a soft robot.
3. **SWBAT** create a Venn diagram using Google Drawings IOT use Drawings tools, such as inserting shapes (squares instead of circles), text boxes, fill color, background color, etc.
4. **SWBAT** complete a Venn diagram that compares soft robots to traditional robots IOT determine both similarities and differences between the two types of robots.
5. **SWBAT** identify 5 different types of soft robots and their applications IOT determine how they could best be used to solve current world problems.
6. **SWBAT** create a Google Slides presentation IOT share new video clips of different types of soft robots.
7. **SWBAT** brainstorm ideas about additional applications for soft robots IOT generate possibilities for future applications for soft robots.
8. **SWBAT** compose a Google Doc IOT present several applications for soft robots.
9. **SWBAT** explain 5 advantages of using soft robots IOT establish the practicality of developing soft robotics technologies.
10. **SWBAT** create a Google Site IOT showcase the types, applications, and advantages of using soft robots.

Classroom Activities

Lesson 1: Introduction to Robots (4-5 days)

Objectives:

1. **SWBAT** analyze the movie *Big Hero 6* IOT determine at least 5 ways the character Baymax fits the criteria for a soft robot.
2. **SWBAT** create a Venn diagram using Google Drawings IOT use Drawings tools, such as inserting shapes (squares instead of circles), text boxes, fill color, background color, etc.
3. **SWBAT** create a Google slides presentation describing the characteristics of soft robots IOT determine what sets them apart from traditional robots.
4. **SWBAT** complete a Venn diagram that compares soft robots to traditional robots IOT determine both similarities and differences between the two types of robots.

Standards:

ISTE Standard 3: Knowledge Constructor: Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts and make meaningful learning experiences for themselves and others.

ISTE Standard 6: Creative Communicator: Students communicate clearly and express themselves creatively for a variety of purposes using the platforms, tools, styles, formats and digital media appropriate to their goals.

ELA Reading

CC.1.2.8.B Cite the textual evidence that most strongly supports an analysis of what the text says explicitly as well as inferences, conclusions, and/or generalizations drawn from the text.

ELA Writing

CC.1.4.8.U Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas efficiently

CC.1.4.8.V Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

CC.1.4.8.W Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation

Materials Needed:

Student Chromebooks/Computers

Introduction to Robots Slides Teacher Presentation
https://docs.google.com/presentation/d/1i99V1tx13adOvPVgpG2FJDfHAa1ovOQ4eGBF2ueJVuc/edit?usp=sharing

Characteristics of a Soft Robot Handout
https://docs.google.com/document/d/1ytEv8j8G83mCCf6VXcRtR6XSFU2G2prRVYLD6p3Leoc/edit?usp=sharing

Movie: *Big Hero 6* (Can be rented or purchased from YouTube or other streaming services. May be possible to stream for free, depending on which sites are blocked by each school district) https://www.youtube.com/watch?v=-AWpph_Rvoo

Graphic Organizer- Finding Supporting Evidence
https://docs.google.com/document/d/1X8tQySP9UzSXGsNCxb_iMatTfiadFCNBL2d41eqizpE/edit?usp=sharing

Venn Diagram
https://docs.google.com/drawings/d/1Qe_ig8t3NZ3QwC6BxfNu4lnzzhOgIsVZmpLz8buMHpE/edit?usp=sharing

Build a Logo to Express Who You Are (Tutorial on using Google Drawings)
https://applieddigitalskills.withgoogle.com/c/middle-and-high-school/en/build-a-logo-to-express-who-you-are/overview.html

Day 1

Warm-up Activity: "Is this a robot?" Students will be shown a sequence of pictures and asked the following questions: "Is this a robot? Why or why not? How do you know?" This "Introduction to Robots" slides presentation is borrowed from the one created by Cynthia Sung for use in her seminar, "Soft Robots" at the University of Pennsylvania (slides 1-7). It has been modified for use with this curriculum unit. This activity will determine how much prior knowledge have before beginning the lesson.

Introduction to Robots Slides Teacher Presentation
https://docs.google.com/presentation/d/1i99V1tx13adOvPVgpG2FJDfHAa1ovOQ4eGBF2ueJVuc/edit?usp=sharing

What is a Soft Robot?

For the remainder of this lesson, the teacher will continue to use the slides presentation to introduce students to the attributes of soft robots. Students will be given a handout that includes the following information:

Soft Robots…

- Are made from soft materials, such as silicone, rubber, or plastic
- Flexible, malleable, compliant
- May have shape-shifting properties so it can fit into small spaces
- Can mimic the movement of living organisms–biomimicry, biomimetic
- Integrate sensors (so it can sense its environment), actuators (so it can move), and computation (so it can and respond to its environment appropriately)
- Safer, gentler interaction with humans
- Can be designed using 3D printing, making them inexpensive to make
- May be self-healing
- Can serve many functions, not just the one for which they were designed

Characteristics of a Soft Robot Handout
https://docs.google.com/document/d/1ytEv8j8G83mCCf6VXcRtR6XSFU2G2prRVYLD6p3Leoc/edit?usp=sharing

Exit Ticket: "Name three characteristics of a soft robot."

Days 2-3

Warm-up Activity: Review the characteristics of a soft robot using the handout.

Activity: Students will watch the movie *Big Hero 6* over the course of 2 days, looking for evidence to support the thesis that Baymax fits the criteria of a soft robot and documenting their findings on the graphic organizer. The movie can be streamed on YouTube for a fee. It may be possible to stream the movie for free. Half of the movie will be watched on Day 2 and the other half on Day 3.

Graphic Organizer- Finding Supporting Evidence
https://docs.google.com/document/d/1X8tQySP9UzSXGsNCxb_iMatTfiadFCNBL2d41eqizpE/edit?usp=sharing

Exit Ticket: "Name 2 examples of evidence you found from today's portion of the movie." Students will share their answers orally and write down on their graphic organizer any examples they may have missed. They will complete this exit ticket each day after watching the movie.

Day 4

Activity: In this activity, students will use Google Drawing to create a Venn diagram, using squares instead of circles. If your students are familiar with Google Drawings, they will use shapes, text boxes, fill color, and background color to create a Venn diagram. I have included an example which I created by using 3 square shapes, side-by-side, which I elongated into rectangles. Text boxes are needed to write inside the shapes and fill color adds the color inside each box. Background color adds the color to the overall drawing.

Venn Diagram Example:
https://docs.google.com/drawings/d/1Qe_ig8t3NZ3QwC6BxfNu4lnzzhOgIsVZmpLz8buMHpE/edit?usp=sharing

If students have never used Google Drawings, you may want to use Applied Digital Skills to teach them how to use the application. Applied Digital Skills is a free program for both students and teachers to use. It uses video instruction to take students step-by-step through the process of using the Google suite. The "Build a Logo" lesson will teach students the skills necessary to create the Venn diagram. Explain to students that they will not be creating a logo, but learning how to use shapes, text boxes, and fill color in Google Drawings.

Build a Logo to Express Who You Are (Google Drawings)
https://applieddigitalskills.withgoogle.com/c/middle-and-high-school/en/build-a-logo-to-express-who-you-are/overview.html

Teachers may decide to use the Venn diagram that has already been created instead. In this case, students will simply need to complete the example Venn diagram. They may need to google information about traditional (hard) robots.

Day 5 (optional)

If students began creating their own Venn diagram on Day 4, they will need to complete their diagram with the information about soft robots and traditional robots. They may also need additional time to create their diagram, especially if they needed to refer to the video instruction. If they used the example diagram provided instead of creating their own, they will have already completed this assignment.

Lesson 2: What are Some Types of Soft Robots? (2-3 days)

Objectives:

1. **SWBAT** identify at least 5 different types of soft robots and their applications IOT determine how they could best be used to solve current world problems.

2. **SWBAT** create a Google slides presentation IOT showcase new video clips of different types of soft robots.

Standards:

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Video: Presenting the Universal Jamming Gripper https://youtu.be/Rna03IlJjf8

Video: Wearable Assistive Robotics with Integrated Sensing https://youtu.be/Itt8bTHXvYs

Video: Origami-Inspired Soft Robot https://youtu.be/ngL2m0G3OME

Video: Flippy: A Soft Autonomous Climbing Robot https://youtu.be/AQcBEuOAlWE

Video: Watch This Robot Crawl Up Walls https://youtu.be/eGeIi_GY4W0

Video: Stanford Engineers Develop Crawling and Transforming Soft Robots https://youtu.be/XqgbLb8m77U

Video: Octopus-Inspired Robots Can Grasp, Crawl, and Swim https://youtu.be/L7FEJJsvHRQ

Video: A Swarm of Nano Quadrotors https://youtu.be/YQIMGV5vtd4

All About a Topic (Google Slides) https://applieddigitalskills.withgoogle.com/c/middle-and-high-school/en/create-a-presentation-all-about-a-topic/overview.html

In this lesson, the teacher will use the short video clips to show students examples of different types of robots. They will then explore the Internet on their own to find more video clips that they can include in their own Google Slides presentation. They may look different examples of the same types of soft robots they have seen during this lesson. They may also look for video clips of different types of soft robots not presented in this lesson. Students must correctly cite the source (website) from which they found their video clips. The teacher (or students) may compile all these new videos into a file of resources that can be used with this lesson in the future.

If students have never created a Google Slides presentation before, they may use the Applied Digital Skills tutorial, "All About a Topic" to help them do so. These videos will help to differentiate instruction depending on each student's skill level. Students may work collaboratively with other students to help them with this process, or they may work independently.

Lesson 3: What are some of the applications of soft robots? (2-3 days)

Objectives:

1. **SWBAT** identify 5 different types of soft robots and their applications IOT determine how they could best be used to solve current world problems.
2. **SWBAT** brainstorm ideas about additional applications for soft robots IOT generate possibilities for future applications for soft robots.
3. **SWBAT** compose a Google Doc IOT present several applications for soft robots.

Standards:

ISTE Standard 3: Knowledge Constructor: Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts and make meaningful learning experiences for themselves and others.

ISTE Standard 6: Creative Communicator: Students communicate clearly and express themselves creatively for a variety of purposes using the platforms, tools, styles, formats and digital media appropriate to their goals.

ELA Reading

CC.1.2.8.B Cite the textual evidence that most strongly supports an analysis of what the text says explicitly as well as inferences, conclusions, and/or generalizations drawn from the text.

ELA Writing

CC.1.4.8.U Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas efficiently

CC.1.4.8.V Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

CC.1.4.8.W Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation

Materials Needed:

Student Chromebook/Computer

Research and Develop a Topic (Document)

https://applieddigitalskills.withgoogle.com/c/middle-and-high-school/en/research-and-develop-a-topic/overview.html

Handout- Applications of Soft Robots
https://docs.google.com/document/d/1g8G78Hf9twovbptRTmLQZLQZQLtMAvr9NhLAoyKFqaw/edit?usp=sharing

Video: Octopus-Inspired Robots Can Grasp, Crawl, and Swim
https://youtu.be/L7FEJJsvHRQ

Researchers Design Soft Robots That Can Move on Their Own
https://youtu.be/fUqPPdl9ujk

Meet the Inflatable Robots of Pneubotics https://youtu.be/83PCCR0LKP0

The Age of Soft Robotics is Coming: Here's How They Work
https://youtu.be/4MfZuLpHUqM

George Whitesides: Soft Robotics https://youtu.be/Lhbh-aEWRFU

Activity: In this lesson, students will watch video clips, complete the applications handout, and do research to complete a document explaining at least 5 applications of soft robots. Students should include the additional applications they added to their handout. Finally, students will use the Applied Digital Skills tutorial videos to assist them in a completing a Google Doc that shares their information. Students may work independently or in small groups.

Teachers will provide the links to the videos above, but students will search for video clips of their own to add to their presentation. Students will begin to take responsibility for what they learn in this lesson.

Lesson 4: What are the advantages of developing and using soft robots? (2-3 days)

Objectives:

1. **SWBAT** explain 5 advantages of using soft robots IOT establish the practicality of developing soft robotics technologies.
2. **SWBAT** create a Google Site IOT showcase the types, applications, and advantages of using soft robots.

Standards:

ISTE (International Society for Technology in Education)

ISTE Standard 1: Empowered Learner: Students leverage technology to take an active role in choosing, achieving and demonstrating competency in their learning goals, informed by the learning sciences.
ISTE Standard 3: Knowledge Constructor: Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts and make meaningful learning experiences for themselves and others.
ISTE Standard 6: Creative Communicator: Students communicate clearly and

express themselves creatively for a variety of purposes using the platforms, tools, styles, formats and digital media appropriate to their goals.
ISTE Standard 7: Global Collaborator: Students use digital tools to broaden their perspectives and enrich their learning by collaborating with others and working effectively in teams locally and globally.

Business Computer and Information Technology

15.4.8.K: Create a multimedia project using student-created digital media.

ELA Reading

CC.1.2.8.B Cite the textual evidence that most strongly supports an analysis of what the text says explicitly as well as inferences, conclusions, and/or generalizations drawn from the text.

ELA Writing

CC.1.4.8.U Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas efficiently

CC.1.4.8.V Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

CC.1.4.8.W Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation

Materials Needed:

Student Chromebook/Computer

Advantages of Using Soft Robots Worksheet
https://docs.google.com/document/d/1rRmqPSJ2zkh6C1T2M5uwLeCpzbhxFOriCqONVshXuY4/edit?usp=sharing

Build a Portfolio with Google Sites (Sites)
https://applieddigitalskills.withgoogle.com/c/middle-and-high-school/en/build-a-portfolio-with-google-sites/overview.html

Activity: For this culminating activity, students will complete the advantages worksheet. Then they will use the Applied Digital Skills program, "Build a Portfolio with Google Sites," to compile all the information gathered in this unit into a website that describes what soft robots are, gives examples of some types of soft robots, shares applications of soft robots, and explains some advantages of using soft robots.

As with all of the Applied Digital Skills lessons, students will learn step-by-step how to create a Google Site and students add information they have already gathered. Teachers will function as facilitators and encourage students to gather information on their own. If teachers choose to use this unit multiple times, they should collect the new information gathered from the research of the students and include it in future lessons.

Lesson 5 (Optional Extension)

If teachers would like to provide a hands-on opportunity for students to build their own simple robot, they can use the lesson provided here: The SDM Finger: Teaching engineering design through soft robotics

Resources

Instructional Videos

Soft Robotic Gripper https://youtu.be/csFR52Z3T0I

Presenting the Universal Jamming Gripper https://youtu.be/Rna03IlJjf8

Wearable Assistive Robotics with Integrated Sensing https://youtu.be/Itt8bTHXvYs

Origami-Inspired Soft Robot https://youtu.be/ngL2m0G3OME

Watch This Robot Crawl Up Walls https://youtu.be/eGeIi_GY4W0

Flippy: A Soft Autonomous Climbing Robot https://youtu.be/AQcBEuOAlWE

Stanford Engineers Develop Crawling and Transforming Soft Robots https://youtu.be/XqgbLb8m77U

A Swarm of Nano Quadrotors https://youtu.be/YQIMGV5vtd4

Octopus-Inspired Robots Can Grasp, Crawl, and Swim https://youtu.be/L7FEJJsvHRQ

Targeted Muscle Re-Innervation (TMR) for Advanced Prosthetic Control https://youtu.be/-u8KkvZvVVI

Researchers Design Soft Robots That Can Move on Their Own
https://youtu.be/fUqPPdl9ujk

Meet the Inflatable Robots of Pneubotics https://youtu.be/83PCCR0LKP0

The Age of Soft Robotics is Coming: Here's How They Work
https://youtu.be/4MfZuLpHUqM

The Incredible Potential of Flexible Soft Robots: Giada Gerboni
https://youtu.be/AI7M-JTC6_w

George Whitesides: Soft Robotics https://youtu.be/Lhbh-aEWRFU

Bibliography for Teachers

Berndt, S., Herman, M, Walsh, C., & Holland, D. "The SDM Finger: Teaching engineering design through soft robotics" *Science Scope* 43.4: 14-21 (2019).

Brown, E., Rodenberg, N., Amend, J., Mozeika, A., Steltz, E., Zakin, M. R., Lipson, H., Jaeger, H. M. " (Brown 2010)" *Proceedings of the National Academy of Sciences* 107: 18809-18814 (2010). https://doi.org/10.1073/pnas.1003250107 (Links to an external site.)

Hortense, L. "Robotics: Science Preceding Science Fiction." *MRS Bulletin* 44, no. 4 (2019): 295–301. doi:10.1557/mrs.2019.68.

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Trivedi, D., Rahn, C., Kier, W. & Walker I. (2008) Soft robotics: Biological inspiration, state of the art, and future research, Applied Bionics and Biomechanics, 5:3, 99-117, DOI: 10.1080/11762320802557865

Yang, G.-Z., Bellingham, J., Dupont, P. E., Fischer, P., Floridi, L., Full, R., Jacobstein, N., Kumar, V., McNutt, M., Merrifield, R., Nelson, B. J., Scassellati, B., Taddeo, M. Taylor, R., Veloso, M., Wang, Z.L., Wood, R. "The Grand Challenge of *Science Robotics"* 3.4: aar7650 (2018). https://doi.org/10.1126/scirobotics.aar7650

Websites:

Will Nanotechnology Soon Allow You to 'Swallow the Doctor'?
https://edition.cnn.com/2015/01/29/tech/mci-nanobots-eth/index.html

Applications of Soft Robotics

https://www.whatnextglobal.com/post/applications-of-soft-robotics

5 Innovative Applications of Soft Robotics

https://www.automate.org/blogs/5-innovative-applications-of-soft-robotics

The Incredible Potential of Soft Robotics

https://coe.gatech.edu/news/2020/01/incredible-potential-soft-robotics

Why Soft Robots Have NASA, Doctors, and Tech Whizzes So Excited

https://fortune.com/2021/01/01/soft-robots-applications-advantages-surgery/

Why Do We Need Soft Robotics?

https://www.robotshop.com/community/blog/show/why-do-we-need-soft-robotics

Soft Robotics: Bend Them, Shape Them, Any Way You Want Them

https://www.machinedesign.com/markets/robotics/article/21172100/soft-robotics-bend-them-shape-them-any-way-you-want-them?gclid=Cj0KCQiA95aRBhCsARIsAC2xvfzFSfDyjmfpBYB4gSIwYKUDgaaiCAQUy5O91ziXQDLsggMhlQsiUxEaAh4DEALw_wcB

Soft Robotics

https://biodesign.seas.harvard.edu/soft-robotics

Soft Robotics

https://gmwgroup.harvard.edu/soft-robotics

Soft Robots: A Review

https://www.elveflow.com/microfluidic-reviews/general-microfluidics/soft-robot/#:~:text=Soft%20robotics%20is%20a%20growing,achieve%20smooth%20and%20complex%20motion.

Introduction to Soft Robotics: the first year of soft robotics

http://opensoftmachines.com/2018/02/intro-soro_first/#:~:text=We%20may%2C%20therefore%2C%20consider%202010,first%20year%20of%20soft%20robotics.%E2%80%9D

“Big Hero 6”: The Science Behind Baymax, Disney’s Big, Soft Robot

https://www.nbcnews.com/tech/gadgets/big-hero-6-science-behind-baymax-disneys-big-soft-robot-n240241

Does Technology Like That Seen in Big Hero 6 Actually Exist?

https://the-take.com/read/does-technology-like-that-seen-in-big-hero-6-actually-exist#:~:text=Big%20Hero%206's%20co%2Dlead,until%20the%20patient%20is%20helped.

This Soft Robotic Arm is Straight Out of Big Hero 6

https://techcrunch.com/2018/04/27/this-soft-robotic-arm-is-straight-out-of-big-hero-6-its-even-from-disney/

Inflatable Soft Robots Like Baymax May Be Used in Hospitals

https://www.theguardian.com/science/2015/oct/25/inflatable-soft-robots-used-in-hospitals-baymax

Baymax From Big Hero 6 May Soon Be a Real Thing

https://www.science20.com/print/246438

Baymax in Real Life? How Soft Robotics Might Change the Future

https://www.likeablestem.com/single-post/baymax-in-real-life-how-soft-robotics-might-change-the-future

The Challenge of Big Hero 6: How to Make a Huggable Robot
https://www.npr.org/sections/alltechconsidered/2014/11/07/362030044/the-challenge-of-big-hero-6-how-to-make-a-huggable-robot

The First Tendril-Like Robot Able to Climb https://phys.org/news/2019-01-tendril-like-soft-robot-climb.html#:~:text=Researchers%20at%20IIT%2DIstituto%20Italiano,been%20published%20in%20Nature%20Communications.

Appendix

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>
> CC.1.4.8.W Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation

Speaking and Listening: Comprehension and Collaboration

CC.1.5.8.A Collaborative Discussion

Engage effectively in a range of collaborative discussions, on grade level topics, texts, and issues, building on others' ideas and expressing their own clearly.

CC.1.5.8.B Critical Listening

Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and the relevance and sufficiency of the evidence.

CC.1.5.8.F Multimedia

Integrate multimedia and visual displays into presentations to add interest, clarify information, and strengthen claims and evidence

Teaching Resources

Introduction to Robots Slides Presentation
https://docs.google.com/presentation/d/1i99V1tx13adOvPVgpG2FJDfHAa1ovOQ4eGBF2ueJVuc/edit?usp=sharing

Build a Logo to Express Who You Are (Google Drawings)
https://applieddigitalskills.withgoogle.com/c/middle-and-high-school/en/build-a-logo-to-express-who-you-are/overview.html

All About a Topic (Google Slides)
https://applieddigitalskills.withgoogle.com/c/middle-and-high-school/en/create-a-presentation-all-about-a-topic/overview.html

Research and Develop a Topic (Document)

https://applieddigitalskills.withgoogle.com/c/middle-and-high-school/en/research-and-develop-a-topic/overview.html

Build a Portfolio with Google Sites (Sites)

https://applieddigitalskills.withgoogle.com/c/middle-and-high-school/en/build-a-portfolio-with-google-sites/overview.html

Student Handouts:

Graphic Organizer (Finding Supporting Evidence)
https://docs.google.com/document/d/1X8tQySP9UzSXGsNCxb_iMatTfiadFCNBL2d41eqizpE/edit?usp=sharing

Venn Diagram
https://docs.google.com/drawings/d/1Qe_ig8t3NZ3QwC6BxfNu4lnzzhOgIsVZmpLz8buMHpE/edit?usp=sharing

Characteristics of a Soft Robot Handout
https://docs.google.com/document/d/1ytEv8j8G83mCCf6VXcRtR6XSFU2G2prRVYLD6p3Leoc/edit?usp=sharing

Handout- Applications of Soft Robots
https://docs.google.com/document/d/1g8G78Hf9twovbptRTmLQZLQZQLtMAvr9NhLAoyKFqaw/edit?usp=sharing

Advantages of Using Soft Robots Worksheet
https://docs.google.com/document/d/1rRmqPSJ2zkh6C1T2M5uwLeCpzbhxFOriCqONVshXuY4/edit?usp=sharing