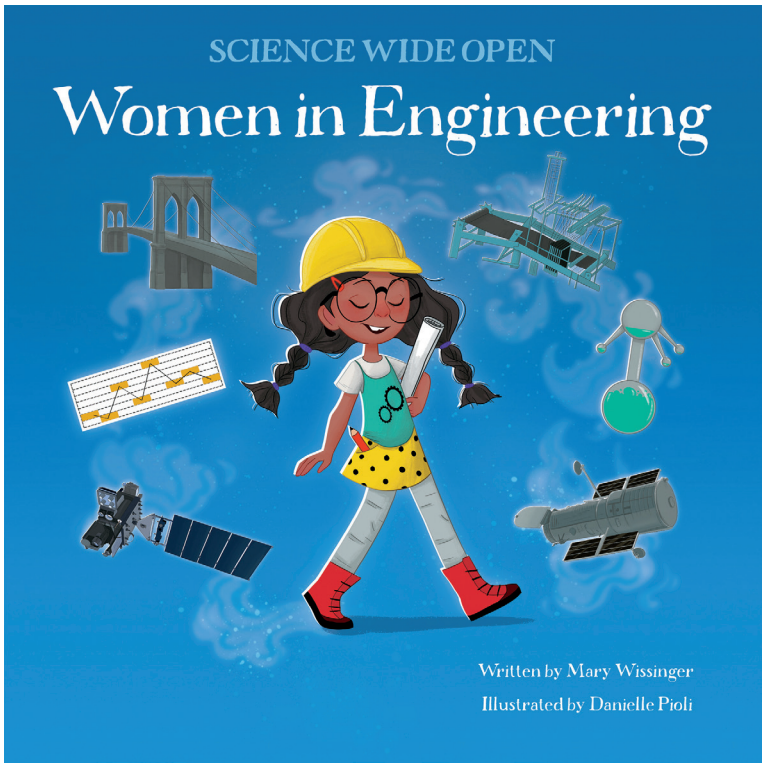
Women in Engineering
Teacher's Guide

Written and designed by Caitlin Burnham, Hannah Thelen, Marlee Brooks, Yu Young "YY" Lee, and Liliann Albelbaisi



To be used with *Women in Engineering* and *Las mujeres en la ingeniería*
Written by Mary Wissinger
Illustrated by Danielle Pioli

English editions:
Hardback ISBN: 978-1-938492-52-5
Paperback ISBN: 978-1-938492-53-2
eBook ISBN: 978-1-938492-54-9
Spanish editions:
Paperback ISBN: 978-1-938492-95-2
eBook ISBN: 978-1-938492-98-3

Science, Naturally! - An imprint of Platypus Media, LLC
Sparking curiosity through reading
750 1st St NE, Suite 700 • Washington, DC, 20002
Office: 202-465-4798 • Fax: 202-558-2132
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Sparking curiosity through reading

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About the Author: Mary Wissinger

Mary was born in Wisconsin where she spent most of her childhood singing, reading, and daydreaming. She dove into storytelling through acting, singing, and writing (and writing and writing).

While spending time as a classroom teacher sharing the magic of music, she saw firsthand the incredible life-changing power of stories. The stories children read become the stories they play, and then the stories they tell.

Mary can now be found at her standing desk in St. Louis, MO, writing stories that inspire curiosity about the world and connection with others. (But don't worry, she still sings with the Saint Louis Symphony Chorus.)

Mary is the author of the Science Wide Open series. She can be reached at Mary.Wissinger@ScienceNaturally.com.

About the Illustrator: Danielle Pioli

As children usually do, Danielle always loved drawing. The idea of creating a whole universe—from her mind to paper—made her fall in love with art and storytelling. She also always felt like a healer at some level. As a child in São Paulo, Brazil, she was so drawn to magic—what she calls Quantum Physics now—that she was certain she could heal and help people. Because of this, she grew up to become an artist and hypnotherapist/energy healer.

Danielle is the illustrator for the Science Wide Opens series. She can be reached at Danielle.Pioli@ScienceNaturally.com.

Women in Engineering
Teacher's Guide Contributors

Science Naturally would like to thank the following people for their hard work, invaluable insight, and dedicated time in creating *Women in Engineering* and its accompanying Teacher's Guide:

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Resources

Human beings have always been engineers. Where there is a problem or inefficiency, engineers are there to find a solution through thorough research, trial and error, and hands-on construction and prototyping, all of which are fueled by deep curiosity, expansive imagination, and sudden inspiration.

No matter where we are, our lives are touched by the inventions of engineers. Electrical engineers connect us to the internet and give us light. Civil engineers help us reach new places by constructing bridges and roads. Mechanical engineers tinker with the machines to improve our techniques. Biomedical engineers fashion new hips and skin grafts to heal people. Aerospace engineers literally go to the ends of the Earth to explore outer space.

Engineers are inquisitive, just like young children. This is a guide, complete with visual aids, worksheets, and activities, made to help foster interest in engineering. The listed resources are a way for students to expand and deepen their knowledge about the subjects covered in *Women in Engineering*.

Videos on Engineering

- "What's an Engineer? Crash Course Kids #12.1" by Crash Course Kids
- "How to be an inventor! | Kid President" by Participant
- "What Makes Bridges So Strong? | Engineering for Kids | STEAM | SciShow Kids" by SciShow Kids
- "NASA for Kids: Intro to Engineering" by NASA Goddard
- "22 Inventions That Are Saving The Earth" by Insider Tech
- "Great Inventors: Hedy Lamarr" by Adventure Academy

Books to foster curiosity:

- *Goldilocks and the Three Engineers* by Sue Fliess
- *How Does My Home Work?* by Chris Butterworth
- *The Most Magnificent Thing* by Ashley Spires
- *Cleonardo The Little Inventor* by Mary GrandPré
- *Ada Twist's Big Project Book for Stellar Scientists* by Andrea Beaty
- *Spin the Golden Light Bulb* by Jackie Yeager
- *The Boy Who Harnessed the Wind (Young Reader's Edition)* by William Kawkwamba

Podcasts to listen to:

- STEM Everyday Podcast
- But Why: A Podcast for Curious Kids (NPR)
- Wow in the World (Tinkercast)

Websites to interact with:

- Ask Dr. Universe (Technology, Engineering, Math) *https://askdruniverse.wsu.edu/category/tem/*
- Exploratorium (Engineering and Technology) *https://www.exploratorium.edu/explore/engineering-and-technology*
- Engineering, Go for It! (eGFI) for Teachers / for Students *http://teachers.egfi-k12.org/category/activities/grades-k-5-activities/*
- PBS Nova *https://www.pbs.org/wgbh/nova/topic/tech/*
- Free Rider *https://www.freeriderhd.com/create*
- Martha's Stories: "How to be an Inventor" *https://pbskids.org/martha/stories/truestories/inventor_story.html*
- Engineering is Elementary *https://www.eie.org/*

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Meet the Women

Women in Engineering and *Las mujeres en la ingeniería* offer young readers some insight on women who have made big strides with their inventions and research in engineering. The six women profiled, all of whom had the odds stacked against them, worked diligently to see their ideas and creations come to fruition. Today, those special ideas and inventions have shaped our world into what it is. From biomedical enginnering to civil engineering, this book encompasses the broad history of women in engineering.

Women in Engineering and *Las mujeres en la ingeniería* explore the discoveries of the following women:

Emily Warren Roebling (United States, 1843-1903): When her husband, Washington Roebling, fell ill and became bedridden during his term as chief engineer of the Brooklyn Bridge, Emily took it upon herself to relay information back and forth between her husband and his assistants on the bridge. She quickly became adept in her understanding of the construction of the bridge and its resources through her husband and his teachings. Ten years later, she took on the role and responsibility of project manager and oversaw day-to-day duties on the bridge while still working closely with her husband on the bridge's construction. She met with politicians and others working on the bridge, and even defended her husband when his position as chief engineer was questioned.

Huang Daopo (China, 1245-1330): After running away from a forced marriage, Huang found herself in Yahzou, where she learned how to spin and weave cloth. She quickly learned and transformed ginning, spinning, stretching, and weaving techniques. She invented a method for a machine to remove the seeds from cotton, instead of doing it by hand. This allowed the machine to produce three rolls of yarn simultaneously, creating a more efficient system and abundant production. She was also able to improve the techniques for spinning cotton into yarn, making a spinning wheel and weaving tools, which made the process of creating fabric even faster. When she returned to her hometown with all her knowledge, her new inventions significantly increased the production of yarn and fabric.

Mary the Prophetess (Egypt, ~3rd Century A.D.): Considered to be the first alchemist in the western world, Mary created and invented many chemical apparatuses. As she was inventing so early in recorded history, most of our knowledge of her work comes from historical texts, which call her a masterful alchemist who gave metals personified characteristics—like a body, soul, and spirit. Three inventions that have been attributed to Mary are: the tribikos (a three-beaked distillation apparatus), the kerotakis (a distillation apparatus), and the bain-marie (a double boiler).

Hedy Lamarr (Austria/Hungary/United States, 1914-2000): Hedy had a long and impressive career as an actress, but she was also quite interested in tinkering and inventing. She was never formally taught, and would invent and create things as a hobby during her free time. During

Meet the Women Continued

World War II, when the idea of radio-controlled torpedoes was raised, many people were concerned with the thought that an enemy could jam the torpedo's system to push it off course. Hedy discovered a way around this issue: frequency-hopping. She worked with her friend, George Antheil, to create a miniature machine that contained radio signals. Hedy and George received many awards and accolades for their work, and their machine was one of the inventions that led us to create things like Wi-Fi and GPS systems.

Sandra Cauffman (Costa Rica, 1962): Ever since she saw the moon landing as a little girl in Costa Rica, Sandra knew she wanted to work in space science. After starting college at the University of Costa Rica, she transferred to George Mason University, where she received her bachelor's degree in physics and electrical engineering, and her master's degree in electrical engineering. She also learned English during her time at George Mason. For a little over thirty years, Sandra has worked with NASA on many projects: the Mars Atmosphere and Volatile Evolution mission (MAVEN), the Geostationary Operational Environmental Satellites-R (GOES-R), and the Hubble Space Telescope Servicing Mission. She is currently the Deputy Director of the Astrophysics Division within the Science Mission Directorate at NASA Headquarters in Washington, D.C.

Treena Livingston Arinzeh (United States, 1970): Inspired by science experiments she did as a child with her mother, Treena decided to pursue a career in STEM. She studied biomedical engineering when she was a graduate student and pursued a career in academia at the New Jersey Institute of Technology. In 2001, she helped found the Tissue Engineering and Applied Biomaterials Laboratory at NJIT. She works as a professor in biomedical engineering and has been published over 60 times. She is credited with discovering a method that allows bone growth regeneration and the repair of tissue damage through stem cell research and therapy. She also actively works with the American Chemical Society in their Project Seeds program, where she invites teens from underrepresented and disadvantaged groups to visit her laboratory and learn about engineering and her research.

Before Reading: Define Engineering

Grades: 2nd grade - 4th grade

NGSS: K-2-ETS1-1 Engineering Design

Materials: *Women in Engineering*

Skills: making inferences, critical thinking

Subject: What is engineering?

Background

Women in Engineering is an extensive introduction to the diverse fields of engineering, a crucial branch of science that affects virtually everything—engineering is responsible for the clothes we wear, the machines we use everyday, and the technology that connects us with the entire world. In preparation for reading this book, discuss engineering with your students, what they already know about it, and how it has impacted and continues to impact the world.

Activity

1. Write the acronym STEAM on the board, and ask your students if they know what each letter stands for (Science, Technology, Engineering, Arts, Mathematics).
2. Inform your students that today you'll be focusing on the "E" of STEAM and delving into what engineering is, and what is actually involved in this field.
3. Pair up your students, and ask them to brainstorm and write down their answers to the following questions:
   a. What do you think an engineer does?
   b. What engineers do you know about, either in history or in the present?
   c. How do you think engineering affects our lives?
   d. What kinds of skills do you think engineers use everyday?
5. After giving them a couple of minutes, create a mind map on the board with the answers your students give, with each question forming a new branch.

Discussion

Discuss how the students' answers, and the connections made on the mind map, show how engineering truly impacts our lives in so many different ways. The work of engineers is essentially everywhere—they are the inventors who imagined and built our machines, infrastructure, power systems, and more. Try opening up the conversation to discuss the things in the room you are in, and how engineers were involved in making them. Encourage interest in the field by bringing up the creativity and expansiveness of engineering. With older students, feel free to delve into more specifics, such as identifying different branches of engineering, or discussing the lack of diversity in the field in more depth.

Define Engineering Continued

Expanding on the Activity

1. Explain and discuss what engineers do.
    a. Questions to ask the students to initiate discussion: How do engineers creating an invention or design and implement it? What problems do you think you could solve through engineering? Are there any inventions that would improve the room you are in?
2. Take suggestions from the students and have them brainstorm on an issue that the class could fix during their class period. Once the class has decided on a problem to fix (noticing a problem), have them work together to figure out what solutions there are (brainstorming).
3. Have the students create/build the invention that will solve your problem, and try it out together to see if it works (planning and testing). Then discuss why it worked or where it went wrong. Explain to them that engineers have to do multiple rounds of testing on their inventions before they produce an efficient solution.

After Reading: The *Bain-Marie* and the the Double Boiler

Grades: 2nd grade - 4th grade

Materials: *Women in Engineering*, a double boiler (pot with water inside and heat safe bowl), a small pot, a hot plate or stovetop, chocolate, thermometer

Subject: Inventions as versatile and useful, efficient innovations in life

NGSS: K-2-ETS1-1 Engineering Design, K-2-ETS1-3 Engineering Design, 3-5-ETS1-3 Engineering Design

Skills: observation, critical thinking, experimentation

Background

Women in Engineering highlights the ingenuity of engineering, and the timeless, universal nature of human invention. The inventions themselves, too, can be enduring, such as Mary the Prophetess's version of a double boiler, the *bain-marie*. Years after Mary's invention, engineers have expanded upon the bain-marie and have created the much more reliable double boiler. This activity will show your students the power of engineering, even in everyday tasks such as melting chocolates. By fashioning your own double boiler, your students will observe the practical and diverse types of inventions engineers make.

Activity

1. Read *Women in Engineering* aloud to your class.
2. Discuss the different inventions that you read about, and how inventions can be replicated and upgraded to improve the efficiency of a process.
3. Explain that while Mary invented the *bain-marie,* her work inspired the creation of the double boiler. Compare and contrast the similarities and differences the *bain-marie* has with the double boiler, and discuss how Mary's influence on the double boiler is still significant.
4. Melting chocolate is a simple process and can be done in several ways, but chefs complete this task using a double boiler because its design results in the best chocolate!
5. You can show your students how inventions can make a difference and improve our methods for doing something by creating your own double boiler!
    a. For set up you will need: a hot plate (or a stovetop, if you are in a kitchen), a pot of water, a heat-proof bowl that can be placed on top of the pot (e.g. glass), another small pot, and four bars of chocolate.
    b. Gather your students around your double boiler. Make sure they are cautioned against touching the set up, as the hot plate is a safety hazard.

The *Bain-Marie* and the the Double Boiler Continued

Activity Continued

3. Inform your students that you'll be melting chocolate in two ways: by direct heat and by double boiler.
4. Keep certain parameters the same between these two methods (i.e. the equipment you use, the same amount of chocolate, same degree of heat). Discuss with your students why it's important in scientific experimentation to keep your controls consistent, so that you can directly compare the melting methods.
5. Turn the heat on to medium. In the small pot, melt two of the chocolate bars directly in the pot and keep stirring for a minute. For this method, you will not need water or the bowl.
6. The chocolate will melt, but explain how the chances of the chocolate burning is very high, given that it's so close to the heat source, and you have less control over how quickly the chocolate is melting. This is important for professionals who cook with chocolate, because it has to reach a very specific temperature in order to stay shiny and not break apart when it cools.
7. Melt the other two bars of chocolate in heat-proof bowl, which should be on top of other pot (this pot should have two inches of water in it, set to simmer in medium heat), this is your double boiler set up. Have your students observe the differences in process, and explain how using Mary's invention allows for the chocolate to melt evenly, and how you can even lift the bowl off the heat and cool it for a bit. Use your thermometer to ensure that you temper the chocolate to the correct temperature (110-115 degrees Fahrenheit).
8. Have your students taste test the chocolate!

Discussion

Ask your students the following questions to start a discussion about inventions, and how they can help improve the methods we use:

1. What method worked better? Was there a difference?
2. How do you think the double boiler method works? How does it melt chocolate differently than when melting the chocolate directly in the pan?
3. Have you seen anyone use the bain-marie or a double boiler method outside of this experiment? Discuss the many different uses for this invention.

After Reading: Building Bridges

Grades: 2nd grade - 4th grade

Materials: *Women in Engineering,* stacks of books, straws/popsicle sticks, tape, glue, and string, a weight (i.e. a can)

Subject: Bridges, civil engineering, design

NGSS: K-2-ETS1-2 Engineering Design, 3-5-ETS1-1 Engineering Design, 3-5-ETS1-3 Engineering Design

Skills: critical thinking, experimentation, building

Background

The first woman engineer that is introduced in *Women in Engineering* is Emily Warren Roebling, who was crucial to the development and completion of the Brooklyn Bridge. The book briefly touches on suspension bridges, and how there are other types of bridge structures. In this activity, delve further into the different types of structures and how they are built. Students will be able to use the handout and worksheets to think about bridges and imagine their own type of bridge. There is an option to expand the activity by having students test the design of their bridges to see if they will hold weight and long they can stay standing.

Activity

1. Read *Women in Engineering* aloud to your class.
2. Share The 7 Types of Bridges Handout with students. You can either print out the handout to distribute amongst the students, or present it to the students instead (either by using a board or screen).
3. Go through each of the bridge styles, and discuss the different features and benefits of each bridge. Feel free to delve deeper into the physics of the bridge structures (i.e. how force interacts with the physical structure of one bridge versus another). Or, talk about the history of each of these bridges, such as different records set (i.e. the oldest bridge in the world, the longest bridge in the world).
4. Print off The 7 Types of Bridges Worksheet and/or the Identify the Bridge! worksheet and distribute them to your students.
5. Work through the worksheets as a class, or give your students independent/group work sessions before coming together again to review the answers.
6. After these worksheets are completed, hand out or discuss the questions in the Reflection. This worksheet can be completed individually, for a turn-in assignment, or together as a class.

Building Bridges Continued

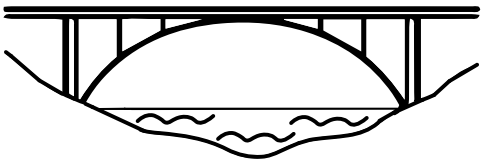
Expanding the Activity

1. If you have older students, or time to expand the activity, distribute the Design and Build Your Own Bridge worksheet. This worksheet can be done individually, in pairs, or groups of four.
2. Give thes students time to imagine their bridge and draw it on the worksheet. Ask them to consider creating a design that would hold a lot of weight, and that is inspired by the bridges they just learned about.
3. After finishing the worksheet, have your students build a bridge inspired by their design.
4. For every individual student or group, set up two stacks of books on a desktop and space them apart so that your students can build their "bridge" over the created gap. Provide straws and/or popsicle sticks, or any other suitable and available materials for constructing the bridge, along with glue or tape for putting it together. Inform the students that their bridges should hopefully be able to hold a given object of substantial weight (i.e. a soup can).
5. After a set amount of time (15-20 minutes suggested), go around and test the students creations.

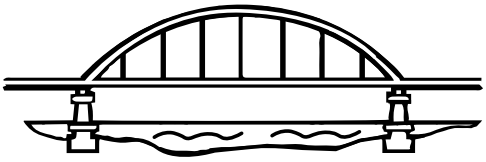
Discussion

Discuss how the students used the different bridge types, ask if any students combined two or more types of bridges in their design. If they worked in groups, ask the students how they consulted, brainstormed, and planned with each other to work together and build their bridges. Reflect and discuss how everyone felt about the activity. What did they learn from building a bridge themselves? What was easy and what was challenging? Did any bridges hold? Ask students why they think those bridges were successful. Did any bridges fail? Ask students to discuss why those bridges were not able to hold the weight.

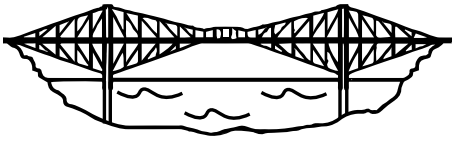
The 7 Types of Bridges: Handout



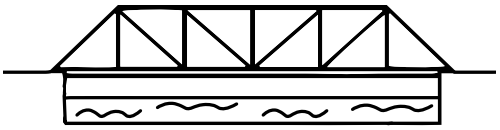
Arch Bridge



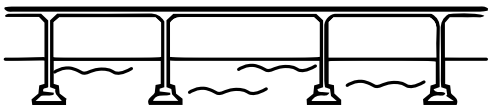
Tied Arch Bridge



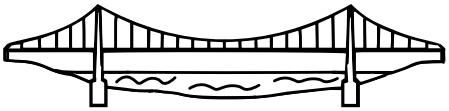
Cantilever Bridge



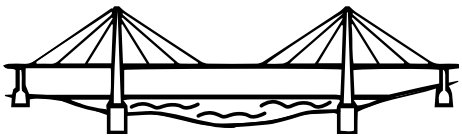
Truss Bridge



Beam Bridge



Suspension Bridge



Cable-Stayed Bridge

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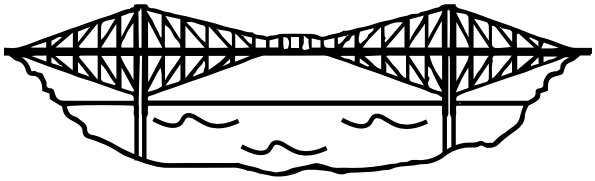
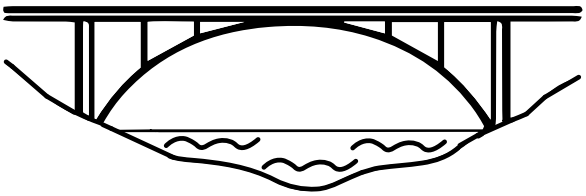
The 7 Types of Bridges: Worksheet

Draw a line connecting the bridge structure to its correct name!

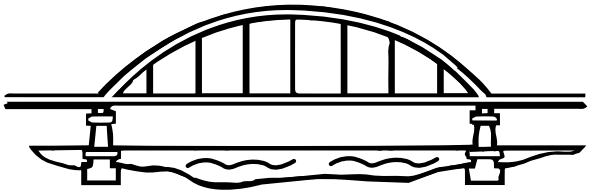
Adapted from scienceandsteamteam



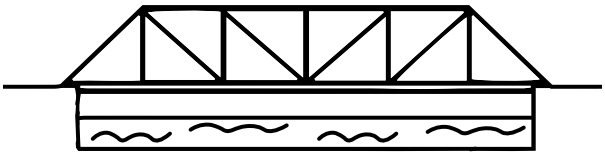
Suspension Bridge



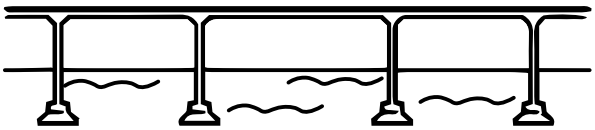
Beam Bridge



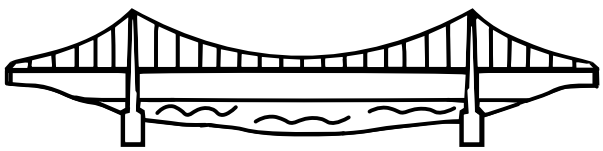
Tied Arch Bridge



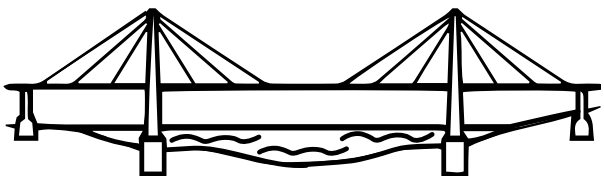
Cantilever Bridge



Truss Bridge



Cable-Stayed Bridge



Arch Bridge

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Identify the Bridge!

Identify the type of bridge! There is one picture for each type.

Adapted from Types of Bridges presentation

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Reflection

1. **Which is your favorite bridge structure? Why?**

2. **Which bridge structure is the strongest? Why do you think so?**

3. **What bridge structure do you think looks the best?**

4. **Why are bridges important? Why must engineers be very careful when they are building bridges?**

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Design and Build Your Own Bridge

Design your own dream bridge in the space below!

How will you construct it in real life? Think about how much weight it needs to support, but don't forget to consider how it looks too! Bridges can be strong and functional, but they are also amazing works of art.

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After Reading: Biomaterials

Grades: 2nd grade - 4th grade

Materials: *Women in Engineering*

Subject: Biomaterials, biomedical engineering

NGSS: K-2-ETS1 Engineering Design, K-2-ETS1-2 Engineering Design, 3-5-ETS1-2 Engineering Design

Skills: scientific drawing

Background

Some engineering feats are easy to see. We can observe how bridges are both functional and fantastic structures. But there are also incredible inventions that are used inside the human body to save people's lives. Over time, engineers have developed synthetic, or human made, materials that can replace organ tissue or even to help construct new bones. Biomaterials are briefly touched upon in *Women in Engineering,* but this activity further explores the diversity of engineering in a medical context.

Activity

1. Read *Women in Engineering* out loud to your class.
2. Discuss Dr. Treena Livingston Arinzeh's work with adult stem cells with the class.
3. Further explain her worth through descriptions of biomaterials and they ways these special materials interact with your body safely, and help heal any wounds, or help your body function better.
    a. Expand on the many different kinds of biomaterials. Here are a few:
        i. Sutures, clips, staples: Materials used to repair broken or torn skin, or surgical incisions.
        ii. Blood glucose monitoring devices: An easy machine that monitors glucose, mostly used by people with diabetes to monitor their health.
        iii. Pacemakers: A machine placed inside the body that helps someone maintain a regular heartbeat.
        iv. Joint replacements: Replacing a damaged joint with an artificial one so that a person can continue to easily use that joint.
        v. Heart valves: Artificial tissue replacement that can replace someone's old or damaged heart valve.
        vi. Contact lenses: Small, plastic lenses people wear in their eyes to help their vision, instead of wearing glasses.
        vii. Hearing aids: Devices placed in the ear to assist people with hearing loss.
        viii. Dental implants: These are implants for the teeth that can help someone chew, replace lost teeth, or change their jaw structure.

Biomaterials Continued

Activity

ix. Braces: Small metal pieces that are attached to teeth to change their shape. Often used to change someone's appearance, but also helpful for chewing and jaw structure.

x. Stents: An artificial tube that is used inside of the body to hold passageways open, such as repairing clogged or damaged arteries.

xi. Hydrogels: Materials that are used in different types of biomaterials to make them water-insoluable. Some examples include contact lenses, wound dressing, and various hygiene products.

b. Discuss how these examples of biomaterials can use different materials, such as titanuim, silver, silicone, plastic, and even artificial tissue.

c. Discuss whether or not the students have ever been in contact with biomaterials. Maybe they know someone who has one, or have one themselves.

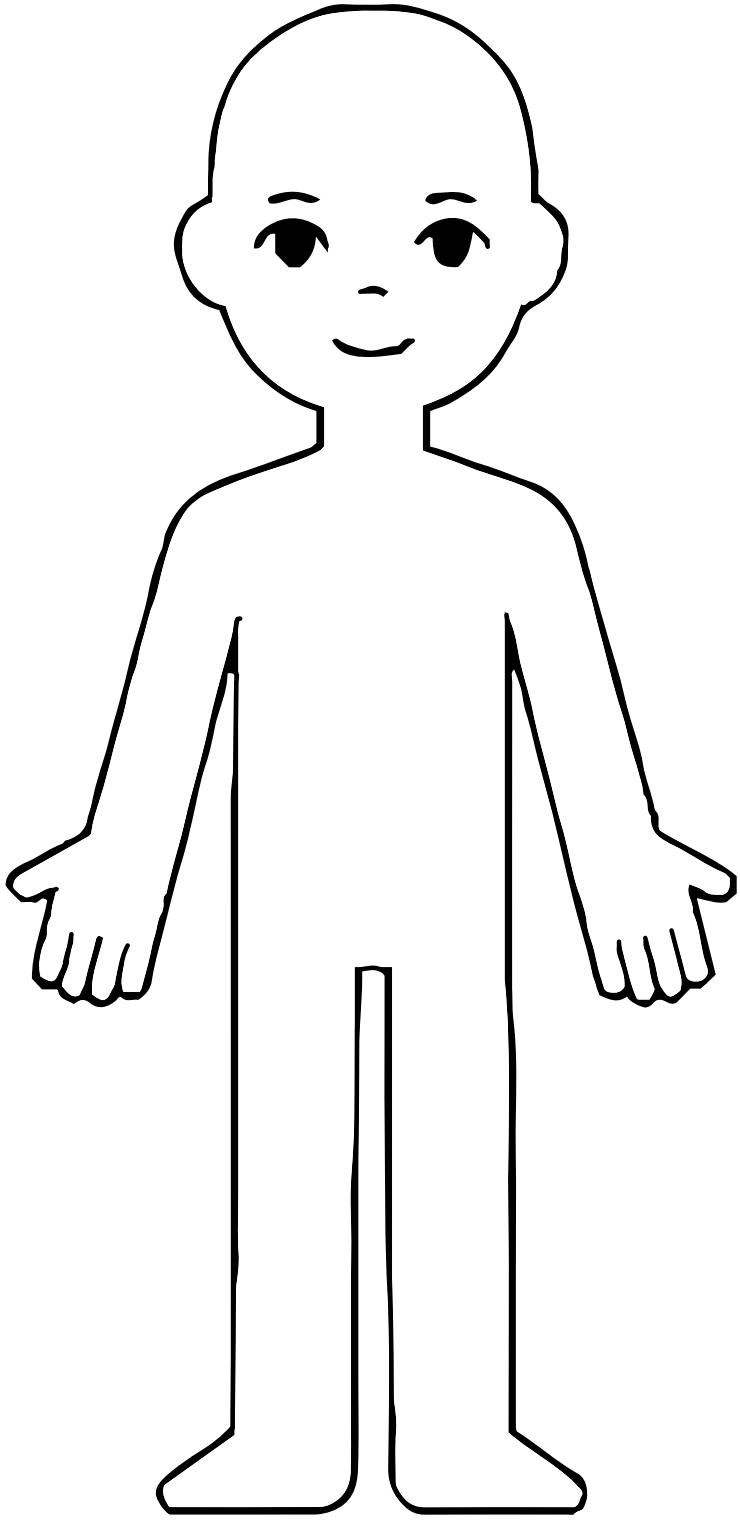
4. Print out the worksheet for your students to draw, annotate, and write notes on. Using the knowledge they know from discussing the examples of biomaterials above, they can try to create their own biomaterials.

Discussion

Discuss the different types of biomaterials students created. Where any inspired by the biomaterials you discussed? How do they improve the body or make someone healthier? Encourage students to think about these biomaterials might be created. Would they use metal, or silicone? Would they be on top of our outside of the body? Compare your students answers to how the engineers behind the biomaterials being used today had to think about everything that might affect the use of the biomaterial. The most important question to ask your students to answer, which all engineers ask themselves, is: what problem are you solving?

Build a Biomaterial

Design your own biomaterials to help this person stay healthy. Use your imagination, and draw your new biomaterials onto the person below! Plan out your biomaterials by writing notes about the type of material you would use, and what problem you are fixing.



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After Reading: Paper Airplanes

Grades: 2nd grade - 4th grade

Materials: *Women in Engineering*

Subject: Biomaterials, biomedical engineering

NGSS: K-2-ETS1-2 Engineering Design, 3-5-ETS1-1 Engineering Design

Skills: critical thinking, experimentation, prototyping, building

Background

At its core, engineering asks us to be creative problem solvers. Trial and error is crucial, and one must often start at the smallest, simplest iteration of a greater invention. Get your students in the headspace of an engineer by trying different designs of a very basic, but ingenious device: the paper airplane. Though today they may start with a blank sheet of paper, someday, they may launch rockets into space.

Activity

1. Read *Women in Engineering* out loud to your class.
2. Discuss Dr. Sandra's Cauffman's work in aerospace engineering with the class. Highlight how her projects refined and improved satellites, and how engineers are always working to improve existing designs. Ask the students how many times they think Dr. Cauffman tested different ideas before finding the best one.
3. Like Dr. Cauffman, we can design and test our own aeronautical inventions, by trying different paper airplane designs!
4. Either individually or in small groups, have students fold different designs of a paper airplane. Encourage students to try their own designs, or improve upon the classic design.
    a. For younger students, feel free to walk through one design together as a class.
3. Have the students try flying the paper airplanes! Observe the different distances and different flight paths. For a competition, consider marking out a "flight path" on the ground, and marking where planes land with tape.

Discussion

Discuss takeaways from the activity as a class. What worked best? What did you enjoy most out of the whole process? What would you do differently? What kind of factors affected how far the plane could fly, and do you think those factors affect real airplanes and spacecraft? Mention the shape it was folded in, the type of paper, the angle you throw it, the force you put into the throw, the wind speed and direction. All of these are things engineers consider when designing an invention or machine. Ask your students: if you could invent anything, what would you invent? If you could make something work more efficiently, what would it be?

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