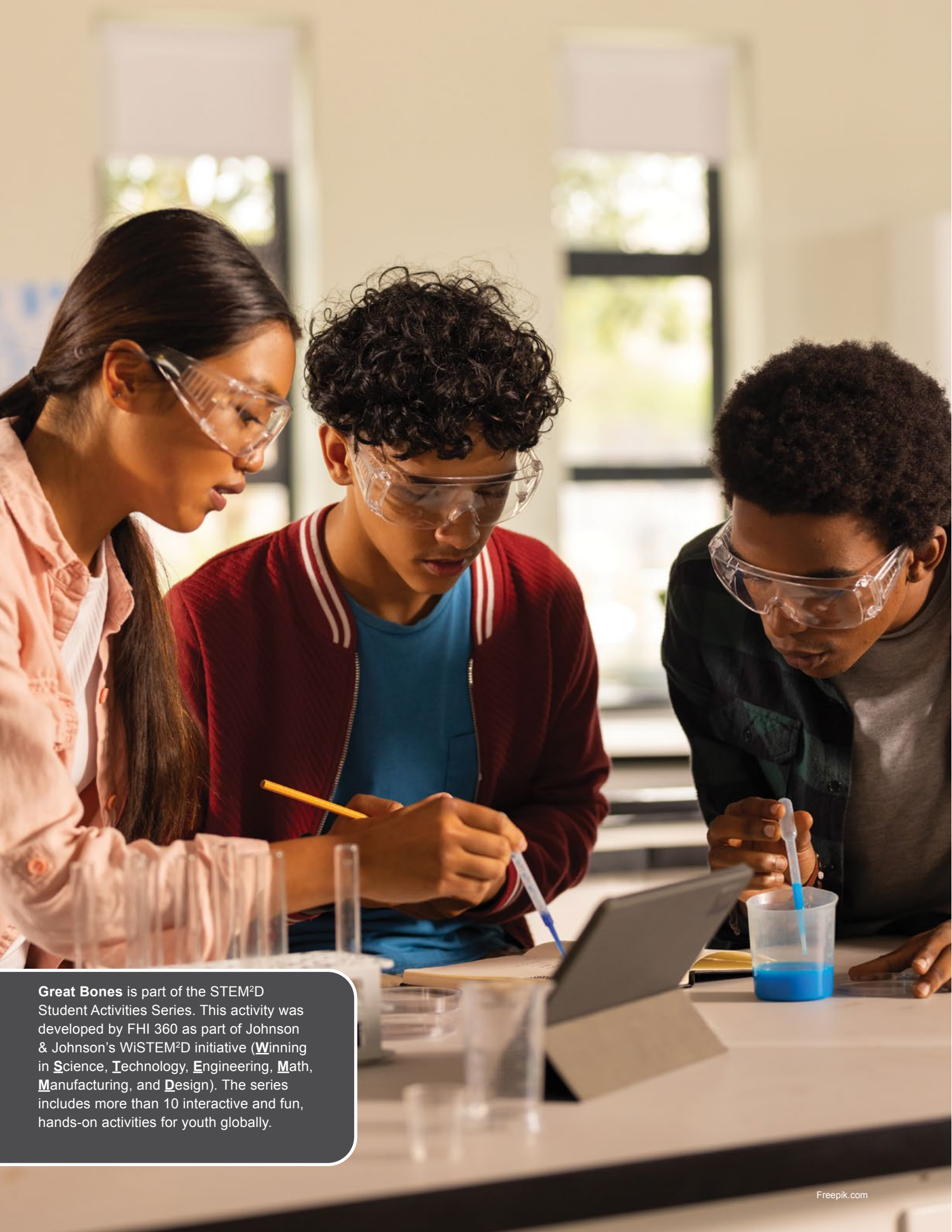





GREAT BONES

STEM²D Topics:
Design,
Engineering

Target Population:
Students, ages 12–16



Great Bones is part of the STEM²D Student Activities Series. This activity was developed by FHI 360 as part of Johnson & Johnson's WiSTEM²D initiative (**W**inning in **S**cience, **T**echnology, **E**ngineering, **M**ath, **M**anufacturing, and **D**esign). The series includes more than 10 interactive and fun, hands-on activities for youth globally.

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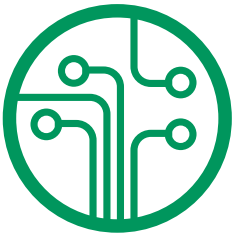
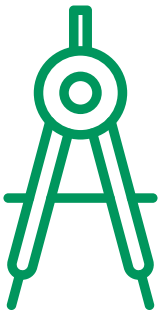




ACTIVITY DESCRIPTION

In this team-based, hands-on activity, students will learn about research and development (R&D) and how engineers use this process to design different technologies and medical devices to help doctors successfully treat patients.

ESTIMATED TIME

This session typically takes **90 minutes** to complete and should be conducted in **one** session.

STUDENT DISCOVERIES

Students will:

- Learn about research and development.
- Participate in a team-based learning experience.
- Build important STEM²D skills, such as creative thinking, critical thinking, problem solving, decision making, and teamwork.
- Realize that STEM²D offers diverse and exciting career opportunities.
- Have fun experiencing STEM²D.

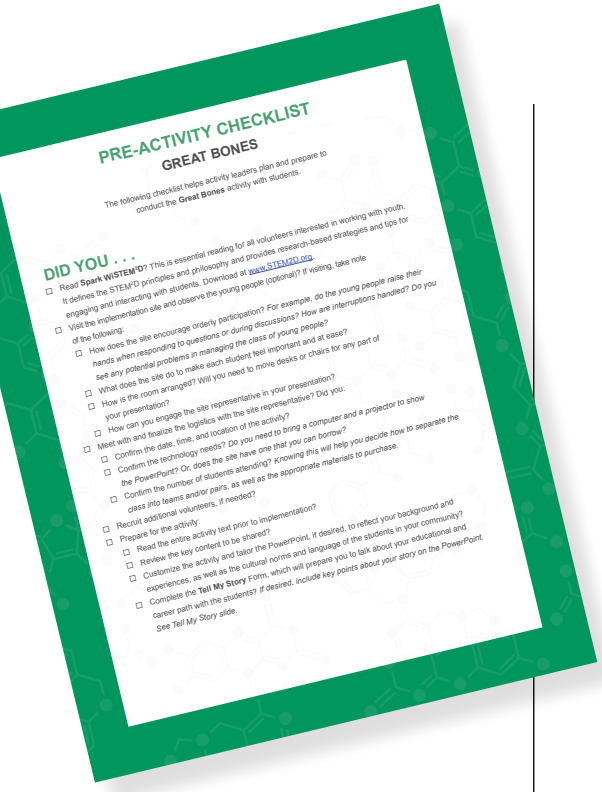
GETTING READY

Materials:

- Pre-Activity Checklist
- Tell My Story Form
- Activity Leader Guide: Salt Dough Bones Recipe
- Computer with projector
- PowerPoint: Great Bones!
- Student Handout: Great Bones Challenge, *1 per team*

STEM²D Skills

- Collaboration
- Communication
- Critical Thinking
- Decision Making
- Problem Solving
- Teamwork
- Testing



PRE-ACTIVITY CHECKLIST

GREAT BONES

The following checklist helps activity leaders plan and prepare to conduct the **Great Bones** activity with students.

DID YOU . . .

- ☐ Read **Spark WiSTEM²D**? This is essential reading for all volunteers interested in working with youth. It defines the STEM²D principles and philosophy and provides research-based strategies and tips for engaging and interacting with students. Download at www.STEM2D.org.
- ☐ Visit the implementation site and observe the young people (optional)? If visiting, take note of the following:
  - ☐ How does the site encourage orderly participation? For example, do the young people raise their hands when responding to questions or during discussions? How are interruptions handled? Do you see any potential problems in managing the class of young people?
  - ☐ What does the site do to make each student feel important and at ease?
  - ☐ How is the room arranged? Will you need to move desks or chairs for any part of your presentation?
  - ☐ How can you engage the site representative in your presentation?
- ☐ Meet with and finalize the logistics with the site representative? Did you:
  - ☐ Confirm the date, time, and location of the activity?
  - ☐ Confirm the technology needs? Do you need to bring a computer and a projector to show the PowerPoint? Or, does the site have one that you can borrow?
  - ☐ Confirm the number of students attending? Knowing this will help you decide how to separate the class into teams and/or pairs, as well as the appropriate materials to purchase.
  - ☐ Recruit additional volunteers, if needed?
- ☐ Prepare for the activity:
  - ☐ Read the entire activity text prior to implementation?
  - ☐ Review the key content to be shared?
  - ☐ Customize the activity and tailor the PowerPoint, if desired, to reflect your background and experiences, as well as the cultural norms and language of the students in your community?
  - ☐ Complete the **Tell My Story** Form, which will prepare you to talk about your educational and career path with the students? If desired, include key points about your story on the PowerPoint. See *Tell My Story* slide.

- Student Handout: Great Bones Materials Cost Form, *1 per team*
- Paper, *1 piece per student*
- Pen/pencil, *1 per student*
- Great Bones Kit, *1 set of the following items per team:*
  - 4 pipe cleaners
  - 2 straws
  - 1 ft (30 cm) duct tape/silver tape
  - 2 popsicle/wooden sticks
  - 1 toilet paper roll or cardboard tube
  - 2 ft (60 cm) aluminum foil
- Sawbone or salt dough bone, *1 per team*

  Note: making salt dough bones takes at least 3 hours; be sure to plan accordingly. See the **Activity Leader Guide: Salt Dough Bone Recipe** for directions. To make 7–8 bones, the following additional materials are required:
  - 4 cups (560 g) flour
  - 2 cups (380 g) salt
  - 2 cups (480 ml) water

Estimated Cost:

Activity leaders can expect to incur less than $20.00 (excluding optional items) in materials costs when completing this activity with 20 students organized into teams of four students.

Activity Leader Preparation

- Read Spark **WiSTEM²D**. This is essential reading for all volunteers interested in working with youth. It defines the **STEM²D** principles and philosophy and provides research-based strategies and tips for engaging and interacting with students. Download at www.STEM2D.org.
- Review the **Pre-Activity Checklist** (at the end of this document) for details and specific steps for planning, preparing, and implementing this activity.
- See the **STEM²D Student Activities Overview** for additional information.

STEP-BY-STEP INSTRUCTIONS: GREAT BONES

1. **Welcome and Introduction (5 minutes)**
   - Welcome the students.
   - Introduce yourself by saying your name, title, and your organization/company.
   - Share that students will be learning about STEM²D careers and will be applying STEM²D skills during the session.
   - **(What is STEM²D? Slide)** Explain that **STEM²D** refers to: Science, Technology, Engineering, Math, Manufacturing, and Design.
   - Ask students and other volunteers to introduce themselves and state their favorite area of STEM²D.
   - **(Today's Plan Slide)** Review the agenda. Explain that today students will learn about bones and the methods of repairing broken bones.
2. **Career Awareness: Design and Engineering in the World of Work (10 minutes)**
   - **(STEM²D in the World of Work Slide)** Initiate an opening discussion and brainstorming activity. Consider asking:
     - How do you think design and engineering are used every day in the workplace?
     - What kinds of careers do you think people with an interest, aptitude for, or degree in engineering or design would have?
   - **(Tell My Story Slide)** Talk about your educational and career path. Use the **Tell My Story Form** as the basis for your remarks. Be prepared to describe your job or a typical day, and provide information about your background including:
     - When/why you developed an interest in engineering and design.
     - The classes/courses you took in secondary school.
     - Your post-secondary path, including the institution you attended and your degree. If you switched disciplines, make sure you explain why to the students.
     - What your current position entails. Be sure to include how you use engineering and design and what you do on a typical work day.

KEY WORDS

- Biocompatibility
- Cancellous bone
- Compression
- Cortical bone
- Economically
- Immune system
- Inventive
- Prototype
- Rigidity
- Tension
- Torsion

TIPS ABOUT STEM²D CAREERS

Share with students that there are many different kinds of careers related to STEM²D. Some STEM²D careers related to this activity are:

- Design Engineer
- Bioengineer
- Quality Engineer
- Manufacturing Engineer
- Test Engineer

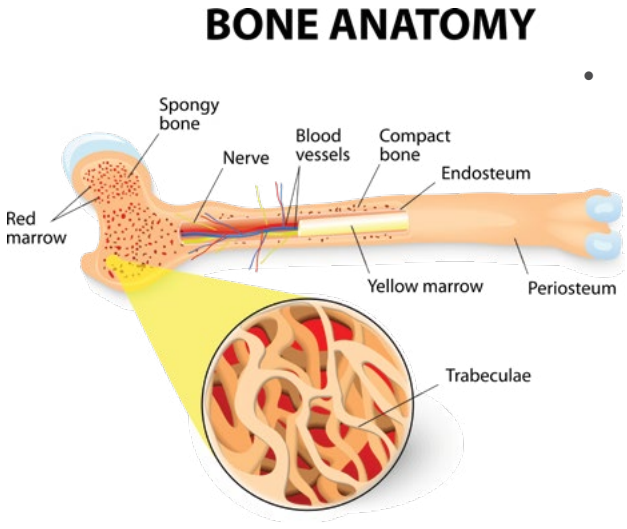
TIPS FOR MAKING CONNECTIONS

Encourage students to:

- Ask questions if they don't understand.
- Summarize what they have learned.
- Explain their thinking process aloud.
- Describe examples of bone repair/treatment that they are familiar with.

- Weave in facts about engineering and design and STEM²D careers:
  - Tell the students that your career is only one of the many careers available in the STEM²D disciplines.
  - Explain that STEM²D careers are high-demand, high-growth careers and are predicted to remain in demand over the next ten years.
  - Share a few Johnson & Johnson job titles and careers that may align with this activity.

3. **Content Presentation: Learning About Bones (20 minutes)**
   - **(Has Anyone Ever Broken a Bone? Slide)** Choose 4–5 students to answer the following questions:
     - What was your experience?
     - Which bone did you break?
     - How was it repaired/fixed?
     - How long did it take to heal?
   - **(Why do We Have Bones? Slide)** Explain that bones:
     - Give Structure. Bones provide a strong and stiff frame for your body. The spine keeps us up-right; all limbs hang off the spine.
     - Provide Protection. Bones stop damage to your internal organs. For example, your skull and rib cage protect your internal organs.
     - Afford Movement. Bones give our muscles something to attach to and work with. "Long bones" in the arms and legs provide **rigidity** (unable to be bent) for muscles to work against and move us around.
   - **(What are Bones Made of? Slide)** Explain:
     - Bones are made of a tough outer shell that forms a protective layer around the internal cavity. This is a called a **cortical bone**, or compact bone. Cortical bones account for 80 percent of the human skeleton's weight. Cortical bones are directly responsible for providing structural support for our muscles, protection for our internal organs, and the release of calcium to form new bone and repair damaged bones.



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- The **cancellous bone**, or spongy bone, is typically found at the end of long bones. This is a dense tissue that contains red bone marrow. Bone marrow helps support our body's immune system.
- Our **immune system** is made up of a network of cells, tissues, and organs that work together to protect the body. Red bone marrow is the site of red blood cell formation. Red blood cells are responsible for carrying oxygen to all parts of your body.
- Bones are strong and light. *A good analogy to use here can be a chocolate bar, which has a tough chocolatey outer shell and a honeycomb/sponge toffee/air center (e.g. Nestle Aero Bar, Hershey's Air Delight, Cadbury Crunchie, etc.).*

- **(What is the Doctor's Role? Slide)**
  Explain: A doctor has five main aims in repairing broken bones:
  - Straighten the bones
  - Preserve the original length
  - Allow healing
  - Reduce movement
  - Preserve the original rotation
- Discuss with students the problems/challenges for the patient if any of these things are not achieved. For example, having one leg shorter than the other, hip problems, pain, or lack of full movement.
- **(How Do We Fix Broken Bones? Slide)** Explain that there are four different ways to fix broken bones:
  - Cast: Simple, effective, stabilizes the bone
  - Internal Fixation: Temporary or permanent, requires surgery
  - External Fixation: Allows continual adjustments, reduces mobility
  - Implant: Complex, requires extensive surgery, maintains length
- Explain that the doctor will choose an appropriate method based on the patient's lifestyle, injury, and potential/future problems associated with the injury.

- **(How Do Bones Heal? Slide)** Explain:
  - Immediately, the blood clots and brings in an army of cells – cells that remove dead bone and cells that begin to lay down new bone.
  - Then, bone cells (osteoblasts) begin to form a callus. A callus is softer than normal bone, but strong enough to stabilize the bone and bridge the gap created by a fracture/break.
  - Finally, the callus then remodels, shrinks, and reorganizes itself to form hard bone. Within 12 months, the bone is completely healed.
- **(The Engineer Slide)** In addition to doctors, engineers play a critical role in fixing broken bones. Engineers design the devices and technologies that are essential for successful bone healing.
- **(What Makes a Good Engineer? Slide)** Engineers:
  - Are **inventive**. Engineers have the ability to create or design new things or to think originally.
  - Never give up. They are persistent and don't give up when faced with a challenge.
  - Want to save money. They think **economically** – carefully and efficiently, using resources so that the cost to make the device does not outweigh the small benefit that may be gained.
  - Solve problems. Their goal is to find solutions to challenges by being inventive.
  - Work as a team. They recognize that finding solutions to problems will take the work of more than one person, each playing an important role.
  - Want to help people. They know that the solutions they create will help make patients' lives easier.
- **(What Should the Engineer Think About? Slide)** Engineers need to consider the following things when creating a device to help bones heal (give examples, based on your experience):
  - What is my plan?
  - What does my device need to do?
  - What materials should I use?
  - How much money do we have?
  - What do the patient and Doctor want?

- **(What Materials Can Be Used? Slide)** Indicate that when engineers design/create devices to fix broken bones, they consider the following:
    - Strength: What material should be used to ensure that the device won't break? Is the strength directional?
    - **Biocompatibility** (being compatible with living tissues or systems and not being toxic or causing negative reactions): Will the patient be allergic to the material used in the device? Will the device cause the patient pain? For example, some people are allergic to latex; therefore, they can't come into contact with any devices that contain latex or they may have an allergic reaction.
    - Flexibility: Can the device bend? Should it bend?
    - Fixation: How do the materials fit together? How does the device make the bones firm and stable?
    - Cost: Is the device cost effective? Can the device be made cheaper?

4. **Learning Activity: Great Bones Challenge (45 minutes)**
    - **(We Need Your Help! Slide).** Introduce the challenge. Indicate that patients, doctors, and engineers need their help.
    - **(The Challenge Is . . . Slide)** The challenge is to design a new device to fix a broken bone.
    - **(What Makes A Successful Device? Slide)** Explain that successful medical devices stabilize the bone to support healing with no further breakage or splintering and can withstand three specific forces:
        - **Compression:** a force that squeezes something together.
        - **Torsion:** a force that twists or wrenches an object.
        - **Tension:** a force that stretches something.
    - Inform teams that each prototype these three factors.
    - **(The Details Slide)** Explain:
        - You will be working in a team of 4 people to design and build a device that can fix a broken bone.
        - Each team will be given one broken bone and a kit of materials that can be used to repair the bone. You many not use any other materials than what is contained in your kit.
        - Keep track of the cost of the materials you used to repair your bone, using the materials cost form. You will report the cost when we test the bones later on.

TIPS FOR WORKING WITH STUDENTS:

- Ask open-ended questions to encourage student reflection and discussion. For example:
    - How did you decide what materials to use?
    - What factors determined the design of your device?
    - What is most challenging about repairing the bone?
    - What other ideas do you have for the bone?
- Encourage all students to participate in the challenge.
- Move around the learning space and provide support when necessary.

TIPS FOR WORKING WITH STUDENTS:

Some of the bones may break when you test them.

Be conscious that some students may become emotional if their device breaks. Reassure them that successful ideas often fail multiple times before they are eventually workable. Ask them what they thought was good about their design and would do differently next time.

- Break the large group into teams of 4 students per team.
- Distribute 1 copy of each student handout, a Great Bones Kit, 1 Sawbone or Salt Dough Bone, paper, and pencils/pens to each team.
- **(Brainstorm Slide)** Tell the teams to spend 10 minutes brainstorming ideas for a device that could be used to repair a leg bone. Encourage students to spend the first 5 minutes individually sketching potential designs using the paper/pencils provided; using the remaining time, the team should decide on a design to build.
- **(Build Your Prototype Slide)** After 10 minutes, instruct teams that they have 20 minutes to make a **prototype** (a model) based on the selected design.
- **(Time to Test Our Devices Slide)** After 20 minutes, reconvene the large group. Be sure all students are able to see the devices while they are being tested. If a team has failed to complete its device, highlight the features of the early prototype that are good.
- Begin testing each device one at a time using the following process:
  - Ask the team to state the cost of materials used in its prototype.
  - Record the team's cost on flip chart paper or white board.
  - Test compression: hold one end of the device in each hand, push the ends of the device towards each other.
  - Test torsion: twist the ends of the device/bone in opposite directions – one away from you and one towards you.
  - Test tension: pull the ends of the bone away from each other. *Tension is when devices are most likely to break.*
  - Record key findings for each team on the flip chart paper or white board.
- **(Recap Slide)** After all devices are tested, ask the large group:
  - Which prototype was most successful? Which prototype should be recommended for further study? Why?
  - What was difficult about fixing your bone?
  - What would you change about your design if you were to do it again?

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5. **Student Reflection (10 minutes)**
    - **(Reflection Slide)** Ask students to reflect on the activity:
        - What did you learn about engineering? The research and development of medical devices?
        - How do you think this activity relates to a career in design and engineering and/or working at Johnson & Johnson? Think about the different roles apart from the engineer; how does the whole team come together to ensure a successful device? Point out the wide variety of STEM²D careers that are integral to developing, producing, and selling a new medical device:
            - Finance
            - Law/Regulatory Affairs
            - Manufacturing
            - Marketing
            - Operations
            - Quality
            - Project Management
            - Sales
        - Can you see yourself as a STEM²D professional? In what role? Why or why not?
        - What would you need to do to make that happen?

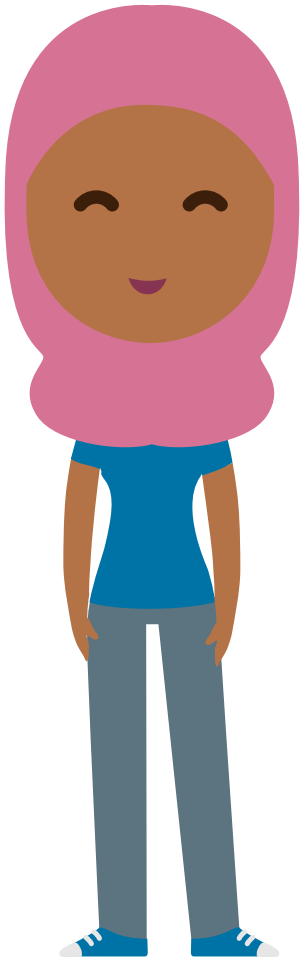
Extended Learning

Here are a few ways to extend the learning:

- **Present the Design. (See Make a Poster Slide)** Prior to prototype testing, instruct each group to create a poster containing the following and present to the class (add 30–45 minutes to the session):
    - A drawing of their prototype
    - An explanation of the materials and cost
    - A list of advantages and disadvantages
    - A description of the special features of their design
    - The names of the team members
- **Make a Bone Diagram.** Have students create a diagram of all the parts of a human bone.

TIPS FOR STARTING CONVERSATIONS:

- What area of STEM²D is your favorite?
- Why did you choose that area of STEM²D as your favorite?
- What would your dream job be?
- Where do you see yourself in 5–10 years?



Key Words

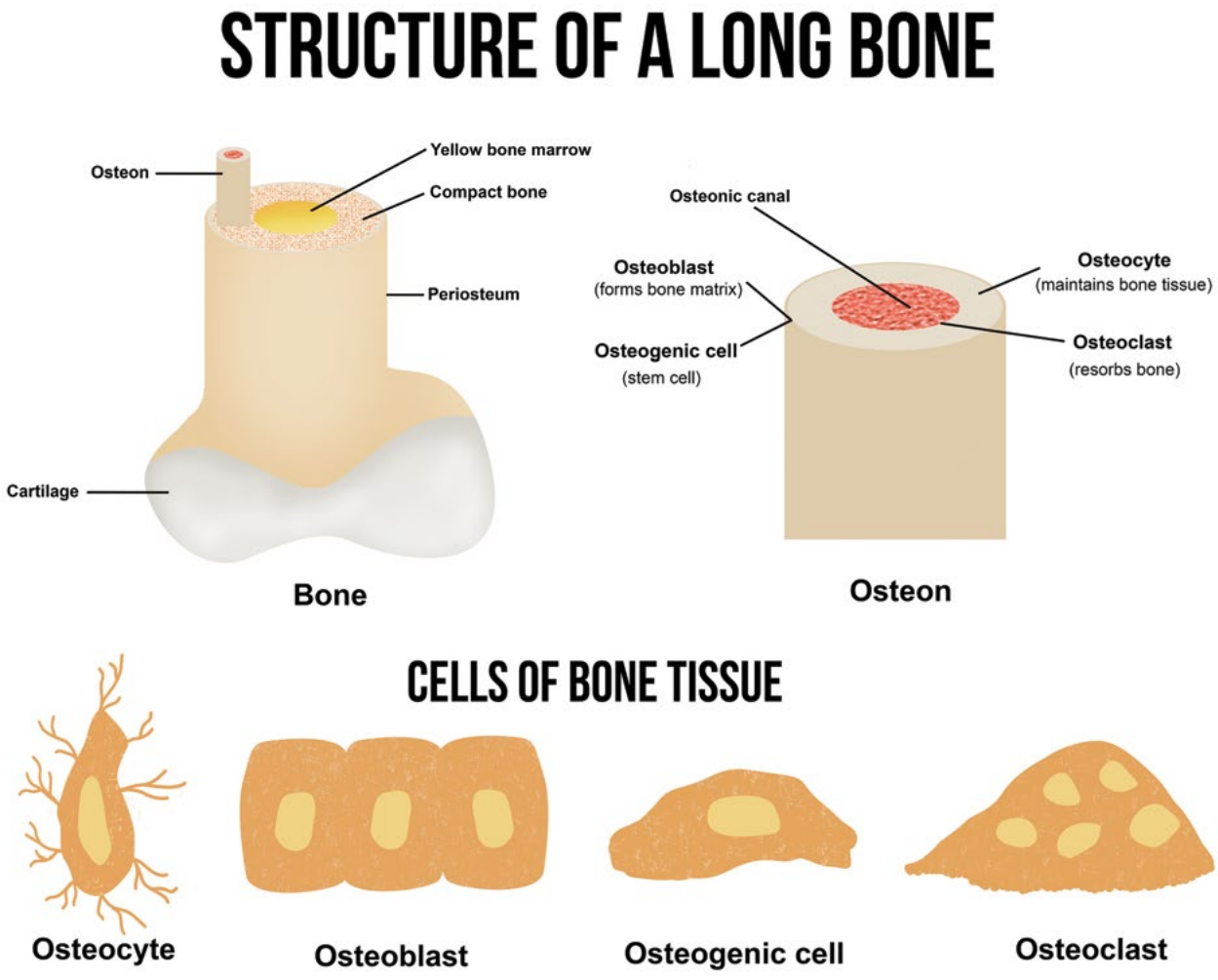
Biocompatibility—being compatible with living tissues or systems; not being toxic or causing negative reactions.

Compression—force or pressure that flattens, squeezes, or presses something together.

Cortical Bone—a tough outer shell that forms a protective layer around the internal cavity. Also called the compact bone.

Cancellous Bone—typically found at the end of long bones. This is a dense tissue that contains red bone marrow. Also called the spongy bone.

Economically—carefully and efficiently using resources so that the cost to make the device does not outweigh the small benefit that may be gained.



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Immune system—made up of a network of cells, tissues, and organs that work together to protect the body
Inventive—having the ability to create or design new things or to think originally.
Prototype—a model
Rigidity—unable to be bent
Tension—a force that stretches something tight
Torsion—the action of twisting or wrenching an object

Resources and References

Special thanks to Emma Bowyer, CEng, Test Engineer, Biomechanics, WW Research and Development, DePuy Synthes for her insights and assistance with this activity.

The following resources provide additional information or activities:

- "Best Bones Forever Activities." http://www.bestbonesforever.org/parents/educator/lesson.html
- "Bones, Muscles, and Joints." https://kidshealth.org/en/parents/bones-muscles-joints.html
- "Give Your Bones a Break Activities." https://teachhealthk-12.uthscsa.edu/unit/43
- "Your Bones." https://kidshealth.org/en/kids/bones.html

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PRE-ACTIVITY CHECKLIST

GREAT BONES

*The following checklist helps activity leaders plan and prepare to conduct the **Great Bones** activity with students.*

DID YOU . . .

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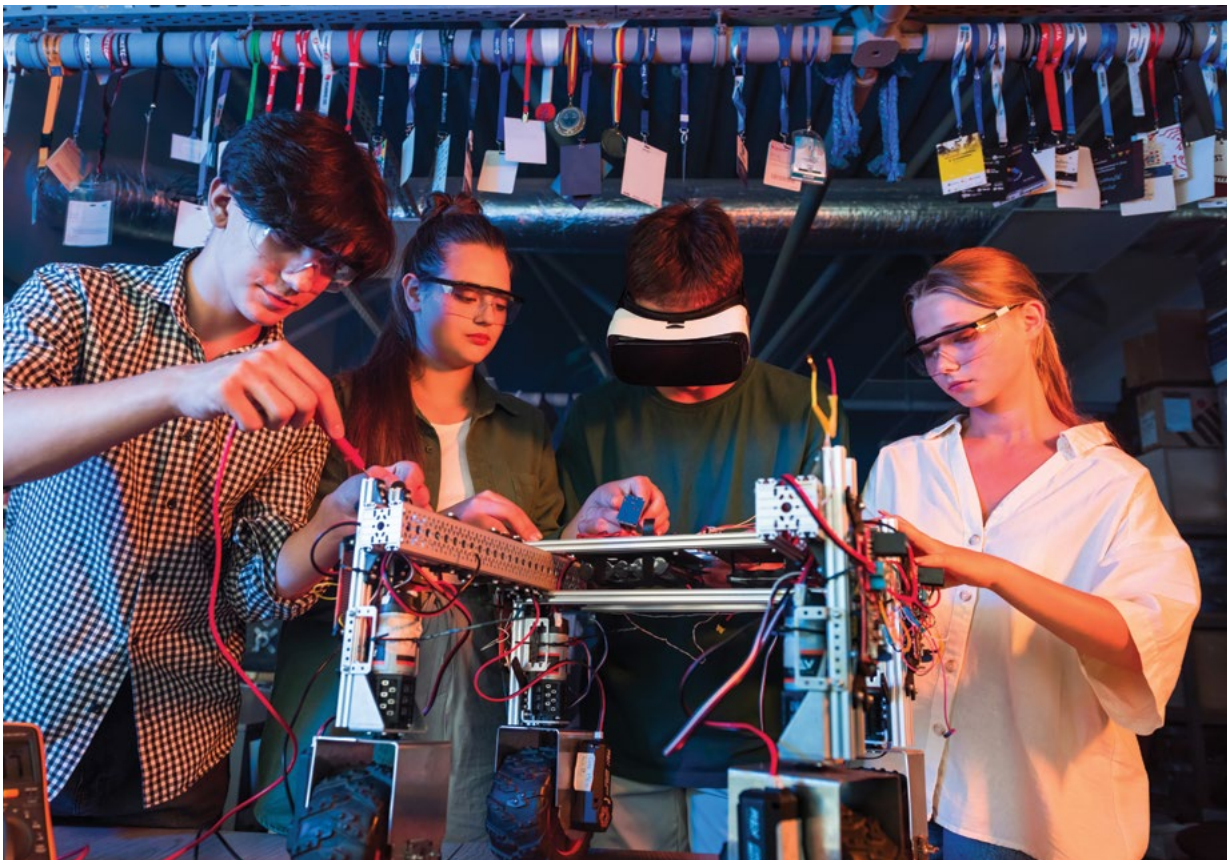
  - ☐ How does the site encourage orderly participation? *For example, do the young people raise their hands when responding to questions or during discussions? How are interruptions handled? Do you see any potential problems in managing the class of young people?*
  - ☐ What does the site do to make each student feel important and at ease?
  - ☐ How is the room arranged? Will you need to move desks or chairs for any part of your presentation?
  - ☐ How can you engage the site representative in your presentation?
- ☐ Meet with and finalize the logistics with the site representative? Did you:
  - ☐ Confirm the date, time, and location of the activity?
  - ☐ Confirm the technology needs? *Do you need to bring a computer and a projector to show the PowerPoint? Or, does the site have one that you can borrow?*
  - ☐ Confirm the number of students attending? *Knowing this will help you decide how to separate the class into teams and/or pairs, as well as the appropriate materials to purchase.*
- ☐ Recruit additional volunteers, if needed?
- ☐ Prepare for the activity:
  - ☐ Read the entire activity text prior to implementation?
  - ☐ Review the key content to be shared?
  - ☐ Customize the activity and tailor the PowerPoint, if desired, to reflect your background and experiences, as well as the cultural norms and language of the students in your community?
  - ☐ Complete the **Tell My Story Form**, which will prepare you to talk about your educational and career path with the students? *If desired, include key points about your story on the PowerPoint. See Tell My Story slide.*
- ☐ Photocopy the Student Handouts?

- ☐ Obtain the required materials for the **Great Bones Materials Kit**, including the sawbones or salt dough bones? *See the Materials and Estimated Materials Costs sections. If making the salt dough bones, be sure to plan accordingly. This process takes at least 3 hours. See the* ***Activity Leader Guide: Salt Dough Bone Recipe*** *for additional materials and instructions.*
- ☐ Practice your presentation, including the hands-on, minds-on activity? Be sure to:
  - ☐ Do the activity! *Make sure you are able to explain the concepts to students and that you know the correct answers.*
  - ☐ Be prepared to explain the engineering design process including the steps (component ideas) involved.
- ☐ Set up the site appropriately for the activity? Did you:
  - ☐ Make sure tables and chairs are arranged to accommodate teams of 4 students?
  - ☐ If additional volunteers are available, assign adults to specific teams?
  - ☐ Set up the computer and projector for the PowerPoint presentation?
- ☐ Bring a camera, if desired, to take photographs?
- ☐ Obtain and collect permission slips and photo release forms for conducting the activity if applicable?
- ☐ **Have fun!**



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Tell My Story Form

This form will help volunteers serving as activity leaders prepare to talk about their STEM²D interests, education, and career path.

ABOUT YOU

Name: _____

Job Title: _____

Company: _____

When/Why did you become interested in STEM²D? _____

_____

_____

What do you hope young people will get out of this activity? _____

_____

FUN FACT

Share a little about your background. Ideas:

- Share a memory from childhood where you first had your 'spark' or 'interest' in STEM²D.
- Detail your journey—highlight what you've tried, what you learned, steps to success, etc.
- Failures or set backs are also great to talk about difficulties and/or challenges and how you overcame them

EDUCATION AND CAREER PATH

What classes/courses did you take in secondary school and in college that helped or interested you most?

_____

_____

How did you know you wanted to pursue a STEM²D career?

_____

_____

What was your postsecondary path, including the institution you attended and your degree? *If you switched disciplines, make sure you explain why to the students.*

_____

_____

What your current position entails. *Be sure to include how you use STEM²D on a typical work day.*

_____

_____

ACTIVITY LEADER GUIDE

Salt Dough Bone Recipe

If sawbones are not available, activity leaders should use the following recipe to make the salt dough bones for the Great Bones Challenge.

OVERVIEW

This recipe makes approximately 7-8 bones. For the challenge, each team requires one bone; adjust the recipe based on the number of teams (bones) required.

INGREDIENTS

The recipe makes approximately 7–8 bones. For the challenge, each team requires one bone; adjust the recipe based on the number of teams (bones) required.

- 4 cups (560 g) flour
- 2 cups (380 g) salt
- Up to 2 cups (480 ml) water (add gradually)

DIRECTIONS

1. Combine the salt and flour.
2. Gradually add the water, stopping when it has become dough-like and not too sticky. There should be no residue left on your fingers when you touch it.
3. Knead the dough on a floured surface for a few minutes to make it soft, workable, and stretchy, like you would with any dough.
4. Form dough into bones—2 inches (or 5 centimeters) minimum width and 8 inches (or 20 centimeters) minimum length
5. Lay the bones on a non-greased baking tray or tray covered with baking/parchment paper.
6. Cook the bones on low heat (around 202º F/100º C) for up to 3 hours. It is VERY important not to have the oven on too high. This will cause the salt dough to bubble up, fill with air, and cook. Rather, you are aiming to dry the bones thoroughly, over a gradual period of time.
7. Once bones are fully cooked, let them cool on the baking tray or baking rack.
8. Break bones in the middle so that students have 2 halves to fix back together.

Great Bones Challenge

Student Handout

Challenge:

As a team, to develop and build a device that can be used to fix a broken leg bone.

Instructions:

As a team, to develop and build a device that can be used to fix a broken leg bone.

1. **Brainstorm (10 minutes)**
   - Individually sketch potential designs on the paper provided of a medical device that could be used to repair a broken leg bone.
   - As a team, discuss the designs and select one to build.
2. **Build (20 minutes)**
   - Build the selected prototype (a model) to fit the broken leg bone (provided). Teams can ONLY use the materials provided in the Great Bones Challenge Kit. The kit contains:
     - Pipe cleaners
     - Straws
     - Duct tape/silver tape
     - Popsicle sticks/wooden sticks
     - Toilet paper roll/cardboard tube
   - Determine the cost of the device. Each of the materials has an allocated cost. You may use as many of the materials as needed, but you must keep track of the total cost using the Great Bones Material Cost Form.
   - Have fun!
3. **Test**
   - At the end of the building period, each team's prototype devise will be tested. Successful devices will withstand the following forces:
     - **Compression:** a force that squeezes something together.
     - **Torsion:** a force that twists or wrenches an object.
     - **Tension:** a force that stretches something.

Great Bones Materials Cost Form

Student Handout

Instructions:

Keep track of the materials used by your team to repair the broken leg bone; record the number of each item used in the “Number Used” column. Then, calculate the cost of each item by multiplying the “Number Used” column by the “Per Unit Cost” column. Record the amount in the “Total Cost” column. Add all costs to determine the total cost of the prototype. Teams will be required to report the total cost when testing the medical device.

Item	Available Quantity	Per Unit Cost	Number Used	Total Cost (per unit cost x number used)
Cardboard Tube / Toilet Paper Roll	1	$20.00		
Pipe Cleaner	4	$10.00 each		
Straws	2	$30.00 each		
Duct Tape/ Silver Tape	1 length	$50.00		
Popsicle Sticks/ Wooden Sticks	2	$24.00 each		
Aluminum Foil	1 length	$15.00		
			Total Cost of the Prototype:	

Content and graphic layout courtesy of FHI 360.

This work was made possible by the support of Johnson & Johnson.

Revised design, JA Worldwide, April 2018