BUILDING A SCIENTIFIC RESEARCH VESSEL

STEM^{2}D Topics:
Engineering Design

Target Population:
Students, ages 14–18

Building a Scientific Research Vessel is part of the STEM^{2}D **Student Activities Series** developed by FHI 360 for Johnson & Johnson's WiSTEM^{2}D initiative (**W**inning in **S**cience, **T**echnology, **E**ngineering, **M**ath, **M**anufacturing, and **D**esign). The series features interactive and fun, hands-on activities for youth, ages 12–18, globally.

BUILDING A
SCIENTIFIC RESEARCH VESSEL

STEM^{2}D Topics: Engineering and Design
Target Population: Students, ages 14–18

ACTIVITY DESCRIPTION

In this team-based, hands-on activity, students will design and build a seaworthy vessel that floats in water and can hold a specific amount of weight.

ESTIMATED TIME

This session typically takes **60 minutes** to complete and should be conducted in one session.

STUDENT DISCOVERIES

Students will:

- Participate in a team-based learning experience.
- Build important STEM^{2}D—Science, Technology, Engineering, Math, Manufacturing, and Design—skills, such as creative thinking, critical thinking, problem solving, math, and teamwork.
- Realize that STEM^{2}D offers diverse and exciting career opportunities.
- Have fun experiencing STEM^{2}D.

GETTING READY

Materials

- Computer with projector and Internet access
- PowerPoint: Building a Scientific Research Vessel
- Pre-Activity Checklist
- Tell My Story Form

STEM^{2}D Skills

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

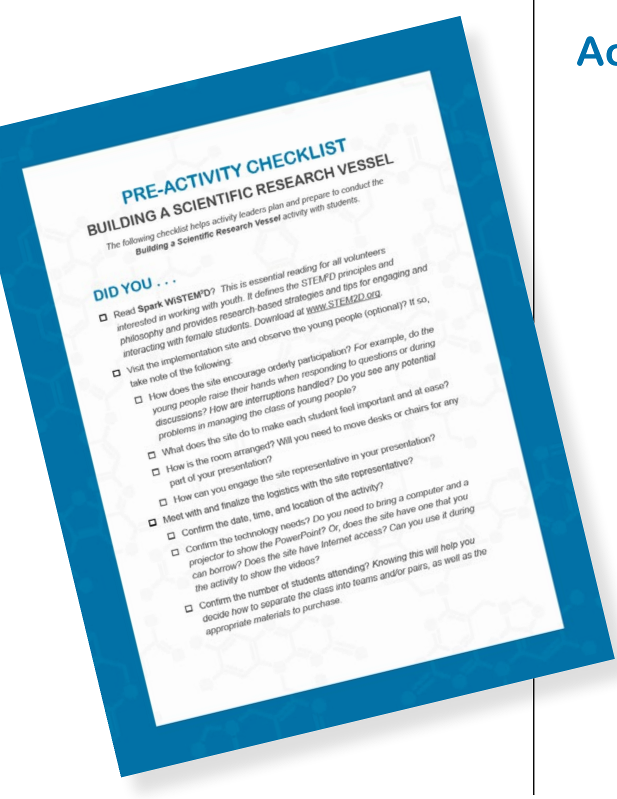
- Student Handout: Building a Scientific Research Vessel Challenge, *1 per student*
- Pen/pencil, *1 per student*
- Metric ruler, *1 per team*
- 2 rolls of aluminum foil
- 4 rolls of duct tape
- 2 rolls of plastic wrap
- 50 Popsicle sticks
- 25 Straws
- 20–30 Corks
- 300 Pennies
- 25 Skewers
- 50–60 Legos
- 1 ball of String
- 2 long plastic containers (e.g., Rubbermaid) filled with water (minimum 24 inches long x 12 inches wide x 8 inches deep)

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 three to four students.

Activity Leader Preparation

1. 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.
2. Review the **Pre-Activity Checklist** (at the end of this document) for details and specific steps for planning, preparing, and implementing this activity.
3. See the **STEM²D Student Activities Overview** for additional information.



PRE-ACTIVITY CHECKLIST

BUILDING A SCIENTIFIC RESEARCH VESSEL

The following checklist helps activity leaders plan and prepare to conduct the **Building a Scientific Research Vessel** 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 female students. Download at www.STEM2D.org.
- ☐ Visit the implementation site and observe the young people (optional)? If so, 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?
  - ☐ 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? Does the site have internet access? Can you use it during the activity to show the videos?
  - ☐ 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.

STEP-BY-STEP INSTRUCTIONS: BUILDING A SCIENTIFIC RESEARCH VESSEL

1. **Welcome & Introductions (15 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 how a vessel's intended use has a large impact on how it is designed. Define vessel: a **vessel** is any floating object used for the carriage of people or goods.
    - Share that they will be able to put their own skills to use in a team design activity.

2. **Career Awareness: Engineering & Design in the World of Work (10 minutes)**
    - (**Engineering & Design 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 design or engineering 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 design or engineering.
        - The classes/courses you took in secondary school.

KEY WORD

- **STEM²D**
- **Vessel**

TIPS FOR FACILITATORS ON STEM²D CAREERS

- Share with students that there are many different kinds of careers related to STEM²D.
- Possible STEM²D careers related to this activity:
    - Marine biologist
    - Environmental protection worker
    - Hydrologist
    - Geologist
    - Mechanical engineer
    - Manufacturing engineer

KEY WORDS

- **Buoyancy**
- **Density**

TIPS FOR MAKING CONNECTIONS

Encourage students to:

- Ask questions if they don't understand
- Summarize what they have learned
- Explain their thinking process aloud
- Provide examples of vessels they have seen, along with their possible uses

    - 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 design and engineering and what you do on a typical work day.
- Weave in facts about design and engineering and STEM^{2}D careers:
    - Tell the students that your career is only one of the many careers available in the STEM^{2}D disciplines.
    - Explain that STEM^{2}D careers are **high-demand, high-growth careers** and are predicted to remain in demand over the next 10 years.
    - Share a few Johnson & Johnson job titles and careers.

3. **Content Presentation (10 minutes)**
    - Before showing the *What is Buoyancy?* slide, ask students what buoyancy means. Choose a few students with hands raised to answer.
    - (**What is Buoyancy? Slide**) Share the definition of buoyancy: **Buoyancy** is the ability or tendency to float in water or air or some other fluid.
    - (**Why do Vessels Float? Slide**) Ask students: Why do vessels float? Choose a few students with hands raised to answer. Share that vessels float because of their density in relation to water.
    - (**What is Density? Why is it Important? Slide**) Share definition of density: **Density** is the mass of a unit volume of a material substance. Explain that whether something sinks or floats is determined by density. If the density is greater than that of water, the object will sink. If the density is less than (or the same as) that of water, the object will float. Even if vessels are made of things that sink, they can float if they are shaped correctly.

- (**Types of Vessels Slide**) Ask students the following questions:
    - Why do vessels have different shapes?
      ANSWER: *Vessels have different shapes based on their uses, the materials they are made of, and the amount of weight they need to be able to carry. These are just a few reasons they have different shapes.*
    - Which of these vessels would be the most stable? Why?
      ANSWER: *The freighter is the most stable. The ship contains tanks below the water level that are filled with water and create stability.*
    - Which of these vessels could support the most weight? Why?
      ANSWER: *The freighter could support the most weight. It is made with very strong materials and designed to float and be stable despite carrying a large amount of weight.*
    - Which of the vessels could go the fastest? Why?
      ANSWER: *The speedboat could go the fastest because of its powerful engine (compared to its size) and the shape of its hull, which is designed to make the boat rise up and glide on the water.*
- (**Vessels for Scientific Purposes Slide**) Review how vessels are used for scientific purposes. You may want to paraphrase the following text on vessel uses and specifications; this information is also in the notes section of the PowerPoint:
    - **Fisheries Research Vessel**—requires platforms that are capable of towing different types of fishing nets, collecting plankton or water samples from a range of depths, and carrying acoustic fish-finding equipment. A fisheries research vessel is often designed and built along the same lines as a large fishing vessel, but with space given over to laboratories and equipment storage, as opposed to storage of the catch.
    - **Deep Sea Research Vessel**—designed to perform hydrographic surveys or oceanographic research, among just a few of their purposes. These vessels often mount equipment on a towed structure. This might include air cannons to generate a high-pressure shock wave to sound

burroblando/Getty Images

the strata beneath the seabed, for example. Or, a depth sensor might be mounted on the keel. These vessels may carry equipment for collecting water samples from a range of depths as well as environmental sensors, scientific divers, and unmanned water vehicles.

    - **Acoustic Research Vessel**—designed especially for underwater acoustic research. They may be equipped with extensive and sophisticated navigation, communications, and computer equipment. They may have winches, cranes, loading frames, and other deck machinery for the deployment, towing, and recovery in all sea conditions of a variety of sensor arrays and oceanographic instrumentation.
    - **Polar Research Vessel**—A polar research vessel is constructed around an icebreaker hull, allowing it to engage in ice navigation and operate in polar waters. These boats usually have dual roles, particularly in the Antarctic where they also function as polar replenishment and supply vessels to the Antarctic research bases.
    - **Coastal Research Vessel**—designed to provide a stable yet flexible sea going scientific platform suitable for operations in shallower waters. They have state-of-the-art communication and navigation systems as well as substantial deck handling equipment.
  - Explain that vessels are used for more scientific purposes than just those highlighted.

4. **Learning Activity: Building a Scientific Research Vessel Challenge (20 minutes)**
  - Introduce the challenge. Explain that students will work in teams to build a vessel for a specific scientific purpose.
  - (**Building a Scientific Research Vessel Challenge Slide**) Give the following instructions:
    - As a team and using the Student Handout, choose a scientific purpose for your vessel.
    - Take note of the specifications for the selected vessel in terms of: maximum length, endurance, number of crew, and minimum amount of weight to be supported.

Top: Aneese/Getty Images | Bottom: agnormark/Getty Images

- Draft a design plan with your team. Determine the supplies you need and use the building costs table in your packet to calculate the cost. The costs are listed in the chart on your Student Handout.
- Once you have a completed design, you must show it to the facilitator or other volunteer and obtain their initials. This is required to ensure your team has completed its design before moving on to the next step.
- Once the design has been signed off on, you may begin purchasing materials for your vessel and begin building. You may return at any time to purchase additional supplies, as long as you have money remaining in your budget.
- You may test your vessel's seaworthiness at any time during the building process.
- Remember that your vessel must meet the specifications required for your vessel's specific purposes.
- At the end of the build time, we will inspect each vessel and test its seaworthiness.
- You have 15 minutes to build your vessel as a team. Keep an eye on the time.

- Break the group into teams of three to four students.
- Distribute the Student Handout.
- If another adult volunteer is available to help, have him/her track the materials purchased by each team and ensure that a team does not exceed its spending limits; the Student Handout has the budget for each team and prices for each item. If another volunteer is not available, you will have to facilitate the purchase of materials and track spending by each team.
- Facilitate group work by walking around the room observing and asking students questions about their designs. Do not give suggestions—you should only provide gentle reminders to make sure that teams are meeting all the specifications. This will ensure that students maintain ownership of their designs.
- Ensure all students are participating in the group task; give encouragement to students who may not be as involved/engaged.

TIPS FOR WORKING WITH STUDENTS

- Encourage students to be creative in their designs.
- Reinforce the concept that for a vessel to float, the density must be less than the density of the water.
- Ask open-ended questions to encourage student reflection and discussion.
  - *For example: Can you tell me about your design?*
- Help students stay on track with time during the group challenge.
- Encourage all students to participate in the different stages of the challenge.
- Encourage students to look at things from a different perspective.
  - *For example: Have you thought about trying this…*
- Move around the learning space and provide support when necessary.

- Give reminders of timing. For example, materials need to be purchased at least half way through the allotted time to ensure students have time to build the vessel.
- Provide support and answer questions as needed.
- Students will need to have their designs initialed by yourself or another volunteer before moving on to purchase supplies. Remember not to evaluate a vessel's design or give suggestions when students show you their design. You should only remind students to meet all the specifications.
- Inform the class when there is 5 minutes remaining in their build time. Remind individual groups that seem to be behind that they may need to speed up their work to complete the task on time.
- Announce to the group when time is up and explain that they will now be moving on to testing the seaworthiness of their vessels and undergoing inspection. All students must observe the testing. No further work can take place on vessels during testing and inspection.

5. **Vessel Testing and Inspection (10 minutes)**
    - (**Vessel Testing and Inspection Slide**) Ask teams to bring their vessels to a table near the plastic containers. Once all vessels are placed on the table, inform the teams that they cannot remove their vessels from the table.
    - Choose 2 vessels at random to be inspected by yourself or a volunteer.
    - You or a volunteer must make sure that the vessel meets the specifications for its designated scientific purpose. Check length and structures for crew. Use a ruler to verify the length in centimeters. See the Student Handout for specifications.
    - If the vessel does not pass inspection, give the vessel back to the team and inform them that they have one opportunity to make revisions and return for re-inspection. You may now choose a new vessel from the table for inspection.
    - Once a vessel has passed inspection, it should be tested in the water. Have the team place their vessel in one of the two containers filled with water.

ShotShare/Getty Images

- One team member should count out the pennies as s/he places them on the vessel.
- If a vessel touches the bottom of the container while the pennies are being placed, it is considered to have sunk. If it does not sink after the required number of pennies have been placed, it is considered seaworthy.
- Since there are two plastic containers, two vessels may be tested for seaworthiness at the same time.
- Once all testing has been completed, provide a recap of learning for the students. You may prepare this yourself or use the following as a guide: Explain that the design of a vessel and the materials selected not only impact the vessel's uses but greatly affect its seaworthiness. Remind students that if the density of a vessel is greater than that of the water, the vessel will sink. Share that improvements are constantly being made to vessels to make them more efficient and more effective. One day they may be involved in designing a vessel for the future.

6. **Student Reflection (5 mins)**
   - **(Reflection Slide)** Ask students to reflect on the activity. Have them spend a few minutes thinking about the following questions:
     - What did you learn about Building a Scientific Research Vessel?
     - What was difficult about designing and building your vessel?
     - What would you change about your design if you were to do it again?
     - How do you think this activity relates to a career in engineering, design, and/or working at Johnson & Johnson?
     - Can you see yourself as a $STEM^2D$ professional? 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:

- Research the design and use of specific vessels currently in service or retired from service around the world.
- Explore current specific oceanic research projects.
- Research the Regional Class Research Vessel (RCRV), with cutting-edge platforms providing scientists and educators access to the marine realm.
- Learn about the Cousteau Society and its role in marine exploration and global advocacy.

Key Words

Buoyancy—the ability or tendency to float in water or air or some other fluid

Density—mass of a unit volume of a material substance

STEM²D—Science, Technology, Engineering, Math, Manufacturing, and Design

Vessel—any floating object used for the carriage of people or goods

Resources and References

The following resources provide additional information or activities:

- ECOGIG Ocean Ecosystem Research: https://ecogig.org/research-vessels
- National Oceanic and Atmospheric Administration: http://oceanexplorer.noaa.gov/technology/vessels/vessels.html
- NATO Centre for Maritime Research and Experimentation: http://www.cmre.nato.int/research/research-vessels
- Oregon State University College of Earth, Ocean, and Atmospheric Sciences: http://ceoas.oregonstate.edu/
- University of Washington, Marine Biology: https://marinebiology.uw.edu/field-stations-ships/research-vessels/
- Woods Hole Oceanographic Institution: http://www.whoi.edu/main/ships

PRE-ACTIVITY CHECKLIST

BUILDING A SCIENTIFIC RESEARCH VESSEL

*The following checklist helps activity leaders plan and prepare to conduct the **Building a Scientific Research Vessel** 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 so, 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?
  - ☐ 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? Does the site have Internet access? Can you use it during the activity to show the videos?*
  - ☐ 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? Did you:
  - ☐ Read the entire activity text prior to implementation?
  - ☐ 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?
  - ☐ Review the notes section of the slides in the PowerPoint for information to be shared?
  - ☐ 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).*
- ☐ Practice your presentation? Did you:
  - ☐ Do the activity? Make sure you can explain the concepts to students, if needed, and that you know the correct answers?
- ☐ Obtain the required materials? *(see the **Materials** and **Estimated Materials Costs** sections)*
- ☐ Set up the site appropriately for the activity? Did you:
  - ☐ Make sure tables and chairs are arranged to accommodate teams of three to four students?
  - ☐ If additional volunteers are available, assign adults to specific teams?
  - ☐ Set up the computer and projector for the PowerPoint presentation; be sure that speakers and an Internet connection are available?
  - ☐ 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!**

TELL MY STORY FORM

This form will help activity leaders prepare to talk about their $STEM^2D$ interests, education, and career paths.

ABOUT YOU

Name: ______________________________

Job Title: ______________________________

Company: ______________________________

When/Why did you become interested in $STEM^2D$? ______________________________

____

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 $STEM^2D$
- 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 & CAREER PATH

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

____

How did you know you wanted to pursue a $STEM^2D$ 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 $STEM^2D$ on a typical work day.* ______________________________

____

____

BUILDING A SCIENTIFIC RESEARCH VESSEL CHALLENGE

Student Handout

INSTRUCTIONS:

1) Choose a vessel

- Using the information in the following chart, choose a scientific research vessel to build as a team.

TYPE	ENDURANCE	MAX. LENGTH	NUMBER OF CREW	MIN. WEIGHT
Fisheries Research	30 days	28.5 centimeters	60	80 pennies
Deep Sea Research	40 days	20.5 centimeters	40	50 pennies
Acoustic Research	30 days	26 centimeters	12	60 pennies
Polar Research	57 days	27.5 centimeters	76	90 pennies
Coastal Research	40 days	23 centimeters	44	70 pennies

2) Design the vessel

- Take note of the specifications for the selected vessel in terms of: maximum length, endurance, number of crew, and minimum amount of weight to be supported.
- Draft a design with your team. Use the graph paper to sketch your design.
- Remember that your vessel must meet the specifications required for your vessel's specific purposes.

3) Calculate the cost

- Based on your design, determine the supplies needed.
- Use the building costs table (below) to calculate the cost. Your team has a total of $300,000 to build the vessel.
- After completing the design and determining the required supplies, show it to the facilitator or other volunteer and obtain his/her initials. This is required to ensure your team has completed its design before moving on to the next step.

ITEM	COST	NUMBER NEEDED	SUBTOTAL
Sheet metal (aluminum foil)	$30,000 per foot		
Welding materials (duct tape)	$30,000 per foot		
Fiberglass (plastic wrap)	$30,000 per foot		
Softwood (corks)	$20,000 each		
Hardwood (popsicle stick)	$20,000 each		
Cable (string)	$20,000 per foot		
Mast (straw or skewer)	$15,000 each		
On-board structures (Legos); each structure holds 20 crew	$5,000 each		
		TOTAL	

4) Purchase the materials

- Once you have a design approval, begin purchasing materials.
- You may return at any time to purchase additional supplies, as long as you have money remaining in your budget.

5) Build

- Your team has 20 minutes to build your vessel.
- Keep an eye on the time.

6) Test

- You may test your vessel's seaworthiness at any time during the building process.
- After 20-minutes, we will inspect each vessel and test its seaworthiness. hard for veins, arteries, and capillaries to push around and can lead to many complications.

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.