Olin College of Engineering

# Float Your Boat Teacher's Guide

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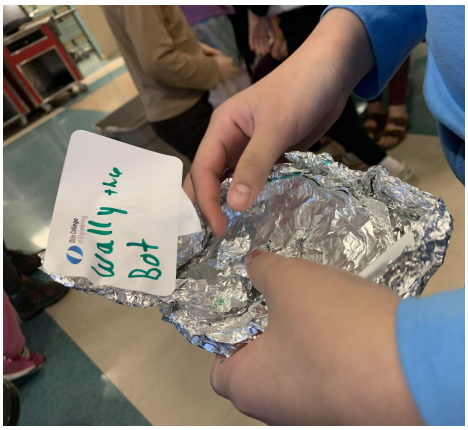
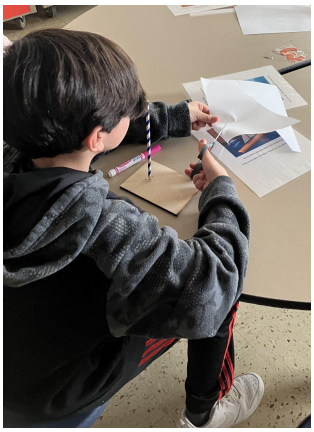
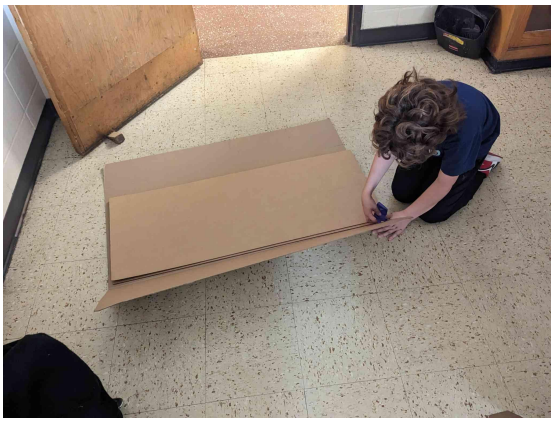






Would your students have fun learning about buoyancy by getting their hands wet with some fun challenges? This workshop will help students learn how boats work through a series of activities that cover buoyancy and sail design through iterative building and hands-on group work. Over the course of this workshop, students will build their own cardboard boat from scratch and see how much "treasure" it can hold!



## Workshop Requirements

- **Suggested ages/grades:** Grades 2-5
- **Time required:** Two one-hour sessions and one 30-minute finale session
- **Session 1 materials:**
  - **Floating Orange Activity Materials:**
  - One printed copy of Floating Orange Activity instructions for each pair of students
  - One large orange per student
  - One plastic tub filled with water per 6 students

  - **Hull Shape Activity Materials:**
  - One printed copy of Hull Shape Activity instructions for each pair of students
  - Use these STL Hull Files to 3D-print one of each hull per 6 students. If you cannot 3D-print materials, you can adapt the activity by cutting the hull cross-sections out of cardboard and using those.
  - One plastic tub filled with water per 6 students

  - **Bouncing Buoyancy Activity Materials:**
  - One printed copy of Bouncing Buoyancy Activity instructions for each pair of students
  - One mason jar or cup per 3 students
  - One container of corn syrup
  - One container of dish soap
  - Various materials of different densities such as: Ping Pong Balls, pennies, grapes, screws, dice, and popcorn
  - Paper/cloth towels for clean up

  - **Foil Frenzy Activity Materials:**
  - One printed copy of Foil Frenzy Activity instructions per 6 students
  - One roll of tin foil
  - One pound of rocks/marbles

  - **Big Boats Activity**
  - One large cardboard sheet per group of 3 students (with a few spares); warehouse stores might be willing to provide the cardboard sheets that separate layers of items packed on pallets
  - One pool noodle per group of 3 students
  - One roll of duct tape per group of 3 students
  - Markers and crayons for writing/decorating
  - One pair of scissors per group of 3 students
  - One cardboard cutter for the teacher to use to help students with large cutting jobs (optional)
- **Session 2 Materials:**
  - One printed copy of Sails Activity instructions per 6 students
  - Cut out boats and sail holders from ¼" plywood using this guide

        - The guide is an svg file that you can send to a laser cutter or just use as a reference to hand cut the boats using basic woodworking materials
    - One straw per student
    - Three sheets of printer paper per student (from the recycling bin is fine!)
    - One or two plastic tubs from session 1 (Can replace with shallow tubs to save water and make transport easier)
    - One stopwatch per tub
    - (Optional) One electric fan per tub
    - Whiteboard/chalkboard to track progress
- **Finale Materials**
    - Inflatable kiddie pool
    - Heavy objects to act as treasure (one idea is to use gold spray paint to create "gold nuggets" from rocks)
- **Prerequisite Knowledge:**
    - Experience using scissors and duct tape
    - An understanding of what a hypothesis is
    - Experience with floating objects in water

## Learning Goals

Overall:

- Fun and engaging hands-on activities
- Group work
- Engineering design/concept application
- Build student confidence and independence

Workshop design principles:

- Make students feel accepted and excited about STEM
- Allow the kids autonomy to rotate as they choose
- Use discovery-based, hands-on learning
- Give students instructions utilizing Universal Design Learning: visual, audio, and kinetic
- Normalizing failure and learning from mistakes

Specific Activities:

- Engage children in learning the behavior of different densities and shapes in water through hands-on learning
- Encourage students to master building and experimenting
- Use students' competitiveness to explore collecting data and iterating designs based on evidence through hands-on activities.

## Suggested Tips for Running this Workshop

- **Pre-workshop preparation.**

- Prefab requirements:
  - Session 1:
    - Fill tubs halfway with water
    - Fill tall jars/cups with layers of corn syrup, water, and soap
  - Session 2:
    - Fill tubs halfway with water
    - If COVID/significant airborne germs are concerns, set up fans near the tubs so that children can use the fan to replace blowing directly
    - Glue together the sail holder onto sail boat as directed in this file
      - Cut out the sail holders from the sail holder file and the boats from the sailboats file out of plywood.
      - Use a watersafe glue to connect the sail holder to the sailboat by gluing the sailholder over the dot in the sailboat file.
  - Finale
    - Fill the kiddie pool with water to test the student's boats
- Physical room set up:
  - Session 1:
    - Create at least 3 stations, a Floating Orange Activity station, a Bouncing Buoyancy Activity station, and a Hull Shape Activity station each with their associated materials for first section of activities:
      - Floating Orange Activity requires students to observe the density change of oranges in a tub before and after peeling them
      - Bouncing Buoyancy Activity prompts students to observe the different behaviors of objects in liquids of different density using the tall jars set up pre-class.
      - The Hull shape activity requires students to observe different behaviors of certain 3d printed hulls. If a 3d printer is difficult to access, using cardboard cutouts or thought experiments would work as well.
    - After students are done exploring the 3 stations, move the tubs to an open area and set out the tin foil for the tin foil boat activity
    - After the tin foil boat activity, put out cardboard, scissors, duct tape, and markers while cleaning up previous stations
  - Session 2
    - Keep a large area as workspace for students to work on boats
    - Keep a whiteboard or chalkboard in a visible place, and add students' sailing times to it so students can track their progress.
  - Finale
    - Make space for the kiddie pool and give students clear angles to watch how their boats do.
- Usage of materials:

        - We suggest for all sessions that you group materials by table or tub and have students share the materials there.
- **Tips for using handouts.**
    - Several of these handouts are written with checkboxes, we recommend that these are either laminated or enough are printed out for each student so that students can mark their progress on the sheet.
- **Guiding questions.**
    - Why is the boat floating?
    - How could you combine your idea and y's idea?
    - What part of the oranges cause them to float/sink?
        - Did the peel sink more or did the orange sink more?
        - Did the orange still float after being peeled?
        - Would a bigger peel float more?
    - Look at the sails and their times, what connects the fastest sails?
    - What could you change about your boat (foil or cardboard) to make it work better next time?
    - How sturdy are your boat attachments? How could you make it sturdier?
- **Intentional commentary.** Comments such as the following can help students build and recognize STEM-related mindsets and skills
    - Talk about sharing ideas with your team
    - Talk about next time and focusing on improving with multiple iterations
    - Point out STEM concepts like surface area, volume, and forces where they appear
        - For example: Do you think it will make your boat faster if you make your sail bigger or smaller? Have you tried making different sized sails and see which one is faster? The bigger sail will have more surface area which can catch more wind.
- Be sure to give students room to experiment and fail, and build in time so students can repeat activities and improve each time.

## Extensions and Enrichments

- Buoyancy is the force that keeps all ships afloat. When a boat is in the water, the water puts a force back on the boat that keeps it up, but rocks and sand sink in water unlike boats. The combination of the boat's large size and small weight increases the force keeping it up allowing the boat to float. Different boats float very differently depending on their shape and what they are made of. Engineers can build boats to successfully carry lots of heavy objects using small-scale models to test their theories. This way, engineers can try out many boat designs before building the final boat.
- These workshop activities focus largely on qualitative measures of good and bad results. Measuring boat performance with weight is one way to add on to this workshop and teach data tracking. For example, testing a tin foil boat with paper

cut outs, plastic coins, or rocks (cannon balls) could be a thematic and diverse way to visualize how well the boat responds to payload.
- These workshop activities don't have students predict or analyze their boats much. If you have older students, you can have them track and plot the sail surface area and boat volume or weight by making 3-5 sails of different areas (triangles or rectangles would be easy shapes to measure) and testing them together.
- For more information on how heavy boats are able to float, check out this video: Why do ships float video!
- For a quick video to show younger students the concepts of floating and buoyancy, check out this video: Float test video

## Educational Design Principles Used to Create this Workshop

We are Olin College undergraduate engineering students who are practicing the engineering design cycle through the iterative design, development, testing, and improvement of STEM workshops for elementary school students. We began our "user research phase" by visiting our partner students. We engaged our partner students with standard engineering design challenges as a way to get to know what they like, what motivates them, their fine motor building skills, their teaming skills, etc. This informed our creation of custom workshops for our partner students, which we then improved and tailored to work with a second class of students.

Our work has also been guided by our learnings about some educational design theories/principles. In this section, we provide information about how these educational design theories/principles have been used in the design of our workshop. We hope this will help teachers understand our motivations and therefore be more able to modify our workshops to work better for their students in their unique educational context.

Throughout our design work, we practiced keeping a tight loop between our goals (i.e., our learning objectives related to STEM content, social-emotional learning, and the development of confidence and belonging in STEM) and the activities we designed to achieve these goals.

- Goal #1: Give students iterative design practice in an exciting, STEM related format.
- The best way to learn is to encourage failure rather than make students feel bad about making mistakes. Helping turn mistakes into a discussion and allowing for reflection improves both a student's confidence in the material as well as their interest in it. To achieve these goals, we used discovery-based learning to guide our workshop development, an approach that "allows students to be in control of their learning through hands-on exploration and inquiry without an emphasis on memorizing and repeating concepts, but to learn through unique experiences." [1] We incorporated

aspects of discovery-based learning or inquiry-based learning throughout all of our sessions.
    - The first activity with three stations was meant to encourage the students' autonomy, and each station was designed to have the students mess around with various materials and figure out - through hands on trial and error - why they worked the way the did (i.e. Why does an orange float with its peel and sink without it?).
    - The tin foil boats were all about trial and error. The goal was to make one design, test it, and then improve the design before putting it to the test again. Which design worked better and why?

- Goal #2: Use Universal Design Learning (UDL) to support visual, audio, and kinetic learners
- We wanted to ensure all students felt included and empowered in their learning activities, so we designed them with UDL principles. UDL can be effective in improving student learning outcomes, increasing engagement, and promoting inclusivity in the classroom [2]. As STEM might often be daunting for students, we want to ensure the activities are as approachable as possible for 2nd to 5th graders. Moreover, since we are teaching across 4 grade levels, we want to make sure that all levels of students feel supported and that they are learning.
- We provided students with multiple mediums of instruction via a combination of lamented bilingual handouts, verbal instructions, and physical hands-on activities for all the workshops (tinfoil boat, 3 stations, sails activity). Ideally, assigning instructors to guide each activity would also help the students to have a more focused experience. However, if teaching staff is limited, the handouts would also help guide students with words and pictures.

- Goal #3: Give students autonomy
- According to Self-Determination Theory (SDT), autonomy is a crucial part of motivation [3]. Therefore we tried to include autonomy in many of our activities to keep students' attention and give them positive experiences with STEM learning. We hope these positive experiences and their sense of autonomy will encourage students to seek out more STEM learning in the future.
- We encouraged autonomy in our activities through giving students the choice of multiple activities in the first session, and by offering further optional experiments for each activity directed by the student. The students were highly encouraged to rotate through all of the stations, but some did prefer to stay in one station instead. As an example, the sailing activity asks that students improve their sails, but students have the freedom to decide if that looks like making the sail larger, changing the sail shape, changing the layout of the ship itself, or some other idea.
- As tempting as it might have been to walk the students through the specific boat building process, we gave very few restrictions on their builds, specifically the amount of materials they had and certain safety features (e.g. students are not allowed to cut cardboard themselves, but can draw lines of where they want the cardboard to be cut and an instructor would help). We gave guidelines on certain boat designs, such as

encouraging a boat instead of a raft design for better weight capacity, but didn't interfere when students chose a raft design instead.

- Goal #4: Encourage teamwork.
- Teaching children teamwork skills from a young age is important for a multitude of reasons. It not only teaches them to speak up for themselves in a group, but also "improves self confidence," "reduces bullying," and "builds success in adults" [4]. Putting a focus on teaming while teachers are present allows them to practice their team-working skills with the support of teacher intervention when necessary.
- We tackled this goal by doing activities in pairs and also small groups of up to five. For the tin foil boats activity, we had them split into pairs and build small models of boats together as partners. This was before we made larger teams so they got used to working with others without the pressure of having to speak up in a larger group. Once we had eased them in with the partner activities, we then asked the students to self organize into groups of 4-5 to work on their main project of large boats.

## Please use these materials and tailor them to your students!

We encourage you to use these materials, editing and modifying them as appropriate for your students in your particular context! When you use, share, incorporate, or modify these materials, please keep the credit and license notice from the footer. We also humbly request that you email sarah.adams@olin.edu if you use these materials, as we are tracking their impact and how far they travel!

## References

References used in the motivation and design of our workshop and/or extensions.

[1]"Discovery-Based Learning - Center for the Advancement of STEM Teaching and Learning Excellence (CASTLE)." *Center for the Advancement of STEM Teaching & Learning Excellence (CASTLE)*, drexel.edu/castle/resources/teaching-topics/discovery-based/#:~:text=Discovery%2DBased%20Learning%20is%20an,to%20learn%20through%20unique%20experiences.

[2] Novak, J., & Rodriguez, J. (2018). Universal design for learning in K-12 classrooms: A systematic literature review. Journal of Educational Research and Practice, 8(1), 1-22.

[3]Ryan, R. M.; Deci, E. L. (2000). "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being". American Psychologist.

[4]Group Dynamix. “How Teamwork Helps Kids Succeed in Life.” *Group Dynamix*, 10 Feb. 2023, https://groupdynamix.com/how-teamwork-helps-kids-succeed-in-life/#:~:text=Teamwork%20will%20help%20kids%20communicate,critical%20aspect%20of%20the%20process.