# Boats and Buoyancy

*Lesson Plan*

Run Time: 8.5-11.5 hrs

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## Learning Targets

I can design a 3D model that meets multiple constraints.

This means I can:

- Design a blueprint of a 3D model.
- Evaluate the model based given criteria and constraints.
- Revise the model according to feedback and observation.
- Explain how balanced and unbalanced forces affected the design.
- Follow agreed-upon rules of discussion and carry out my assigned role.

## Standards Addressed

NGSS:

- 3-5-ETS1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost
- 3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem
- 3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved
- 3-PS2-1 Plan and Conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of the object.

CCSS[1]

- ELA-Literacy - SL.5.1.B Follow agreed-upon rules for discussion and carry out assigned roles
- ELA-Literacy - SL.5.6 Adapt speech to a variety of contexts and tasks, using formal English when appropriate to task and situation.

STEMSCOPES:

- Grade 3: Objects and Motion: Do 2: PBL

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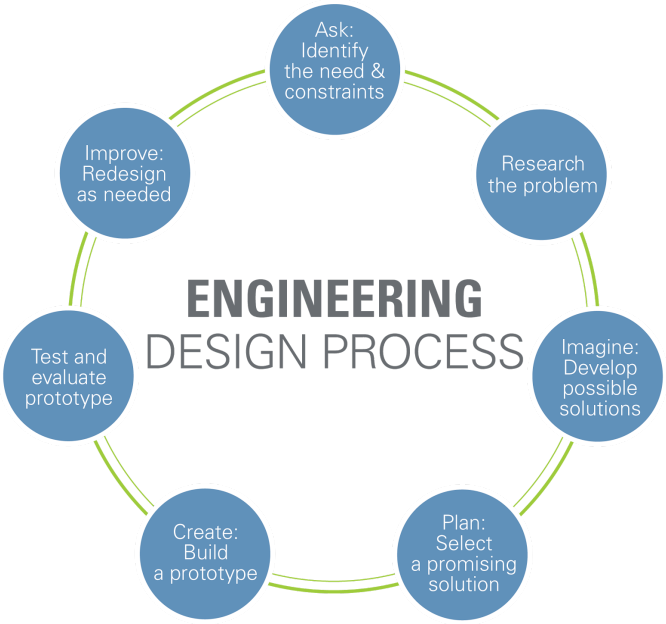
[1] Extensions from CCSS

- MATH-MP1 Make sense of problems and persevere in solving them
- MATH-MP5 Use appropriate tools strategically
- MATH-3.MD.A.2 Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l)

## Procedure

1. Warm-Up Testing Buoyancy
2. Discussion of Buoyancy and hull design
3. Project Ignite (AutoDesk/TinkerCAD) Boat Building Tutorial
4. Print examples from the tutorial
5. Use TinkerCAD for Boat Building Challenge[2]
    a. Identify the need and constraints
    b. Imagine: develop possible solutions
    c. Plan: select a promising solution
    d. Create: build a prototype
    e. Test and evaluate prototype
    f. Improve: Redesign as needed
6. Presentations of Boat Designs




## Key Terms

Buoyancy, force, balanced force, unbalanced force, acceleration, motion, design, criteria, constraints, model, CAD, filament, wind power, density, volume, mass

## Underlying Assumptions

- Students have completed a tutorial for 3D Printing with TinkerCAD
- Students have a working definition of force

## Tools/Materials

- Epic (free online books) Does it Sink or Does it Float?
- Epic (free online books) Discovering Science Making things Float and Sink
- Epic (free online books) Engineers Solve Problems
- TinkerCAD (or equivalent CAD software)
- Makerbot Replicator 2 (or equivalent 3D Printer)
- Materials for floating demonstration
- Laptops/Desktops running (PC/Mac/Linux all work)

[2] https://www.teachengineering.org/k12engineering/designprocess

## Warm-up (.5 hrs)

Prepare multiple samples of materials, and have students make predictions about whether or not they will float. Include examples of materials (i.e. steel) that will float depending on the design of the structure. Include other examples of materials that will float because of their composition (i.e. wood, styrofoam).

Test each of these predictions in a tub of water and record the results.

## Activities

### Discussion of Buoyancy and hull design (.75 hours)

1. View and discuss videos showing how boats float
    a. https://www.youtube.com/watch?v=xniW3_afO-0
    b. https://www.youtube.com/watch?v=pnIlE1xD-yM
2. View images of different boat shapes using Google images, boating websites, Bing images, etc. Discuss why certain designs may be better than others in terms of buoyancy and stability.[3]
3. Ask the question: "If I throw a penny into a wishing well (fountain), does it float?" "Will a metal rowboat float?" "What makes one float and not the other even if they're both made of metal?"
4. Discuss the impact of weight on hull design. For example: If the hull is smaller and the deck is filled with heavy objects, will the boat float high in the water or ride lower? What impact would having a wide hull like a barge have on buoyancy and heavy loads?
5. Discuss how the sail uses wind as a force against the boat. Blow on a piece of paper and explain that there is force on one side of the paper, and the paper moves in the direction of that force.

*Common Misconceptions:*

*Materials that float naturally vs. Objects that float due to structure*
*Relationship between weight/mass and buoyancy*
*Relationship between weight/mass and density*

### Project Ignite (AutoDesk/TinkerCAD) Boat Building Tutorial (1 hr)

The teacher will be using Project Ignite to introduce students to TinkerCAD. Through the Project Ignite class program, the teacher will be able to monitor the progress of the students. In Project Ignite, the students will complete the Explore Buoyancy: Designing Sea Craft[4] exercise. The teacher will be able to use Project Ignite as a formative

[3] Consider center of mass placement above supports
[4] https://projectignite.autodesk.com/app/project/257/Explore-Buoyancy-Designing-Sea-Craft/overview/

assessment tool. By the end of the tutorial exercise, the students should be able to use TinkerCAD to begin to build their own boat.

*Common Misconceptions:*

*3D printed material is solid (3D printed material is actually filled with a honeycomb structure)*

*Perspective view vs. printed product*

### Print examples from the tutorial (outside of class time)

Allow at least 30 minutes per model for print time, consider putting multiple models on each build plate, and printing overnight/during other class activities.

## Boat Building Design Challenge (Total 5.5-8.5 hrs)

### Identify the Need and Constraints (.5 hrs)

Use the accompanying student materials to guide students through initial plans and roles for the boat building challenge.

**The Problem**

You must design a boat that will be able to float, stay upright and be able to be propelled by wind.

**The Challenge**

Design a boat with **buoyancy**, **stability**, and a **method of wind propulsion**.. Create a blueprint of your design. Stay afloat as long as you can while a fan propels your boat.

**Constraints**

- The 2D design must be included with labels and measurements.
- The method of wind propulsion may be made with the 3D printer or with other materials.
- The boat needs to be designed with 3D printing software and printed on the 3D printer.
- Groups will have a 10 minute time limit to present the project and float their boat.

Lead a discussion with students to generate criteria for their projects.

**Examples of Criteria**

- Aesthetics
- Speed and efficiency of propulsion
- Mass
- Stability in wind or waves
- Payload capacity

Explain the responsibilities of each of the group roles, and students self-select their roles.

- Design Team Expert
- Materials Engineers
- Architectural Engineer
- Mechanical Engineer

### Imagine: Develop Possible Solutions (.5 hrs)

Instruct students to brainstorm solutions, individually and then in their groups. Students should record samples of their solutions in the student journal. Consider allowing individuals to design in TinkerCAD rather than on paper.

*Common Misconceptions:*

*Fixed Mindset - limited by first attempt*

### Plan: Select a Promising Solution (.5 hrs)

In assigned groups, instruct students to combine their ideas into a single promising solution, focused on the previously determined criteria and constraints. Reinforce collaboration according to group roles and inclusion of multiple viewpoints or ideas. Consider allowing individuals to design in TinkerCAD rather than on paper.

Conference with each group to approve the proposed sketch.

### Create: Build a Prototype (1 hr)

Reinforce the use of TinkerCAD. Encourage students to produce a minimally functional product - something that is testable - rather than a complete, perfected solution.

Print products after.

*Common Misconceptions:*

*Prototype is a finished, polished product*

### Test and evaluate prototype[5] (.75 hrs/iteration)

Give students access to a variety of materials to test their design. Allow students to create their own environment and procedure for testing.

[5]If time, repeat the test, evaluate, and redesign process for 2-4 iterations.

Encourage students to spend time discussing the test results, and the relation to principles of balanced and unbalanced forces before changing their design in TinkerCAD. Consider conferencing with groups at this point.

*Common Misconceptions:*

*Sinks because of weight*
*Effects of the center of the mass*

### Improve: Redesign as needed[6] (.75 hrs/iteration)

Return to TinkerCAD to modify the design based on the test results.

Collaborative discussion across multiple groups about the process of testing, evaluating and redesign. *What worked or did not work and why?* Encourage students to relate the discussion to balanced and unbalanced forces.

Students complete Exit Ticket to check for understanding and misconceptions, before the next iteration. Consider giving portions of the exit ticket in each iteration, increasing in complexity.

## Class Wrap-up Discussion

### Presentations of Boat Designs (1.0 hr)

Options for presentation format

| | |
|---|---|
| ● Slideshow<br>● Document reader<br>● Poster - Computer or Hand<br>● Projector/TV/Smartboard | ● Show ME/SeeSaw/Explain Everything/Notability<br>● Interview<br>● Other |

## Formative Assessment

- Student Lab Journal
- TinkerCAD Online Progress
- Exit Slip

[6] If time, repeat the test, evaluate, and redesign process for 2-4 iterations.

## Plan After Formative Assessment

If students are not on track to proficiency, see materials below to supplement the lesson.

- http://www.morethanaworksheet.com/2015/06/20/teaching-balanced-and-unbalanced-forces/
- http://beyondpenguins.ehe.osu.edu/issue/icebergs-and-glaciers/using-icebergs-to-teach-buoyancy-and-density
- https://www.youtube.com/watch?v=YyJSlclbd-s
- https://www.youtube.com/watch?v=ABMJgz9Ja_s
- Bill Nye Forces in Motion

## Summative Assessment

| Next Gen/CCSS Standards | 1<br>Doesn't Meet | 2<br>Partially Meets | 3<br>Meets | 4<br>Exceeds |
|---|---|---|---|---|
| 3-5-ETS1-1<br>Criteria Expectations<br><br>Source of Evidence:<br>Teacher Observation | Only one or none of the criteria were followed. | Two of the criteria were followed | Three of the criteria were followed | All of the criteria for the design were followed. |
| 3-5-ETS1-2<br>Quality of Blueprint<br><br>Source of Evidence:<br>BluePrint | Included no detail, science concepts were not addressed. Included no design. No constraints were met. | Included little to no detail, science concepts were not addressed. Constraints were not met. Included little to no design. | Included some detail. Science concepts were partially addressed. Only some constraints were met. | Included adequate detail. Science concepts were fully addressed. All constraints were met. |
| 3-5-ETS1-3<br>Presentation<br><br>Source of Evidence:<br>Teacher Observation | Explanations by most group members did not indicate much of an understanding of science principles that were used. | Explanations by most group members indicated a relatively a relatively accurate understanding of scientific principles that were used. | Explanations by all group members indicated a relatively accurate understanding of scientific principles that were used. | Explanations by all group members indicated a clear and accurate understanding of scientific principles that were used. |
| 3-PS2-1<br>Effects of balanced and unbalanced forces on the motion of the object.<br>Source of Evidence<br>Student Presentation | Does not show understanding of balanced and unbalanced forces. | Can design a boat that floats.<br><br>-or-<br><br>Can explain why a boat did not float. | Can revise the design of a boat to float or move in the wind.<br>-and-<br>Can explain the reasoning of revisions | Can discuss the effects of the additional features[7] to the design, and relate to balanced and unbalanced forces after independent research |
| CCSS-SL 5.1B<br>I can follow | I had difficulty functioning in my | I functioned in my assigned role while: | I functioned in my assigned role while: | I functioned in my assigned role while: |

[7] Features may include: Pontoons, Keel (Sailboat), Centerboard, Outriggers,

| | | | | |
|---|---|---|---|---|
| agreed-upon rules of discussion and carry out my assigned role.<br><br>Source of Evidence:<br>Self-Assessment | group. | • Listening well<br>• Waiting my turn<br>• Staying focused<br>• Being respectful<br>• Doing my job well<br>**SOME** of the time | • Listening well<br>• Waiting my turn<br>• Staying focused<br>• Being respectful<br>• Doing my job well<br>**MOST** of the time | • Listening well<br>• Waiting my turn<br>• Staying focused<br>• Being respectful<br>• Doing my job well<br>**ALL** of the time |
| CCSS-SL 5.6/6.6<br>I can change the way I am speaking depending on the task and situation.<br><br>Source of Evidence:<br>Oral presentation | Student appropriately uses **2** or less of the following:<br>• Delivery speed<br>• Expression<br>• Accuracy<br>• Posture<br>• Voice projection | Student appropriately uses **3** of the following:<br>• Delivery speed<br>• Expression<br>• Accuracy<br>• Posture<br>• Voice projection | Student appropriately uses **4** of the following:<br>• Delivery speed<br>• Expression<br>• Accuracy<br>• Posture<br>• Voice projection | When speaking, student appropriately uses **all** of the following:<br>• Delivery speed<br>• Expression<br>• Accuracy<br>• Posture<br>• Voice projection |

## Extensions

States of Matter
Density

## Additional Documents

- Student Materials
- Exit Ticket
- Rubric

## Background Information

- Sailing and Wind Power:
  - UNSW
  - Physics Buzz
  - Real World Physics
- Buoyancy
  - HyperPhysics
- Forces and Motion
  - HyperPhysics
  - Physics Classroom
  - Utah Science

# Boat Build Challenge

Name: _____

Student Journal

## The Problem

You must design a boat that will be able to float, stay upright and be able to be propelled by wind.

## The Challenge

Design a boat with **buoyancy**, **stability**, and a **method of wind propulsion**.. Create a blueprint of your design. Stay afloat as long as you can while a fan propels your boat.

## Criteria and Constraints

- The 2D design must be included with labels and measurements.
- The method of wind propulsion may be made with the 3D printer or with other materials.
- The boat needs to be designed with 3D printing software and printed on the 3D printer.
- Groups will have a 10 minute time limit to present the project and float their boat.

## Expert Roles

- Design Team Expert _____
- Material Engineers_____
- Architectural Engineer_____
- Mechanical Engineer_____

## Boat Samples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# Boat Build Challenge

## Expert Roles

There are four expert roles. Your group needs to have at least one expert for each role. You will choose what role you would like to be an expert in. You may choose from the following roles.

- Design Team Expert
- Materials Engineers
- Architectural Engineer
- Mechanical Engineer

**Design Team Expert**

As the Design Team Expert, your role is to ensure that your team successfully complete the task in the allowed amount of time. You will lead and keep track of all planning, encourage communication among engineers and make sure that all members of the team fully know and understand all parts of the plan. You and your team members will present your final product.

**Material Engineer(s)**

As the Material Engineer, your role is to communicate with your team and are responsible for getting the designed boat printed. You also need to gather materials your group chooses for the propulsion method and assemble it to the printed boat. You and your team members will present your final product.

**Architectural Engineer**

As the Architectural Engineer, your role is to ensure that your team develops a blueprint for your design. Be sure to keep all blueprints to track changes that are made after testing. You will guide the team's activities to ensure that all the required elements of the blueprint are included in your design and presentation. You and your team members will present your final product.

**Mechanical Engineer**

As the Mechanical Engineer, your role is to ensure that your team included scientific principles in your design process. You will guide the team's activities so that all the required elements of criteria and constraints are used in your boat design and presentation. You will be responsible for testing your design model and keeping track of the changes you made. You and your team members will present your final product.

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# Boat Build Challenge

Student Journal, continued

## Design Team Expert

Date: Progress Made:

_____ _____
_____ _____
_____ _____
_____ _____

## Material Engineer

What materials will you need for propulsion?

_____ _____ _____ _____

## Architectural Engineer:

Draw the final draft of your boat or include the 2D printed design.

## Mechanical Engineer:

List the parts of your boat that will help with the buoyancy, stability, and method of propulsion.

**Buoyancy**

| Design Piece | Reason |
|---|---|
| _____ | _____ |

**Stability**

| Design Piece(s) | Reason |
|---|---|
| _____ | _____ |

**Method of Propulsion**

| Design Piece | Reason |
|---|---|
| _____ | _____ |

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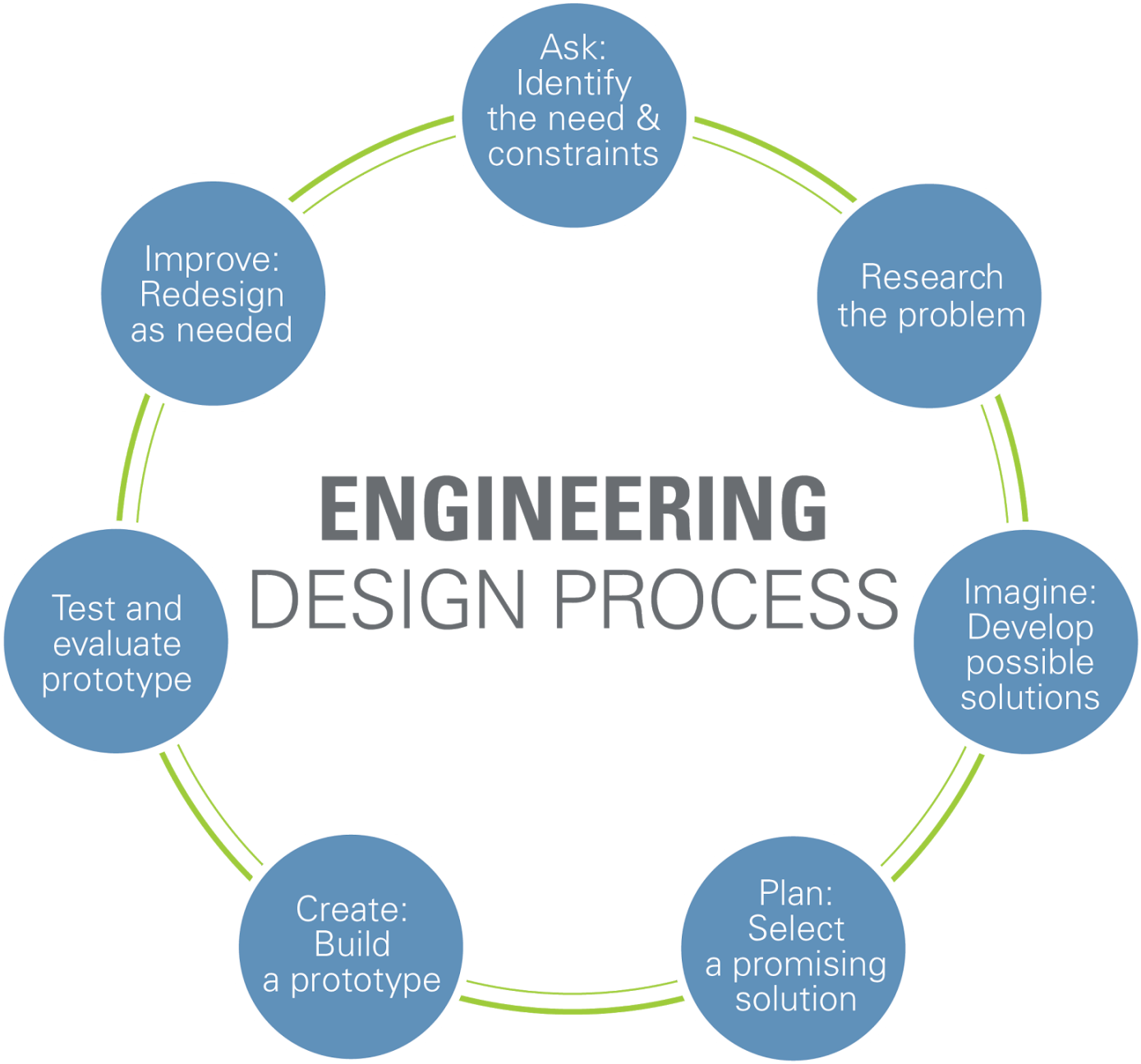
# Boat Build Challenge




[1]

[1] https://www.teachengineering.org/k12engineering/designprocess

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# Boat Build Challenge

## Imagine: Develop Possible Solutions

It's time to start brainstorming solutions. Take some time to sketch out some different ideas. Don't just settle for your first. Make sure that every group member's voice is heard. This is where synthesizing, or putting different ideas together, can really make the solution better.

## Plan: Select a Promising Solution

Choose one solution that you brainstormed, or take pieces from multiple solutions.

**When you have an idea, sketch it out here, and then you can submit your proposal!**

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# Boat Build Challenge

## Create:  Build a Prototype

So, you've proposed your plan and brainstormed some solutions.

Now, it's time to start trying out the solutions.  Use TinkerCAD to make a 3D model of your prototype.

**Use the space below to draw notes and make schematics.**

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# Boat Build Challenge

## Test and evaluate prototype[2]

Simulate your environment and test it. Use the resources in the classroom to test different scenarios that your design might face.

- What worked?

- What didn't work?

## Improve: Redesign as needed

Now, your boat may not have worked perfectly in every scenario. Remember **persistence**, these are opportunities to improve our design.

**Use the space below to draw notes and make _____, update your TinkerCAD model and print a new prototype.**

[2] Print multiple copies of this page for multiple iterations of the test, evaluate and redesign process

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# Boat Build Challenge

## Communicate Results

Now you are on your last prototype generation. Hopefully your feel like the boat is going well, but there may still be problems that need solving. That's OK! We will be able to suggest future improvements to our peers and professionals.

You can suggest future improvements for:

- More time
- More funding
- Future technology
- Highly skilled labor

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**Boat Build Challenge Rubric**

Names: _____ _____ _____ _____

| Next Gen Standards | 1<br>Doesn't Meet | 2<br>Partially Meets | 3<br>Meets | 4<br>Exceeds |
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| 3-5-ETS1-1<br>Criteria Expectations<br><br>Source of Evidence:<br>Teacher Observation | Only one or none of the criteria were followed. | Two of the criteria were followed | Three of the criteria were followed | All of the criteria for the design were followed. |
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| 3-PS2-1<br>Effects of balanced and unbalanced forces on the motion of the object.<br><br>Source of Evidence | Does not show understanding of balanced and unbalanced forces. | Can design a boat that floats.<br><br>-or-<br><br>Can explain why a boat did not float. | Can revise the design of a boat to float or move in the wind.<br>-and-<br>Can explain the reasoning of revisions | Can discuss the effects of the additional features to the design, and relate to balanced and unbalanced forces after independent research |
| **Score:** | Comments: | | | |

# Boat Build Challenge Rubric

Names: _____ _____ _____ _____

| Common Core Standards | 1<br>Doesn't Meet | 2<br>Partially Meets | 3<br>Meets | 4<br>Exceeds |
|---|---|---|---|---|
| CCSS-SL 5.1B<br>I can follow agreed-upon rules of discussion and carry out my assigned role.<br><br>Source of Evidence:<br>Self-Assessment | I had difficulty functioning in my group. | I functioned in my assigned role while:<br>• Listening well<br>• Waiting my turn<br>• Staying focused<br>• Being respectful<br>• Doing my job well<br>**SOME** of the time | I functioned in my assigned role while:<br>• Listening well<br>• Waiting my turn<br>• Staying focused<br>• Being respectful<br>• Doing my job well<br>**MOST** of the time | I functioned in my assigned role while:<br>• Listening well<br>• Waiting my turn<br>• Staying focused<br>• Being respectful<br>• Doing my job well<br>**ALL** of the time |
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| **Score:** | Comments: | | | |

Name: _____

# Test and evaluate prototype: Exit Slip

When you tested your prototype today:

- What are the steps in the engineering design process?

- What worked?

- What didn't work?

- What surprised you?

- How did you use the **principles of balanced and unbalanced forces** to modify your design?