MeTEOR Learning Modules

STEM MEA (Model Eliciting Activity)

Designing Boats

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METEOR
CONNECTING THE DOTS

Designing Boats

Reflective Planning

Description/Summary of Lesson:
Students will complete research on how boats float using math and science used in a real-world setting. Then, students will design and construct a boat out of aluminum foil and a few other simple materials. The boats will be tested by floating them in a tub of water, and then adding marbles until the boat sinks. Using prior math skills, students will calculate the largest volume possible to hold the most weight before sinking. To be considered operational, the boat must be able to float in water with at least 10 marbles inside of it. Throughout this activity, students will gain an understanding of how engineers must use volume, density and force to consider the efficiency and safety of the boat they are constructing. In addition, students will gain an understanding of how the math processes they are performing relate to various careers in the world, such as engineering.

Essential Questions:
- What are the specific qualities that go into engineering a safe and efficient boat?
- Some cargo ships travel with a load of containers that is larger than the ship — why do you think it doesn't sink?

Suggested Grade Level: Grade 8

Approximate Time: Two days (50 minute class periods)

Teacher's Role: Facilitator

Class Set-Up: Groups of two students at tables or desks put together

Success Standards:
- Students can analyze volume, density, mass and motion in real-world and mathematical problems.
- Students can solve problems involving volume, mass, density and motion.
- Students can define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution — taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- Students can develop and use models.
- Students can engage in argument from evidence.

Learning Purpose:

- Students will define the problem.
- Students will communicate their problem-solving plan.
- Students will use volume, density, mass and motion to create a boat that will hold 10 or more marbles and propel across the water.
- Students will use social, interaction skills for completing projects with peers.
- Students will understand the concepts of buoyancy and water displacement to design a boat that will support a given amount of weight.
- Students will explore the shapes of boats and construction techniques that may work for the boats.
- Students will incorporate the scientific principles of force and motion with engineering design and mathematics to participate in a boat-building challenge.

Vocabulary:

- Gravity
- Water Displacement
- Density
- Volume
- Motion
- Force
- Buoyancy
- Mass
- Archimedes' Principle
- Area

Math Practices:

- MP 1: Make sense of problems and persevere in solving them.
- MP 3: Construct viable arguments and critique the reasoning of others.
- MP 4: Model with mathematics.
- MP 6: Attend to precision.

Depth of Knowledge:

- DOK Level 3: Strategic Thinking

Materials:

Teacher Materials

- Masking Tape
- Beaker of Water
- Duct Tape
- Steel Bolt or Washer
- Challenge Letter to Students
- Copies of Rubric
- Exit Slip

Student Materials:

Student groups need a zip-lock bag per group with the following items:

- 2 Pair of Scissors
- 4 Rubber Bands
- Aluminum Foil Sheets (12" x 12")
- Ruler
- 4 Straws
- Sheet of Cardstock Paper
- 5 Large Popsicle or Craft Sticks
- 2 Large Paperclips
- 10 Marbles
- Tub or Container of Water

Summary of Tasks/Experiences

Spark Activity:

Have you ever wondered how a ship made of steel can float? *Teacher drops a bolt into a beaker of water so students can observe*. Ask the class what just happened? If you drop a steel bolt (washer) in a bucket of water, the bolt (washer) quickly sinks to the bottom. How can a steel ship float? And better yet, how can a steel ship carry a heavy load without sinking? Today, you are going to research how boats float. Then, design and build a boat that will float the most mass without sinking while it propels across the water. In order to build the boats, you must use and understand the scientific law of buoyancy.

Lesson Descriptions:

Introduction: Day 1

The teacher will:

- discuss the real world challenge listed above.
- hand out the description letter to each group.
- show the students the materials in the zip-lock bags they get to use and hand them out.
- hand out copies of the rubric for evaluation.
- hand out 8 inches of masking tape and duct tape to each group.
- allow students to collaborate around a plan of action to accomplish their goal.

Day 1 and 2

The students will:

- research information needed on computers or student electronic devices to design and build boats that will float and propel across water.

- apply the thoughts gained from their research to the design of their boat with their partner.
- build and test their boat.
- write about their design explaining and defending what type of boat they built to propel across the water for both efficiency and safety.
- complete their exit slip (can finish for homework if needed).

Teacher facilitates class asking guiding questions as students work in groups:

- What types of materials will you need to construct your design?
- What types of structural changes would you make to construct an improved model of your boat if it fails?
- What is the most challenging part of the design process?
- Which is more important - function or appearance?
- What do things that sink have in common?

Student Engagement

Social/Emotional Engagement: Students will use social, interaction skills for completing projects with peers.

Physical Engagement: Students will collaborate while completing research regarding boats through the use of electronic devices and discourse while working in groups of two.

Cognitive Engagement: Students will work together using math and science concepts such as volume, density, mass and motion to complete their task.

Evidence of Learning

Checks for Understanding/Expected Outcomes:

- Students will complete the description letter of their boat.
    - Letters should include the measurements of the boat along with an explanation of why they built this design.
- Students will build their boat.
    - The boats with the largest area of volume to displace water will hold the most marbles.
    - The boats using a propeller made from the card stock with wound up rubber bands should propel across the water when let go.
- Students will complete an exit slip.
    - The exit slip will allow students to show they did some research as requested and reflect on their success or lack thereof.
- Students will be evaluated using the included rubric.
    - The rubric should be given as a guide to help students as they write their findings and build their boat.

Designing Boats
RUBRIC

CATEGORY	4	3	2	1
Research	Research shown with much detail about building a boat that will hold weight and propel across the water.	Research shown with some detail about building a boat that will hold weight and propel across the water.	Research shown with little detail about building a boat that will hold weight and propel across the water.	Research shown with no detail about building a boat that will hold weight and propel across the water.
Modification/ Testing	Clear evidence of troubleshooting, testing, and refinements based on scientific principles.	Clear evidence of troubleshooting, testing and refinements.	Some evidence of troubleshooting, testing and refinements.	Little evidence of troubleshooting, testing or refinements.
Function	Boat functions extraordinarily well, holds 10 marbles without sinking and propels across the water.	Boat functions well, holds 10 marbles without sinking and begins to propel across the water.	Boat floats, holds less than 10 marbles without sinking but cannot propel across the water.	Boat floats but cannot hold any marbles or propel across the water.
Group Member	The student worked well with team member throughout the entire course of the project and was present in each day.	The student worked well with team member throughout most of the project and was present each day.	The student worked with team member on some of the project and was present each day.	The student worked with team member only slightly throughout the project and was absent.

Challenge Letter to Students:

Your task is to research how boats float. Then, you are to design and build a boat that will float, hold weight *and* propel across the water in a bin of water.

Below, you must explain and defend why you and your partner choose to build this type and size of boat. Be sure to include why this would be the most efficient model to build and your boat's measurements of length, width and height.

To pass the endurance test, your boat must hold the weight of 10 marbles. Then, to pass the safety test, it must propel across the water without capsizing.

You will have a total of two class periods to research, build and test your boat using any of the materials from the bag you will have been given. No additional materials may be used. Brainstorm ideas for the design of your boat with your partner, then begin.

Team Member:

Description:

Marble count boat held:

Did your boat propel across the water?

Using your dimensions, calculate the volume of your boat**:**

Designing Boats
Exit Slip

Name:

Upon completion of this lesson you are to answer the following:

1. Write the formula for calculating density:

2. Who is the Greek philosopher who discovered buoyancy?

3. Density is equal to mass _____volume

4. One gram per millimeter is equal to _____gram per centimeter cubed.

5. A gas tank holds 50 L. If the density of gasoline is 0.7g/mL, how much mass will the tank of gas have?

6. What is Archimedes' Principle?

7. What is displacement?

8. (Complete this sentence) The reason you never want to sit or step onto the side of a boat is because your weight could make it "heel" too much and it _____

9. What causes a boat to sink?

10. How might you have improved the performance of your boat? What could you have changed, added, or deleted?

11. Describe the best shape for a boat and why:

ADDITIONAL TEACHER INFORMATION:

Answers to Description of Boat:

Answers will vary, but should mention some of the listed information listed below.

- Buoyancy forces objects that are lighter than the water to stay at the surface of the water.
- When an object sinks, gravity is pulling it down. Buoyancy works against gravity to keep lighter objects at the surface of the water.
- Research shows that boats that are rounded and stretched somewhat like a canoe, with higher sides, hold more weight.
- Buoyant force is the upward force that keeps things afloat. The buoyant force is equal to the weight of the water the boat displaces.

Answers to Exit Slip:

1. Density = Mass divided by Volume or students may write something equivalent.
2. Archimedes
3. divided by
4. 1 (one)
5. 35
6. Answers may vary in wording, but should include: "It states that a body partially or completely immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced by the body."
7. Answers may vary, but should include: "When an object is placed in water, it pushes enough water out of the way to make room for itself."
8. may tip over
9. Answers may vary, but should include: "It sinks because its weight is greater than the weight of the small amount of water it displaces."
10. Any reasonable or logical answer is acceptable if it shows thought and reflection.
11. Answers will vary but research shows the best shape for a boat would be rounded, somewhat in the shape of a traditional canoe. The deeper the boat is made, the longer it needs to be made as well. This will prevent the boat from tipping over in the water.