ATLANTA SCIENCE FESTIVAL

Lesson Title	Penny Boats: An Exploration of Density
Grade Band	Middle or High School Physical Science
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Georgia Performance Standards:

S8P1. Students will examine the scientific view of the nature of matter.
d. Distinguish between physical and chemical properties of matter as physical (i.e., density, melting point, boiling point) or chemical (i.e., reactivity, combustibility).

S8P3. Students will investigate relationship between force, mass, and the motion of objects.
a. Determine the relationship between velocity and acceleration.
b. Demonstrate the effect of balanced and unbalanced forces on an object in terms of gravity, inertia, and friction.

SPS2. Students will explore the nature of matter, its classifications, and its system for naming types of matter.
a. Calculate density when given a means to determine a substance's mass and volume.

S8CS9. Students will understand the features of the process of scientific inquiry.
Students will apply the following to inquiry learning practices:
a. Investigations are conducted for different reasons, which include exploring new phenomena, confirming previous results, testing how well a theory predicts, and comparing different theories. Scientific investigations usually involve collecting evidence, reasoning, devising hypotheses, and formulating explanations to make sense of collected evidence.

Safety Considerations:

Wash hands after completing the lab.

Materials & Time Required:

Pennies (500 – 1000)
Aluminum foil
Plastic shoe boxes filled with water
Paper towels
Optional: "prizes" for students who 1) get closest to their predictions, and/or 2) build a boat that holds the most pennies
Excel spreadsheet

Day 1 – Design and test boats
Day 2 – Redesign and test boats

Lesson Logistics (for teacher):

Provide the following materials for each group: plastic shoe box with water, a cup with approximately 100 pennies. Provide groups of students with the same size piece of aluminum foil (for example 5 cm x 7 cm or whatever you choose). A smaller piece works well for testing in the plastic shoe boxes.

Students will need to calculate the area or volume of their boat. The first time students design their boats, they often choose more traditional designs (such as a canoe). This makes it challenging to calculate the area. For this reason, allow students to design any type of boat they would like for the first design round. In the class debrief, focus on the type of designs that held the most pennies. This typically is the barge design. Talk briefly about why, but do not provide too much information. The goal is for students to use this information to help them in the redesign. During the redesign, students will calculate the mass of the pennies held and measure the volume (length x width x height). This is done so they can calculate the density (Mass/Volume) and graph the class results. It is important they measure the volume in centimeters.

Opening: ENGAGE	
	ENGAGE: Why do some objects float (show students a picture of a boat) and other objects sink (show students a picture of a rock)? We are going to investigate this through an engineering design challenge. Engineering Design Challenge – design a boat made of aluminum foil that will hold as many pennies as possible. Constraints: Limit the size of the piece of aluminum foil. Ask students to predict the number of pennies their boat will hold and record on the data sheet.

Work Session: EXPLORE/EXPLAIN	EXPLORE: Provide each group of students with a plastic shoe box half filled with water and a cup of pennies. Have them test the boats and record the number of pennies it took for the boat to sink. Discuss the designs that held the most pennies. Tell students they will have another opportunity to test a redesign. Allow the students to discuss what type of data they might want to collect to help them understand why. Lead them into a discussion about collecting data on the mass and volume of the boat. In line with an ENGINEERING design process, have them brainstorm, and redesign. With the second, boat have them measure mass and volume of the boat. By using the mass of one penny (2.5 g), they calculate the mass of the boat upon sinking.
Closing: EXTEND/EVALUATE	Incorporate TECHNOLOGY by using Excel to make a scatter plot of the data (Mass to Volume). Use the included Excel spreadsheet to record student data. Use the scatter plot function to graph the data. Make a prediction about the best fit line. Discuss the how the line represents the density of the boat at sinking. This should be close to 1 gm/ml which is the density of water. EXTENSION: Collect a variety of objects to test (floating and sinking). Record the mass and volume (use the water displacement method) of each object. Graph the data. There is a great article on this in The Science Teacher (NSTA Publication, February 2015) called "Sinking In" that explores this idea. EVALUATE: How would salt water affect the boat? Make a prediction about how salt water would affect a boat? Research and write an explanation about designing boats for salt and fresh water.

Documentation of Resources:

Other Resources:

- Teach Engineering: http://www.teachengineering.org/
- Engineering Lesson Ideas: http://www.egfi-k12.org/
- STEM Lessons at Teachers Try Science (IBM): http://www.teacherstryscience.org/
- PBS Design Squad: http://pbskids.org/designsquad/
- Try Engineering: http://www.tryengineering.org/
- National Academies of Engineering Grand Challenges: http://engineeringchallenges.org/
- Design Brief Resources: http://www.childrensengineering.com/freeresources.htm
- Spark 101 – Real world, STEM applications and videos: http://www.spark101.org/
- Engineering is Elementary: www.mos.org/eie

The Sink Off…..

Design 1:

You goal is to make a boat from aluminum foil that will hold as many pennies as possible.

Predicted # of pennies	Actual # of pennies

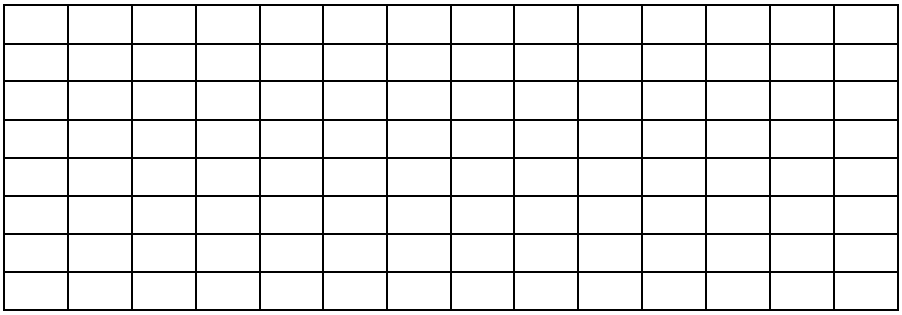
Write an explanation for which design of boat typically held the most pennies. How can you use this information in your redesign plan?

Design 2:

Predicted # of pennies	Actual # of pennies	Total mass of the pennies (1 penny = 2.5 g)	Volume of the boat (l x w x h) in cm^3	Density of Boat at "sinking"

Graph the class data:

Mass (g)



Volume (cm^3)

What trends do you notice in the class data? How can this help in our understanding of density?