4.6 - Design a Boat Challenge

Objectives:

Design a boat that will float the *most* mass without sinking.

Materials:

- Rolls of aluminum foil
- Pennies or small washers (of the same size)
- A sink or large tub to hold water
- Tap water

Procedures:

The purpose of this activity is to have students discover how to create a craft that will float on water and carry the most mass possible.

1. Have the students work in teams of three or four. Ask them to choose a team name.
2. Provide each team with two .5m x .5m sheets of aluminum foil. For older students you may wish to have students measure and cut the foil sheets. Be certain to check the students' work for accuracy and to ensure fairness.
3. Instruct the students that one sheet of foil is to test their design ideas and the other sheet is for their final "boat".
4. Provide the students with the design challenge to create a "boat" that will hold the most pennies/washers. Instruct the students that they are not allowed to use anything to build the boat other than one .5m x .5m sheet of foil.
5. Place a large amount of pennies in a location that is easily accessible to the students.
6. Partially fill a large tub or sink with water.
7. Have the student teams brainstorm ideas for the design of their boat. Monitor their communication for use in discussion at the conclusion of the investigation.
8. Have the students use one sheet of foil to test their ideas. It is important to provide adequate time for the testing process so the students can fully develop their ideas and discover the principles of floatation. Monitor the testing for use in discussion at the conclusion of the investigation. Note: it is a good idea to locate the testing area in a fashion that does not allow other teams to copy each other.
9. Have the students create their final boats. Once completed, they should report to the test location to begin the challenge.
10. Have the teams draw numbers to assign the order in which the teams will complete the challenge.
11. Have the first team place their boat in the water and add pennies to the boat until it begins to sink but does not become submerged. Count the pennies as they are being added to the boat or after the completion of each team's trial (this is the most time effective method).

12. Write the results of the challenge on the board next to the name of each team.
13. Ask the students why they believe one boat could hold more pennies than another could. Their responses will most likely be concerned with the following:
    a. The method in which the pennies were added to the boat such as being dropped or gently placed in the boat.
    b. The boats that performed best had the largest surface area. Although the students most likely will not use the term surface area, their description of this concept provides an opportunity to introduce and discuss the term and its relationship to the distribution of force.

Making Connections

Anyone that has ever lifted an object out of water has noticed that the object gets heavier as more of the object is lifted above the surface of the water. The reason for this effect is that the water is exerting an upward force upon the object. This upward force is called the buoyant force. So, when the weight of an object is greater than the water's buoyant force, the object sinks. When the weight is less than the buoyant force, the object floats, and when the weight and buoyant force are equal, the object will remain at any level in the water. Fish are a familiar example of this last characteristic. Therefore, the greater the surface area of the object being placed in water, the more buoyant force it has being applied to it to help it float.

Extension

- Ask the students if they have ever seen large ships such as naval vessels or ocean liners, and what materials are used to make these ships.
- Tell them that these ships are made of steel and iron.
- Drop an object such as a steel pellet or ball bearing into a tub of water. Have the students observe that the object sank to the bottom.
- Ask the students why this steel object sank while ships made of steel float on water. Hopefully, they will use the knowledge gained from the Design a Boat Challenge to answer that the amount of steel in a ship is spread out more than the steel pellet example. The steel in the ship is distributed over a larger surface area.

Online Resources

http://phet.colorado.edu/en/simulation/buoyancy
http://phet.colorado.edu/sims/density-and-buoyancy/density_en.html
www.brainpop.com (buoyancy)
http://www.sciencewithme.com/article_in_detail.php?cid=2&aid=1

Math

Kindergarten

4.a. Measure the length, weight, and capacity of objects using nonstandard units. (DOK 2)
4.b. Determine and describe comparisons of length (longer, shorter, the same), mass (heavier, lighter, the same), and capacity (holds more, less, or about the same) using different-shaped or congruent containers, objects or figures. (DOK 2)
4.d. Determine attributes of objects that can be compared, such as length, area, mass or volume/capacity. (DOK 1)

1st Grade

4.a. Use nonstandard units (paper clips, unifix cubes, etc.) and standard units (inches, centimeters) to measure length. (DOK 1)
5.a. Gather data, construct, and interpret simple bar graphs and pictographs. (DOK 2)
5.b. Analyze and interpret data by using mathematical language such as more than, less than, etc. (DOK 1)

2nd Grade

4.a. Select appropriate tools and units, estimate, and measure length (to the nearest inch, foot, yard, centimeter, and meter), capacity (to the nearest ounce, cup, pint, quart, gallon, and liter), and weight (to the nearest ounce, pound, gram, and kilogram). (DOK 2)
5.a. Tally, record, interpret, and predict outcomes based on given information. (DOK 3)
5.b. Create line graphs, bar graphs, and pictographs using real data. (DOK 2)

3rd Grade

4.c. Measure capacity, weight/mass, and length in both English and metric systems of measurement. (DOK 1)
5.a. Compare data and interpret quantities represented on tables and different types of graphs (line plots, pictographs, and bar graphs), make predictions, and solve problems based on

4th Grade

4.a. Estimate and measure a given object to the nearest eighth of an inch. (DOK 2)
4.b. Convert capacity, weight/mass, and length within the English and metric systems of measurement. (DOK 1)
4.c. Describe relationships of rectangular area to numerical multiplication. (DOK 2)
4.d. Use appropriate tools to determine, estimate, and compare units for measurement of weight/mass, area, size of angle, temperature, length, distance, and volume in English and metric systems and time in real-life situations. (DOK 1)
5.a. Draw, label, and interpret bar graphs, line graphs, and stem-and-leaf plots. (DOK 2)
5.b. Find and interpret the mean, mode, median, and range of a set of data. (DOK 1)
5.c. Compare data and interpret quantities represented on tables and graphs including line graphs, bar graphs, frequency tables, and stem-and-leaf plots to make predictions and solve problems based on the information. (DOK 3)

5th Grade

4.a. Estimate and measure length to nearest millimeter in the metric system and one-sixteenth inch in the English system. (DOK 2)
4.b. Convert units within a given measurement system to include length, weight/mass, and volume. (DOK 1)
4.c. Develop, compare, and use formulas to estimate and calculate the perimeter and area of rectangles, triangles, and parallelograms. (DOK 2)
4.d. Select and apply appropriate units for measuring length, mass, volume, and temperature in the standard (English and metric) systems. (DOK 1)
5.a. Use the mean, median, mode, and range to analyze a data set. (DOK 2)
5.b. Compare data and interpret quantities represented on tables and graphs, including line graphs, stem-and-leaf plots, histograms, and box-and-whisker plots to make predictions, and solve problems based on the information. (DOK 2)

6th Grade

4.b. Calculate the perimeter and area of regular and irregular shapes using a variety of methods. (DOK 2)
4.f. Apply techniques and tools to accurately find length, area, and angle measures to appropriate levels of precision. (DOK 1)
5.a. Construct, interpret, and explain line graphs, double bar graphs, frequency plots, stem-and-leaf plots, histograms, and box-and-whisker plots. (DOK 2)
5.b. Determine how changes in data affect mean, median, mode, and range. (DOK 2)

7th Grade

4.a. Convert from one unit to another, perform basic operations, and solve real-world problems using standard (English and metric) measurements within the same system. (DOK 2)
4.b. Use formulas and strategies, such as decomposition, to compute the perimeter and area of triangles, parallelograms, trapezoids, the circumference and area of circles, and find the area of more complex shapes. (DOK 2)
5.c. Construct and interpret line graphs, frequency tables, circle graphs, box-and-whisker plots, and scatter plots to generalize trends from given data. (DOK 2)

8th Grade

4.a. Solve real-world application problems that include length, area, perimeter, and circumference using standard measurements. (DOK 2)
4.c. Use formulas and/or appropriate measuring tools to find length and angle measures (to appropriate levels of precision), perimeter, area, volume, and surface area of polygons, circles, spheres, cones, pyramids, and composite or irregular figures. (DOK 1) real-world problems involving volume and surface area.

Science

Kindergarten

2.a. Classify properties of objects and materials according to their observable characteristics. (DOK 2)
- Materials (e.g., wood, paper, plastic, metal)
- Matter (solid or liquid)
- Objects that sink or float in water

3rd Grade

1.d. Draw conclusions and communicate the results of an investigation. (DOK 2)
1.f. Ask questions and seek answers to explain why different results sometimes occur in repeated investigations. (DOK 2)

4th Grade

1.a. Form hypotheses and predict outcomes of problems to be investigated. (DOK 3)

5th Grade

1.a. Form a hypothesis, predict outcomes, and conduct a fair investigation that includes manipulating variables and using experimental controls. (DOK 3)
1.b. Distinguish between observations and inferences. (DOK 2)
1.c. Use precise measurement in conjunction with simple tools and technology to perform tests and collect data. (DOK 1)
- Tools (English rulers [to the nearest one-sixteenth of an inch], metric rulers [to the nearest millimeter], thermometers, scales, hand lenses, microscopes, balances, clocks, calculators, anemometers, rain gauges, barometers, hygrometers)
- Types of data (height, mass, volume, temperature, length, time, distance, volume, perimeter, area)

1.d. Organize and interpret data in tables and graphs to construct explanations and draw conclusions. (DOK 2)
1.e. Use drawings, tables, graphs, and written and oral language to describe objects and explain ideas and actions. (DOK 2)
1.f. Make and compare different proposals when designing a solution or product. (DOK 2)
1.g. Evaluate results of different data (whether trivial or significant). (DOK 2)
1.h. Infer and describe alternate explanations and predictions. (DOK 3)

7th Grade

1.a. Design, conduct, and draw conclusions from an investigation that includes using experimental controls. (DOK 3)
1.b. Discriminate among observations, inferences, and predictions. (DOK 1)
1.c. Collect and display data using simple tools and resources to compare information (using standard, metric, and non-standard measurement). (DOK 2)
- Tools (e.g., English rulers [to the nearest one-sixteenth of an inch], metric rulers [to the nearest millimeter], thermometers, scales, hand lenses, microscopes, balances, clocks, calculators, anemometers, rain gauges, barometers, hygrometers, telescopes, compasses, spring scales, pH indicators, stopwatches)
- Types of data (e.g., linear measures, mass, volume, temperature, area, perimeter)
- Resources (e.g., Internet, electronic encyclopedias, journals, community resources, etc.)

1.d. Organize data in tables and graphs and analyze data to construct explanations and draw conclusions. (DOK 3)

1.e. Communicate results of scientific procedures and explanations through a variety of written and graphic methods. (DOK 2)
1.f. Explain how science and technology are reciprocal. (DOK 1)
1.g. Develop a logical argument to explain why scientists often review and ask questions about the results of other scientists' work. (DOK 3)
1.h. Make relationships between evidence and explanations. (DOK 2)

8th Grade

1.a. Design, conduct, and analyze conclusions from an investigation that includes using experimental controls. (DOK 3)
1.b. Distinguish between qualitative and quantitative observations and make inferences based on observations. (DOK 3)
1.c. Summarize data to show the cause and effect relationship between qualitative and quantitative observations (using standard, metric, and non-standard units of measurement). (DOK 3)
- **Tools (e.g., English rulers [to the nearest one-sixteenth of an inch], metric rulers [to the nearest millimeter], thermometers, scales, hand lenses, microscopes, balances, clocks, calculators, anemometers, rain gauges, barometers, hygrometers, telescopes, compasses, spring scales, pH indicators, stopwatches, graduated cylinders, medicine droppers)**
- **Types of data (e.g., linear measures, mass, volume, temperature, area, perimeter)**
- **Resources (e.g., Internet, electronic encyclopedias, journals, community resources, etc.)**

1.d. Analyze evidence that is used to form explanations and draw conclusions. (DOK 3)
1.e. Develop a logical argument defending conclusions of an experimental method. (DOK 3)
1.f. Develop a logical argument to explain why perfectly designed solutions do not exist. (DOK 3)
1.g. Justify a scientist's need to revise conclusions after encountering new experimental evidence that does not match existing explanations. (DOK 3)
1.h. Analyze different ideas and recognize the skepticism of others as part of the scientific process in considering alternative conclusions. (DOK 3)

Building a Ship

Engineer Team_____

_____

Name of Ship being constructed _____

Instructions:

1. **Take the aluminum foil and measure it to 12 inches by 18 inches/**
2. **Once measured, call for the chief engineer (teacher) to sign off on the measurements. If the measurements are not correct you will be docked 5 points each time.**
3. **Brainstorm ideas for the design of your boat with your engineer group; then construct your boat.**
4. **Weigh your boat and record the weight. Have the chief engineer sign off. Docked 5 points for incorrect weight.**
5. **Your boat will be placed in a tub of water, and you will add pennies to your boat until it sinks. When it sinks, the pennies will be removed and weighed. Record the weight.**

Answer the following questions before your launch.

How much does your ship weigh? _____

How much does a single penny weigh?_____

How many pennies do you think your ship will hold? _____

How much weight would that equal? _____

Explain why you think your ship will hold that much weight. _____

_____

_____

_____

Each engineer team was given the same amount of aluminum foil to build their boat. Do you think each ship will hold the same amount of washers? Why or why not?

_____

_____

_____

weight of the bowl holding the pennies_____

weight of the pennies only_____

write a ratio for the weight of the pennies to the weight of your ship

$$\frac{\text{Penny weight}}{\text{Ship weight}}$$

Next reduce the ratio (If the answer does not terminate, round to the ones place); then write the answer in the second blank below.
Show work here:

Our ship _____ **can hold** _____ **times its own weight!!**
name of ship **answer**

Did you think your ship could hold that any times its own weight?
Explain why or why not.. _____

_____

_____

_____

Would you change the design of your boat if you did this activity over again? If so what would you change? If not, what would you leave the same?

_____

_____

_____

What have you learned from this activity that you did not know before?

_____

_____

_____