Build a Boat

3rd Grade
Unit 4 – The People, The Preamble, and the Presidents
Text Connection: *Coming to America: The Story of Immigration* by Betsy Maestro

Design Challenge Summary

Standards: What standards are addressed?

Science:

NS.1.3.5 Estimate and measure length, mass, temperature, and elapsed time using International System of Units (metric system)

NS.1.3.6 Collect and analyze measurable empirical evidence as a team and/or as individuals

NS.1.3.7 Make and explain predictions based on prior knowledge

NS.1.3.8 Use simple equipment, age appropriate tools, technology, and mathematics in scientific investigations (e.g., balances, hand lenses, microscopes, rulers, thermometers, calculators, computers)

Math:

3.MD.2 Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l). *[Excludes compound units such as cm3 and finding the geometric volume of a container.]*
Add, subtract, multiply, or divide to solve one-step word problems involving masses or volumes that are given in the same units, e.g., by using drawings (such as a beaker with a measurement scale) to represent the problem. *[Excludes multiplicative comparison problems (problems involving notions of "times as much"]*

3.MD.3 Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step "how many more" and "how many less" problems using information presented in scaled bar graphs. *For example, draw a bar graph in which each square in the bar graph might represent 5 pets.*

3.MD.4 Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units - whole numbers, halves, or quarters.

Challenge: What will the students be required to do?

You will build a boat using a 5” by 5” piece of aluminum foil that will float the most mass without sinking.

Result: What will students know, value, and be able to do as a result of the lesson? What’s the big idea?

Know and apply the engineering design loop.
Understand how mass affects a structure.
Understand the relationship between mass and weight.
Understand the impact of gravity and force on an object.
Estimate and measure length and/or mass.
Conduct an inquiry into why objects float.

Assessment: What evidence will be used to determine student learning?

Did they build a boat that met the challenge?
Did they stay within the criteria?
Did they follow the design loop process?
Did they work collaboratively?

Build a Boat

Prior Knowledge/Experiences: What prior content knowledge and skills will the students need?

Connections to the Mathematical Practices
Experiences with weight, mass, and gravity
Investigations in buoyancy – objects sinking/floating
Experiences in measurement and estimation
PS.6.1.2 Relationship between mass and weight
PS.6.K.3 Effects of the force of gravity on objects (buoyancy – sink or float?)
2.MD.2 Measure the length of an object by selecting appropriate tools.

Summary/Connections: How will this design challenge connect with new/future learning, other content areas, real world experiences, etc.?

This lesson will help students develop problem solving skills and collaboration skills that are essential in succeeding in the 21st century. It will allow students the opportunity to transfer and apply skills from various content areas within one task.

As a summary activity, you can take the data from each group and create a line plot (3.MD.4).

Extension:
Have students reflect on their designs. Share with them about the "science of boat design" (included in pages attached). Then, using this new information, complete the challenge again.

Materials/Equipment/Preparation: What materials and equipment will students need to successfully complete this design challenge?

Roll of aluminum foil
Pennies or washers
Tub of water
Scissors
Ruler

*Some additional information on the concepts within this challenge and some reflection questions are attached to this summary. This information is an excerpt from a Project-Based Inquiry Science Unit found at: http://its-about-time.com/pbis/pdf/ls/dig_ls1.pdf

Design a Boat

Many people immigrated to the United States by boat. In this challenge, you will build a boat, using a 5” x 5” piece of aluminum foil, that will float the most mass without sinking.

Group Supplies:
5” x 5” piece of aluminum foil, pennies (or weights), scissors, ruler

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Reflect

Following your *Solution Briefing*, answer the following questions. Discuss your answers and how they may help you better achieve the *Boat Challenge*.

You may find looking at your drawings and your *Solution-Briefing Notes* page helpful as you answer the following questions. Be prepared to discuss your answers with your class.

1. Before each boat design was tested, what did you think would happen when the keys were placed in it?
2. Which boats worked the way you thought they would? Which worked differently than you expected? For the ones that worked differently, what might help you to understand why?
3. What qualities make your boat a good design?
4. What are the problems with your current design?
5. What can you borrow from other designs to make yours work better?
6. What do you need to learn more about to make a better design?

collaborate: to work together.

Be a Scientist

Build on and Benefit from One Another's Ideas

You ask questions and offer suggestions during a *Solution Briefing*. When you do this, you are **collaborating** with one another. You are working together. You offer your ideas for others to think about. You provide suggestions that might help them improve their solutions. Sometimes you learn something that you want to try yourself.

Other teams may come up with solutions or ideas that you want to borrow and make better. You may also find that other teams have used your suggestions. Is the other team copying from you? Are you copying from them?

Think about the other team's success as your success when they use something you suggested. Help them see that your success is theirs if you borrowed something from them.

1.3 Read

The Science of Boat Design

matter: anything that has mass and takes up space.

density: the amount of matter in a given amount of space.

buoyant force: the upward push that keeps objects floating in liquid.

volume: the amount of space that something takes up.

atom: a small particle of matter.

molecule: the combination of two or more atoms.

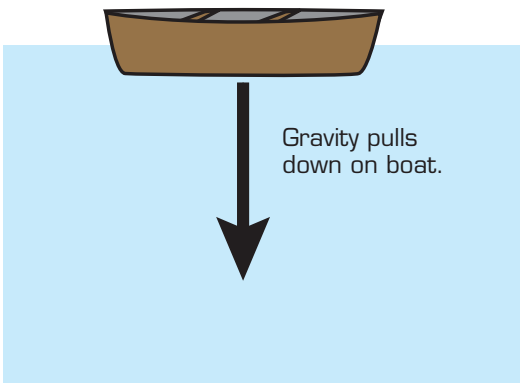
You have just finished your first attempts at building an aluminum foil boat. You also talked about the design ideas and products of other groups. You discovered some ideas that worked well and others that did not. You identified some questions that you want answered before you try again. Soon you will have another chance to build a better boat. Before you do, you will read and think about the science concepts that explain how boats work, and you can then apply this knowledge to your next boat design. To understand what makes things float, it is important to learn about three science concepts—**matter**, **density**, and **buoyant force**. They are all important to making your foil boat carry more keys.

Matter

All objects of any form (solid, liquid, or gas) are made up of matter. All matter has mass and takes up space. The amount of space that something takes up is its **volume**. The boat you are trying to build is made up of matter, and so is the water the boat floats on. Matter is made of extremely small particles called **atoms**. These atoms combine with other atoms to form larger particles called **molecules**. Molecules attach to one another to form all the objects that you see, touch, hear, taste, and smell.

Density

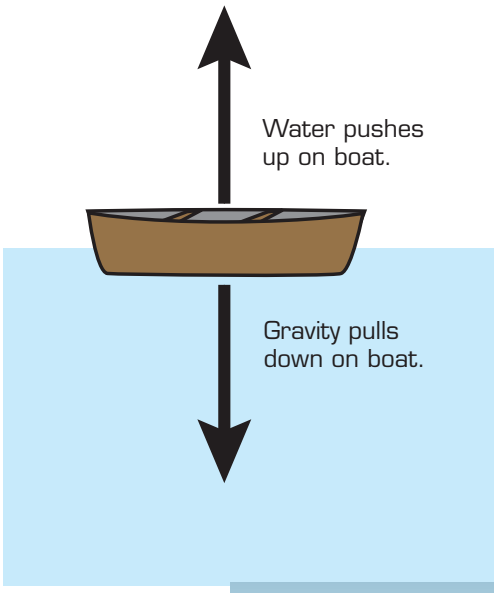
One factor that affects whether or not something can float is its density. Density is the scientific word for the amount of matter in a certain amount of space. It is a measure of how tightly the molecules making up matter are packed together in the space. The more room the molecules have in a given space, the less dense the matter will be.



If you have a cardboard box full of plastic bubble wrap, it will be lighter than the same-sized box full of books. The different materials in each box take up the same amount of space, but each contains a different amount of matter. Since a book-filled box has more matter than a box filled with bubble wrap, the box of books has greater density.

We think of books as being heavier than bubble wrap, but that is misleading. What we are really thinking about in that case is the density of the materials. A book taking up a certain amount of space will be heavier than a piece of bubble wrap taking up the same amount of space. This means that books are denser than bubble wrap. There is more matter in a book than in a section of bubble wrap of the same size as the book. That is why a box of books will be heavier than the same box filled with bubble wrap. For the same volume, the more dense material will be heavier than the less dense material.

Molecules that make up the matter in a book are tightly packed together and do not have much space between them. In the bubble wrap, the molecules have a lot of space between them because each bubble contains a lot of air—air is a gas and is much less dense than a solid. Books are solids and contain a lot less air. This makes bubble wrap less dense than books.



Buoyant Force

A force is a push or pull on matter. The upward push that keeps an object floating is called buoyant force. To understand the buoyant force that makes things float, you first have to understand gravity. You already know a lot about **gravity**. You see and feel the effects of gravity everywhere every day. Gravity is the force that holds you, and all objects, on Earth. It is a force, or pull, between any two objects. All objects have this pull toward other objects. The pull between most objects is small, and unless an object has a lot of mass, you do not feel its pull.

gravity: a pull between two objects. Gravity is the force that holds all objects on Earth.

When one (or both) of the objects is very massive (which means it has a lot of mass and, therefore, has a lot of matter), you can experience gravity's effects. Earth is very massive, and gravity is the force that pulls everything down toward the center of Earth. Because of gravity, almost everything—people, furniture, trains, and dogs—stay put on top of Earth's surface. In your activity with boats, Earth's gravity pulls on the water and keeps the water in the bucket in which you are floating your boats. Gravity also pulls down on the foil boat.

In designing a boat, an important consideration is why some boats stay afloat, while others do not, and sink. This is a question of how much buoyant force the boat produces.

Gravity pulls things toward the center of Earth, but objects do not continue falling toward the center of Earth. The ground, or other surfaces, resists Earth's pull. In the boat-building challenge, the molecules of the water push up on the molecules in the foil boat at the same time that gravity pulls down on the boat. If the buoyant force of the water pushing up on the boat is as strong as the force of gravity pulling the boat down, the boat will float.

The force pulling the boat down is gravity and the water's buoyant force is the upward push helping to keep the boat afloat.

You may have thought that heavy objects sink and light objects float. But some of you might have gotten the heavy keys to float by shaping the boat in different ways. That shows that weight is not the only factor determining if objects float or sink. To illustrate what is happening in the water, look at the way gravity pulls on something that is not in water.

Crumple one of the 5-inch squares of aluminum into a ball, squeezing out as much air as you can. If you place it on a tabletop, you can see that all of the mass of the foil is pushing down on a very small part of the table. Set another 5-inch square of foil flat on the table, and the same mass of foil is now pushing down on a much larger area. The flat piece of foil touches more of the surface of the table. The piece crumpled into a ball touches less of the table's surface. The mass of the foil ball is concentrated into a smaller area of the table, and fewer molecules that make up the table can push back on it.

These children are able to float in the water because the gravity (downward push) of their bodies is equal to the buoyant force (upward push) of the water. Since a flotation device is less dense than the child, it causes a decrease in the overall density of the person wearing it. This means that less of an upward push by the water is needed to keep the wearer afloat.

If you were to place the foil sheet and the foil ball in a bucket of water, what do you think would happen to each? The flat sheet would float. The ball would sink (if *all* the air in the ball had been squeezed out of it). The foil ball would sink because the small area of water in contact with the full mass of the foil does not put enough buoyant force on the foil to keep it above the water. Instead, the water molecules simply slide around and over the foil ball, and it sinks.

When the foil is spread out flat, more of its surface has contact with the water. The same amount of mass from the foil pushes down on a much larger area of water. This creates a situation in which more molecules that make up the water can push up on the foil. As long as the force of gravity pushing down from the foil is equal to the buoyant force pushing up from the water, the foil will float. The flat piece of foil is better able to float because more molecules of water can apply their upward buoyant force to push up on the foil.

The air that fills the open parts in the boat decreases the boat's overall density, making it possible for the buoyant force (upward push) of the water to keep it afloat.

Density and Buoyancy Force

Buoyant force and density work together to affect whether or not something will float. When a boat sits in water, it pushes some of the water away, or displaces it. The water that was pushed away has a certain density. If the boat, including the air in it, is less dense than the water it pushes away, the boat will float. If it is denser than the water it pushes away, the boat will sink. As the density of any object increases, it sinks lower into the water, always displacing an amount of water equal to its weight. The weight of the water that is pushed away, or **displaced**, by the boat is equal to the weight of the boat.

displace: to take the place of.

This is a complicated idea to think about. You will have more opportunities to investigate the effects of gravity, buoyant force, and density. For now, think about your challenge. You are trying to figure out how to make the weight of the keys spread out over a large enough area of the surface of the foil boat so that the buoyant force of the water can keep it afloat. Even as you add more keys, the boat will stay afloat as long as you can find ways to spread the weight of the boat and keys over a larger space.

Reflect

You are going to get another chance to design a boat. You will use the same materials. Think about how your group could design your next boat to better meet the challenge by considering what you now know about gravity, density, and buoyant force. Answering the following questions should help.

1. Think about some of the boat designs that held the most keys. What decisions did the students who designed these boats make that improved the buoyant force of the boat?
2. Did your boat float? If it did not float, why do you think it sank? Discuss *buoyant force* and *density* in your answer.
3. How could you make the boat better able to stay afloat? Remember that you have to float six keys. Use what you have learned about gravity, buoyant force, and density to answer this. Also, take advantage of what you can learn from other groups' designs.

What's the Point?

All objects are made of matter, which is made up of atoms. Atoms combine with other atoms, becoming molecules. All matter, including water and air, is made up of atoms and molecules. Density is the amount of matter in a given amount of space. It is a measure of how tightly the matter is packed together in the space.

For something to float, the force (gravity) pulling down on it cannot be greater than the force (buoyant force) pushing up from the water. To increase the buoyant force pushing up on a boat, you can spread the mass of the object over a greater area of water. This is similar to placing both the flat piece of foil and the crumpled ball of foil in a bucket of water. The flat piece floats, while the crumpled piece, if all the air has been removed, will sink.

When the foil is spread out, more of its surface has contact with the water. The same amount of mass from the foil pushes down on a much larger area of water. More molecules that make up the water can push up on the foil, or any size boat. The greater the surface of an object that touches the water, the more molecules of water can apply their buoyant force and push up the object.