Discovering Density

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Subject: Physics

Grade Level: 4th-8th grade

Standards: ***Next Generation Science Standards (www.nextgenscience.org)***

5-PS1-3 Make observations and measurements to identify materials based on their properties.

Schedule: 3 or 4 - 45 minute lessons

CCMR Lending Library Connected Activities:
Buoyancy

Objectives:	**Vocabulary:**
To further student understanding of density by comparing solids of different densities quantitatively and qualitatively.	Mass Buoyancy Volume Slope Density
Students Will: - Measure mass using a balance scale. - Measure volume using a measuring cylinder and the displacement method. - Calculate the mass/volume ratio. - Graph the mass/volume ratio and calculate the slope of their line. - Make the connection between the mass/volume ratio and density. - Identify materials based on their density. - Understand that materials that are denser than water can float by increasing their volume.	**Materials:** **For Each Group (3-4 students)** ___ Material (set of 4 different sizes) - Aluminum - Copper - Brass - Steel - Plastic ___ Measuring Cylinder **For Class** ___ Balance Scale ___ Aluminum Foil ___ Wood Blocks (4 different sizes) ___ Container
Safety	No safety concerns are associated with this activity.

Science Content for the Teacher:

What is Matter?
Matter is anything that has mass and takes up space. We can measure mass using a balance scale. We can measure volume by measuring the length, width, and height of the object. If it does not have a definite shape, then we can measure volume using the displacement method. If you put an object in water, the object will displace an equal amount of water. The displaced water that you measure is also the volume of the object.

Density = mass ÷ volume

Density is an intrinsic property of all matter (i.e. it is dependent on the *type*, not the amount, of matter). It measures the **ratio** of mass to volume; in other words, *it is a measure of how much matter (mass), is packed into how much space (volume).* The higher the mass to volume proportion the higher the density because the *mass is more tightly packed into a certain amount of space.* In middle school, students usually encounter density in grams per cubic centimeter or grams per milliliter (1 g/cm^3 for solids or 1g/mL for liquids, since 1 cm^3 = 1 mL). Thus, density (in units of g/cm^3) is the mass of 1 cubic centimeter (cm^3) of the substance.
Since water has a density of 1 gram per milliliter (1 g/mL, or equivalently 1 g/cm^3), a material or object with a density higher than one will sink and anything with a density lower than one will float.[1]

As one can see from the Density Equation (d = m/V), there are two ways of changing the density of an object: either changing the mass or changing the volume. If you change both equally, say by cutting an object in half, the density stays the same because you changed both parts of the proportion equally. Middle school students are accustomed to this from math, and can readily tell you that in solving equations "what you do to the numerator you must also do the same to the denominator" to keep the equality. Conversely, if you only change either the numerator or the denominator, or you change either unequally, you've changed the equality. In terms of the density equation, as the *mass gets bigger the density increases* because mass is in the *numerator*, but as the *volume* gets bigger the density *decreases* because volume is in the denominator. This makes sense to even the less math-oriented students when they see that $^2/_1$ punched into the calculator does not give the same numerical value as ½. Thus density **increases** either by *increasing the mass* or by decreasing the volume.

One must be very careful not to confuse mass with weight. Although close to the surface of the Earth they can be interchangeable, they are NOT the same thing. When students use the scale they should realize they are finding the mass, not the weight, of an object. Mass is a property that does not change (until you add more, of course), whereas weight depends on the pull of gravity. On the moon, the weight of a hammer would definitely change (decrease), but its mass would not. Conversely, on Jupiter the weight would be much heavier (because Jupiter is bigger and thus has a larger gravitational pull), but its mass would be the same on Jupiter, Earth, or the moon. It is important for middle school students to understand this distinction. Mass does not depend on gravity, weight does.[2]

In building a boat in **Activity 2**, it is important to realize that the volume of the boat (including the space that it encloses) is a vital parameter. The equation given in the activity (density of the boat = total mass of the boat / volume enclosed by the boat) is

derived from Archimedes' Principle. This law states that the upward buoyant force exerted by a fluid is equal to the weight of the water *displaced by the object*. When a boat is at its sinking point, the total volume of water displaced by the boat is equal to the total volume of the boat. This is why including the volume of enclosed space is important. Then the upward buoyant force = (volume of boat * density of water * gravity) and the downward force = total weight of the boat = (total mass of boat * gravity). The boat sinks because the downward force is larger than the upward force. The students do not need to be confused by these details, but they should know that Archimedes' Principle is the reason why the total density of the boat must take into account the space the boat encloses.

Preparation:

Photocopy activity sheets.

Classroom Procedure:

Day One: Activity 1

Engage (Time: 5 minutes)
Show the students the first animation on the slide presentation. What do they notice about the two objects while they are in the air? What happens when they are placed in water? Ask them to infer why this is.

Explore (Time: 35 minutes)
Students will perform ***activity 1*** by gathering data (Mass and Volume) on a set of 4 cylinders made of the same material, but having different sizes. They will make a graph plot of mass vs. volume and draw a line of best fit. They will then calculate the slope at two spots on the line to see what the ratio is.

Closing Exploration for Day One (5 minutes)
Look at graphs and slope and have the students try to figure out what the mass/volume ratio is. Introduce concept of density.


Day Two: Activity 2

Recap (5 minutes)
Students review their data from previous day and summarize what density is.

Explore, continued (Time: 30 minutes)
Students will perform ***activity 2*** by making a simple boat using aluminum foil. They will then calculate the volume of the boat and how much mass it should be able to hold before sinking. They will then test out their prediction by adding washers to the boat until it sinks.

Explain (Time: 5 minutes)
Review the students calculations and results. Was their predicted mass correct?

Day Three: Activity 3
Challenge: Which boat will carry the most mass? Students will be assigned one of 3 boat templates to test and see which one will hold the most mass.

Assessment:

The following rubric can be used to assess students during each part of the activity. The term "expectations" here refers to the content, process and attitudinal goals for this activity. Evidence for understanding may be in the form of oral as well as written communication, both with the teacher as well as observed communication with other students. Specifics are listed in the table below.

4= exceeds expectations
3= meets expectations consistently
2= meets expectations occasionally
1= not meeting expectations

	Engage	Explore	Explain
4	Shows leadership in the activities and offers creative explanations.	Completes work accurately while providing an explanation for what is observed. Works very will with partner.	Provides an in-depth explanation of findings. Fills out worksheet clearly. Shows understanding for the science behind how a boat floats.
3	Participates in the activities and completes the work.	Completes work accurately and works cooperatively with partner.	Provides clear explanation of findings. Fills out worksheet clearly. Offers good explanation for the science behind how a boat floats.
2	Participates in the activities.	Works cooperatively with partner, but makes some mistakes on the activities.	Provides a limited explanation of findings. Fills out some of the worksheet. Offers some explanation for how a boat floats.
1	Does not participate in the activities.	Has trouble working with partner. Does little to complete the activities.	Is not clear in explanation of findings. Does not fill out worksheet. Does not offer an explanation for how a boat floats.