Buoyancy and Density: Middle School Unit Plan

Questioning Strategies to Promote Critical Thinking
Using a Conceptual Change Model
(Integration of mathematics & physical science)

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Teachers may use and copy this unit plan free of charge, but are asked to provide Drs. Norris-Tull with feedback on its usefulness. Send information to d_norris@umwestern.edu

Standards & Benchmarks:
Montana science content standard 1: Students, through the inquiry process, demonstrate the ability to design, conduct, evaluate, and communicate results and reasonable conclusions of scientific investigations.

> **Benchmark 2: grades 5-8:** select and use appropriate tools including technology to make measurements (in metric units), gather, process and analyze data from scientific investigations

Montana science content standard 2: Students, through the inquiry process, demonstrate knowledge of properties, forms, changes and interactions of physical and chemical systems.

> **Benchmark : grades 5-8:** examine, describe, compare and classify objects and substances based on common physical properties and simple chemical properties

Objectives:
Conceptual Understanding:
- Students can explain a variety of situations using density and buoyancy

Science Process Skill (Science Inquiry Skill)
- Students develop skills in calculating density

Materials: 1 set per group (groups of two work best)
Balance with weights, or digital metric scale
Weights (can use paper clip for a half gram, one Unifix cube for 1 gram, a nickel for 5 grams)
Graduated cylinders (10 ml, 100 ml)
Large beakers or other containers (to hold water)
Water

<u>Ordering supplies:</u>
- You can order inexpensive supplies for Cartesian divers from Educational Innovations http://www.teachersource.com/
- Delta Education has inexpensive plastic balances and graduated cylinders http://www.delta-education.com/ (See “Graduated Cylinders,” “Measurement Kit,” or “Student balance-class set of 15”)

<u>A bag of floating and sinking objects for each group to experiment with:</u>
Film can with lid
Clay
Aluminum foil
Small piece of wood (small enough to fit inside 100ml graduated cylinder)
Small rock (small enough to fit inside 100ml graduated cylinder)

Preliminary phase: Find out what the students already know

Teacher demonstration of a few objects that sink or float
(Have students predict which will sink or float, then show them what happens with each object. Include objects that students typically think should float. No discrepant events needed yet).

Teacher talk:

- What do you predict will happen?
- Explain why you think that will happen.
- What else could happen?
- Why do things sink?
- Why do things float?

(Note: the common misconception is that things sink or float based on their weight. Mass and density are not concepts the students typically will bring up in regards to sinking and floating. At this point, the teacher does not try to correct their misconceptions).

Focus phase: The students explore examples of the concept

(Note: Students do not measure mass and volume yet).

Don't give the groups the water until after they write down their predictions (what do they think will happen) and hypotheses (explanations: what causes this to happen).

Teacher talk:

- Look over the objects in your bag.
- As a group, write down your predictions.
- What do you predict will happen when you drop each object in the water?
- Explain what you think causes sinking and floating (your hypothesis).

- Now test your predictions.
- Record the results.
- Record your explanation (hypothesis) - What caused the results?

(As the students are experimenting with the objects, ask groups informally:)

- What happened?
- Do the results support your predictions?
- Do the results support your original hypothesis (explanation)?
- If not, what new explanation/hypothesis do you have?

Challenge phase (Day 2)
Students exchange views.
Students debate and test out their explanations.

Teacher guides students through the challenge.

Teacher collects all the students' explanations and puts them all on a white board, SmartBoard, or overhead projector. Do not put students' names by their explanations – You want the students to feel comfortable challenging their own explanations in public. Include in the responses a layman's version of the scientific explanation, something like, "floatiness/sinkiness has something to do with weight and size together."

Teacher talk:
Here are all the explanations the class came up with.

Do your results support your explanations?
Do things sink just because they are heavy?
What else do we have to take into account besides the mass of the object? (Note that by repeatedly using the term *mass*, you help the students become familiar with it. Later on you can conduct activities to help them understand the difference between weight and mass).
Are there any of these explanations that anyone wants to challenge?
Are there any that we can eliminate? Explain why.
Are there any explanations that you think we can test further?
How can you test this explanation?

(Have students carry out further experiments with the objects. They may have to manipulate the foil to get it to sink).
(At this point, demonstrate how to use the balances. Direct them to estimate the mass of the objects to 0.5 gram.)

What can we say about the mass of the objects that sink?
What can we say about the mass of the objects that float?

(At this point, they should start realizing that mass alone does not provide enough information to predict which objects will sink or float). (Note, it is ok if the students use the terms "mass" and "weight" interchangeably at this point. You can tell them what the difference is, but don't worry about whether or not they understand the difference yet.)

Now are there any explanations that we can eliminate?
Did anyone come up with any new explanations?

At this point, the students should start getting the idea that weight or mass by itself is not enough information to predict which object will float or sink.

It would now be appropriate to state that the explanation that seems to most accurately represent what is happening is:

"floatiness/sinkiness has something to do with weight (mass) and size (volume) together."

Day 3

(Today, students have access to a balance or scales for measuring mass, and graduated cylinders for measuring the volume of the objects by displacement.)

Show the students how to measure the volume ("size") of small objects using the 100ml graduated cylinders to measure water displacement. Give them time to play around with this idea. Have them test this out with an object that is one cubic centimeter (1 ml) in size (such as a unifex cube) to develop accuracy in estimating volume.

For objects that float, guide the groups to figure out that they will have to push the object under water to measure the volume – the tip of a pencil works well for this.

Then have them measure the volume of all the objects.

Now, give students the formula to calculate the density of the objects.

Have them calculate the density of all the objects.

Some of the students will think that the foil always floats (it will float when it is in certain shapes). You want them to see the foil sink, so guide them to try manipulating the foil to sink (this can be done by folding the foil into a small, flat object, and tipping it so that it slides into the water.)

Density = mass divided by volume
Sample chart for recording results (also see Student Worksheet, at end of this document).

Object	Prediction: Will it float or sink?	Results: Floats or sinks?	Mass (grams)	Volume (ml = cm^3)	Density (g/cm^3)
Film can with lid on					
Clay					
Aluminum foil					
Rock					
Wooden block					

When the students have measured and calculated the densities of the above objects, ask them how they could measure the density of water.

Give them the 10ml graduated cylinder to make it easier to accurately measure the volume of 10ml of water.

Get them to figure out that now all they have to do is measure the mass of the water. Assist them to figure out that they will have to subtract the mass of the graduated cylinder from the mass of the water in the cylinder.

Point out that $1ml = 1cm^3$

Each group puts their data, for all the objects and water, on the board. This quickly allows each group to compare their data with the data of others. This is a good technique to enable students to correct their own mistakes. Guide the students to re-do their measurements and calculations if their data seems to be off.

Some objects (wood, rocks) will have different densities, but all the rocks should have densities greater than 1.0 gram per cubic centimeter. Be sure to select woods that will float, and thus should have densities below 1.0. The foil has a density greater than 1.0, but the groups may have to consult a bit to convince each other of this.

If the groups come up with different answers, have them talk about what might have caused this to happen. For the density of water, some groups may have simply done something incorrectly, as this is a fairly difficult measurement to make. Have them figure out their errors and re-calculate until they can all agree that the density of water is 1.0 gram per cubic centimeter. (In the process of repeated measurements, ask questions to guide them to understand that using the thinnest graduated cylinder will yield the most accurate results).

Teacher talk:
- What do all the floaty things have in common?
- What do all the sinky things have in common?
- How does the density of water relate to this?
- What rule can we make about which things sink and which things float?

Layman's language for explaining buoyancy: Delena's floatiness/sinkiness law

"floatiness/sinkiness is determined by density, which has to do with weight (mass) and size (volume) together. The more dense the object is, the more likely it is to sink."

Translated into scientific language:

Buoyancy:

If the density is greater than that of water, the object will sink.

If the density is less than (or the same as) that of water, the object will float.

Days 5 and beyond: Application phase: Students apply the concept to new situations

Teacher and students generate further examples of things that sink or float. Students test to see if they can be explained by the concepts of density and buoyancy.

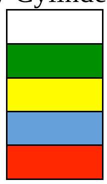
To develop the students' concepts of density and buoyancy, have them do different activities on different days, to help them begin to transfer the scientific concepts to new situations over time. Plan on using at least five applications before most of the class becomes successful in applying the scientific explanations to the new situations. More applications may be needed for some students.

- (Film cans activity) Students are given several film cans with different objects in them to increase the mass without increasing the volume. The students must measure mass and volume to make predictions - this activity reinforces that the buoyancy rules work.
- Cartesian diver (fill a 2-liter plastic soda bottle with water almost to the top. Fill a glass eye dropper partly with water – test its buoyancy in a beaker of water – you want it to float below the surface. To get it to float, put more or less water in the eye dropper. Drop the eye dropper into the bottle. Put the lid on the bottle. When you squeeze the bottle, the eye dropper sinks.) You can do the same thing with a variety of other objects, including those tiny mustard or ketchup envelopes (like you get at restaurants). Leave the mustard or ketchup container sealed and use it like a Cartesian diver. You can use plastic eye droppers, but you have to add some mass to them, such as by pushing a tiny washer or bolt over the bottom of the eye dropper. There are lots of websites with various designs for Cartesian divers.
- Why does ice float? (Have students measure the mass and volume of ice to determine its density, and compare that to the density of water.)
- Have students perform virtual experiments by selecting "Buoyancy Explorer" at http://www.seed.slb.com/labcontent.aspx?id=11452
- Read about Archimedes discovery of the principle of buoyancy http://www.seed.slb.com/labcontent.aspx?id=17490&terms=Archimedes
- Measure the density of different liquids and play around with them to get them to float on top of each other.
- Experiment with the comparative densities of hot and cold water. In a clear plastic or glass container, about the size of a small fish tank, pour hot water into the tank (you can add a few drops of red food color to make the hot water red). Then carefully pour some ice water (with blue food coloring) into the tank of water (To facilitate pouring, cut a few small holes in the bottom of a paper cup, and tape the cup so that the bottom of the cup is below the surface of the hot water. Then pour the cold water into the cup). The ice water will sink below the hot water. Try this in reverse. Then try salt water versus fresh water. The students can continue to

experiment with this by comparing hot salt water versus cold fresh water, and so on. It's all about density!

- Rainbow density lab. Students prepare sugar water, with different amounts of sugar in each of four beakers of water. Then they drop different colors of food coloring in each beaker. Then they see if they can carefully pour the different densities of sugar water into a graduated cylinder is such a manner that they create a layered rainbow of colors. Give the students straws and eye-droppers or plastic pipettes. Let the groups figure out which implements to use to create the layers. This takes practice in careful pouring to create layers of color. You can have students compete with each other to see who can create layers with the least amount of differences in density of sugar water. Rather than giving the students specific amounts of sugar to add, have them experiment with different amounts (masses & volumes) of sugar.

  Rainbow Density Cylinder:



- For a video of a simple way to do this activity: http://www.wonderhowto.com/how-to/video/how-to-perform-the-activity-density-rainbow-experiment-256364/
- Detailed instructions for the rainbow density lab are also included at "How Sweet It Is" on the Flinn Scientific website: http://www.flinnsci.com/Sections/MS/physicalSci/Activities.asp However, it is not necessary to use the precise measurements and techniques they describe. We prefer to let students experiment with the amounts of sugar to use and figure out what pouring techniques work best for producing the layers.

Discrepant events:

- Aluminum foil or clay boats (Why do they float? We didn't change the mass. Did we change the volume? This one is difficult to explain or understand. Don't worry about whether or not the students (or you) understand it, but explore it together. You could say that the shape of the boat creates a functionally larger or "pretend" volume, thereby lowering the functional density of the boat.)
- Ice in alcohol (the students don't know its alcohol – teacher asks them to predict whether the ice will float. The ice sinks, and they have to guess why. The density of alcohol is less than that of water or ice, therefore the ice sinks.)
- How would objects behave in water in microgravity (zero gravity) in the Space Shuttle? See lessons on Toys in Space at the NASA website (look at the Swimming Fish part of the video): You can view the NASA videos online at http://quest.nasa.gov/space/teachers/liftoff/toys.html
  Or you can order the DVD of Toys in Space ($12) at http://corecatalog.nasa.gov/item.cfm?num=009.0-11D
  NASA's lesson plan to go with the videos: http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Toys_In_Space_II.html

Examples of real world applications of buoyancy and density:

- Ice on a lake
- Boats
- Swim bladders in fish
- Scuba divers
- Submarines
- Aquatic plants (such as water hyacinth)

Assessment Rubric:

Criteria	Developing	Proficient
Conceptual understanding	Student explanations reveal inconsistent understanding of density and/or buoyancy	Explanations show that student is able to apply concepts of density and buoyancy to various situations
Calculations	Density calculations are not accurate, and student did not revise them	Student re-measured and re-calculated as needed until results were accurate

STUDENT WORKSHEET ON NEXT PAGE

Sink or float – What is density?

Essential information

Density = mass divided by volume

Mass is measured in grams

Volume is measured in cubic centimeters or milliliters

1 cm^3 = 1 cubic centimeter = 1 milliliter

Problem 1

What determines whether an object will sink or float? ___________________________

Use the bag of objects to test out sinking and floating, and to calculate density of each object.

Item	Prediction – Will it sink or float?	Results – Did it sink or float?	Mass (grams)	Volume (cm^3)	Density (g/cm^3)
Film can with lid on					
Clay					
Aluminum foil					
Rock					
Wooden block					

What does density have to do with sinking or floating?

Problem 2

How can you calculate the density of water?
(Hint – 10 cm^3 of water is a good amount to work with).

Item	Mass (grams)	Volume (cm^3)	Density (g/cm^3)
Water			

Problem 3

Compare the density of water with the densities of the objects that sink and the objects that float. What can you conclude about the objects that sink, in relationship to the density of water?

What can you conclude about the objects that float, in relationship to the density of water?