Will It Float?

A learning cycle investigation of mass and volume

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The idea for this investigation grew from mathematics lessons in which our fifth-grade students were sorting objects by weight. Students were predicting the relative weights of different candy bars based solely on appearance. After finding the true weight using balances, students were surprised by the results; they couldn't believe that larger candy bars such as Three Musketeers weighed less than smaller ones such as Snickers. Soon, students were bubbling with questions about why certain larger objects appeared to have less weight than those that seemed smaller, and they were eagerly sharing their thoughts about what might have caused their results. Students mentioned the amount of air inside the objects as well as what made up each of the objects as possible factors for the differences.

We were thrilled by students' natural curiosity about their observations and the quality of their conversation, and we wanted to let them examine and refine their thoughts as well as develop a deeper understanding of mass, volume, and possibly density. So, we developed a science investigation using the 5E learning model that would let them do just that. The lesson can address varying degrees of student readiness with minor adjustments—from developing students ready to explore the concepts of mass, volume, and graphing to advanced students ready to explore the relationship between mass and volume (density) and the slope of lines on graphs. We conducted the lesson with a group of fifth-grade students that had some knowledge of mass and volume and the metric units of grams and liters. Although students had little, if any, direct instruction with density, it was clear from the math lessons that students were beginning to construct an understanding of the concept. Students had also recently been introduced to line graphs, and most had an understanding of number lines, which was important when helping them graph the results of their measurements.

Engage

To begin, students moved through four different centers designed to focus their attention on the concepts of mass, volume, and density. At these stations, students encountered discrepant events that heightened their curiosity and encouraged discussion with peers about what they expected and observed. They answered questions and made predictions on a worksheet (Figure 1).

At the first center, students observed Lignum Vitae wood from a South American tree species (*Guaiacum officinale* or *G. sanctum*). After their initial observations, students predicted whether the wood would sink or float in water. Surprisingly, the wood is one of the only woods that will sink in water. This added to the discrepancies that students had experienced in the mathematics lesson on weight. It also created more questions, such as "Why does this wood sink, but others float?" "What does the tree look like?" and "Can we make other wood sink?"

At the second center, students observed a pumice rock and again described similarities to and differences from more familiar rocks and predicted if the pumice would sink or float. As might be expected by now (as many students commented), students' initial thoughts about rocks not floating were debunked as the pumice floated in the bowl of water.

At the third center, students were given two steel spheres made of the same metal, one much larger than the other. The students were asked to predict whether each one would float or sink and to predict which sphere weighed more. Although one was much larger than the other, students were surprised to discover that both spheres had the same mass. The mass and size of the spheres caused one to float (the larger, hollow one) and the other to sink (the smaller, solid one).

At the final center, the students were given a Cartesian diver made from a 2L bottle and a glass dropper. They can be made by filling a 2L bottle with water and placing a dropper (3/4 full with water) into the bottle and tightly closing the lid. The dropper, with air visible at the top, floats at the surface and remains upright. As students squeezed the bottle, they observed what occurred. Once again students were amazed; they saw the dropper sink to the bottom of the bottle when they squeezed, only to resurface once they let go.

As students manipulated the diver, they recorded their observations and speculated as to why the dropper sank when pressure was applied to the bottle. Students observed the level of water in the dropper rise as more pressure was applied to the bottle. Most students initially thought that the air left the dropper as they squeezed the bottle, thus causing the dive. We probed students on this by asking them how the air got back into the resurfacing dropper once they let go of the bottle; many were quick to realize they needed a different explanation. After several minutes of observing and discussing, some students began to explain that the increased pressure in the bottle caused the air to compress and the dropper to pull in water and get heavier. This would cause the sinking—and also the resurfacing once the bottle's pressure was released. We chose not to tell students they were correct or incorrect with their explanations; we only questioned and listened to them.

Once students had rotated through each of the centers, the class as a whole discussed their observations, explanations, and questions. Most were quick to explain that heavier things sink while lighter things float. As teachers, we questioned them about the steel spheres that had the same mass but behaved differently in water. We even asked the age-old question "Which weighs more, a pound of feathers or a pound of lead?" Although most students could answer this trick question, many weren't as confident about the two steel spheres, even though we showed the spheres balancing on scales as a class demonstration. Their experience with feeling them and seeing them float/sink caused students to think that the larger, hollow ball was lighter. After allowing students to express their ideas, we then told students that they were going to explore more objects and take measurements to try and better understand what was causing these objects to float or sink.

Explore

Students took measurements of eight objects during this phase, which lasted about 45 minutes, using a new investigation page that allowed them to organize their data and answer questions about their observations. Four objects made of varying amounts of the plastic polypropylene (red) would float, while the other four objects of the same size were made of varying amounts of aluminum (silver) and would sink. (These objects were purchased at a science supply store for about $20 and were part of a larger density set. If teachers have access to solid blocks of plastic and metal, this could easily be substituted.)

Figure 1.

Learning center observation questions.

WOOD:
This wood is from Brazil and is called Lignum Vitae (means "wood of life"). What characteristics does it have in common with wood you are familiar with?

What characteristics does it *not* have in common with wood you are familiar with?

Do you think this wood will float or sink? Why? Test your guess. Does it float?

ROCK:
This rock is called *pumice*. What characteristics does it have in common with the rocks you are familiar with?

What characteristics does it *not* have in common with rocks you are familiar with?

Do you think this wood will float or sink?
Why? Test your guess. Does it float?

STEEL SPHERES:
These two balls are made of the same metal.

Predict if the small one will sink or float.
Predict if the large one will sink or float.

Which of these steel spheres has a greater mass (weighs more)? Why do you think that?

Without using a balance or a scale, how could you figure out which one has a greater mass? Test your ideas if you have time.

DROPPER DIVER:
The 2L bottle has water and a medicine dropper inside it. Squeeze the bottle really hard. What happens?

Closely observe the dropper as you squeeze. What do you notice about the dropper?

Why do you think the dropper sinks when you squeeze the bottle?

First, working in groups of two to four, students recorded and tested predictions on whether each object would sink or float. They then measured the mass and volume of each object and recorded this information on a data table. Some students were able to use displacement to find the volume while others chose to use the formula to calculate the volume (a formula they were working on in math). In addition to the eight objects, students also measured the mass of different amounts of water (5, 10, 15, 20, and 25 mL) using graduated cylinders and balances. Measuring the mass of water was initially a challenge to some until they discovered they could subtract the mass of the cylinder from the mass of the total to get the mass of the water alone.

Finally, each student used the data to create a line graph with three lines—a red polypropylene line, a blue water line, and a black aluminum line. We still did not tell students about density. We wanted them to construct this understanding from the graph and previous experiences.

Explain

In the Explain stage, students began to refine their understanding of mass, volume, and density. Each group created one graph that showed the work of the group and explained how they measured the mass and volume of the objects (displacement and equation). Once every group had presented their graphs, students were asked to explain how the three lines were different and how the lines related to the objects measured. Students easily recognized the black line (aluminum) was the steepest while the red line (polypropylene) was the shallowest; the blue water line was in the middle.

We asked students specifically about how each object felt in comparison to others. We also began to bring the "engage" objects back into the conversation by asking questions such as "How would a line of the steel balls or rock or wood look?" We also encouraged students to look for patterns in the lines/data. Some suggested heavier objects with small volumes would have steep lines while lightweight objects with large volumes would have shallow lines.

Once students began talking about mass and volume in relation to each other, we asked them to explain in their own words what each was. Students began giving ideas and listening to others' ideas about what mass and volume were. We challenged students to give their own examples that would help explain their definition. One girl showed two water bottles of the same volume, explaining that they both occupied the same space and could hold the same amount of water. She then added water to one, explaining how the mass of the object changed but not the volume; in effect it had more weight or "stuff" in it.

The students' explanations of mass and volume allowed us to then try to make sense of the concept of density. We asked students to explain what density was using the terms *mass* and *volume*. This may have been the most challenging part for students because it was applying concepts. Some students talked about density being how much space is left over inside an object, or how much air is inside an object. Although these explanations were on the right track, they still lacked the integration of the concepts of mass and volume. We continually tried to ask questions about the objects they had just worked with; the steel spheres were especially helpful because even though they had the same mass, their volumes were noticeably different. We also referenced the graph in asking how the polypropylene and aluminum could have the same volume but not the same mass. At different points during the discussion, students began expressing and giving examples of how changing the mass of an object but not its volume would change its density, or how changing the volume of an object while keeping the mass the same would change its density. Several students referenced wood or rocks in explaining that those that float have less mass in a certain volume than those that sink.

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In addition to explaining these scientific terms, many students discovered that the location (or *slope*) of the line on the graph indicated whether the object would float or sink; the steeper the line, the more dense the object (more mass in a given volume). By comparing the "water line" on the graph (which represented the density and slope of about 1 g/cm^3 of water) to other data points/lines on the graph, students could predict if an object was a sinker or a floater (sinking objects will have a greater slope/density than water; floating objects will have a smaller slope/density than water). This is true for any "solid" object that has not been shaped to create buoyancy (an aluminum boat will float because it has been formed into a buoyant shape; if just a block of aluminum, it would sink).

Elaborate

Up to this point in the learning cycle, students have had the opportunity to develop a working understanding of mass, volume, and/or density (depending on grade level of students). During the elaboration phase, students apply their understanding to another problem related to the same concepts; this particular phase for this investigation took about 30 minutes and was a good reinforcement of not only the concepts but also the skills of the lesson.

We chose to expand the ideas of mass, volume, and/or density by having students use *new* materials and predict whether the objects would sink or float based on measurements (mass and volume) instead of using "feeling" or "guessing" as was the case in the engage and explore phases of the investigation. In the exploration, students predicted, tested their prediction, and then made measurements. During this phase, students would first make measurements, use those measurements and the graph to predict, and then test their predictions.

Even though we used six different objects—made of oak, maple, copper, PVC, acrylic, and phenolic—teachers could use more or less depending on the level of student.

Many students were quick to realize that by taking the two measurements, mass and volume, they could put a data point on the graph discussed during the explanation phase. For those who didn't see this connection as quickly, group members shared their ideas and explained how the data point would indicate a "sinker" or "floater." The location of the point on the graph would show if the object would float or sink. For example, if you compare 10mL of water against 10mL of aluminum, the water would have a mass of about 10g, while the aluminum would have a mass of about 25g. Because the aluminum has a larger mass to volume ratio (density), it will sink in water. When graphed as a data point, those objects above the "water line" on the graph would sink; those data points below the "water line" would float (a somewhat paradoxical statement for some who viewed objects above the "water line" as being the ones who should float, we made sure to point this out as an apparent discrepancy with the graph).

Evaluate

Throughout the entire investigation, we continually observed and listened to the students. Because the investigation required so many measurements and so much discussion, it was easy to get around to each station and question students about their understanding. In the future, it might be more manageable if there was a premade checklist of skills the students were expected to do/show. In addition to the skills, students were also assessed on their understanding of mass, volume, and/or density by looking over the answers written on the investigation page.

While students were discussing in their small groups and during whole-class discussion, it became apparent which students were deepening their understanding. A majority of students could explain why the maple wood floated in water—students shared that there wasn't as much mass in the wood compared to the same volume of Lignum Vitae.

Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996):

Content Standards

Grades 5–8

Standard B: Physical Science

- Properties and changes of properties in matter

Program Standards

Standard C:

The science program should be coordinated with the mathematics program to enhance student use and understanding of mathematics in the study of science and to improve student understanding of mathematics.

The use of questions was also important to help determine which students were struggling with the investigation. Because the students were working through an investigation page and writing their ideas and thoughts on the page, assessment and evaluation was done during and at the conclusion of the investigation. We had the luxury of doing the investigation over several days, during which time we collected the lab papers, reflected upon and discussed student responses, and analyzed each day's activity. By so doing, we were able to see what things were making sense and address any misconceptions that students still had. We saw after the engagement phase that many students were using the terms *heavy* and *light* to explain why things would sink or float. This allowed us to address this misconception during the explanation, particularly with the steel spheres. We took notes about which students seemed to have developed a deep understanding of the concepts, those who had accurate understanding, and those whose conceptual understanding was still developing.

This investigation, bred from a mathematics lesson on ordering the "weight" of various items, proved to be one that students thoroughly enjoyed. Not only were students investigating questions and thoughts they themselves had thought up, they were also able to explore numerous objects and ideas related to mass, volume, and density. ■

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References

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