

Addressing Misconceptions About Density

In Chapter 5, you read that high school students come to science class with varying conceptions about how the natural world works. Sometimes these prior conceptions align with the universally accepted scientific explanation, and sometimes they don't. When a student holds ideas and notions that are in conflict with the scientific explanation, the ideas are frequently labeled as misconceptions. The term *misconception* may be misleading since the student will probably, in time, change his or her presently held understanding to the scientifically accepted form. Maybe a better label would be naive conceptions or evolving conceptions.

Elementary school students develop an awareness of density years before the topic is taught in middle or high school. Young children develop this understanding from their everyday observations and experiences. A child may notice that two balls can be the same size, yet one is heavier than the other. Such is the case when playing with a Styrofoam ball and a baseball of the same size. However, those same observations and experiences can generate many prior misconceptions about density as well. When 9th graders enter high school, some may hold several misconceptions about density. Here are some examples:

- "An object, such as a boat, floats because water is pushing up on it."
- "The weight of an object determines if it will sink or float. Heavy objects always sink, and light objects always float."
- "Objects with holes in it will sink. Except for a sponge. That's the only exception."
- "The smaller something is, the less density it has. So smaller objects are less dense than larger objects."
- "If you cut a piece of wood in half, the density of each piece is now half of the original piece."
- "Density is the thickness of something. Chocolate syrup is very dense because it's so thick and takes time to pour."
- "Oil weighs less than water. That's why when an oil spill occurs, the oil floats on top of the water."
- "Wood and plastic objects float. Metal objects sink."
- "If you take a ball of clay and add more clay to it, the ball will get larger and the density will increase."
- "Elements with a higher atomic number are denser than elements with a lower number."

If students are to understand the concept of density and, in many cases, give up their stubbornly held prior misconceptions, teachers should know that in spite of giving an in-depth lecture on density, the authority of the teacher is not enough to change students' misconceptions. What research says is more effective is providing students with engaging and motivating opportunities that challenge their presently held conceptions. We will see how inquiry plays an important role in helping students give up their misconceptions and adopt a scientifically accepted understanding.

Scaffolding Toward Inquiry

The transfer of responsibility for learning takes prudent planning. As the ownership of the task shifts from the teacher to the student, we need to be exceedingly clear about the purpose of the learning activity. Teachers do this by communicating desired expectations

and learning objectives, as well as the accountability for success. These objectives become embedded within the inquiry experience. Once we know how to scaffold investigations from more teacher directed to more student centered, we move students along the continuum toward self-directed discovery. Let's now see ways teachers can use the various approaches to inquiry to help students develop sound understanding of density and become proprietors of their learning.

Demonstrated Inquiries

As said before, a new unit can often begin with a demonstrated inquiry that ends in a discrepancy between what the student thought would happen and what actually did. These discrepant events provide a cognitive hook to engage the class at the start of the unit. The following are several demonstrated inquiries that can be used to introduce a unit of density.

Ice in an Unknown Liquid

Get two large clear plastic tumblers. From a separate container filled with water and labeled "Liquid A," fill one tumbler two-thirds of the way with Liquid A and set it aside. From a separate container filled with 70% isopropyl alcohol (IPA) and labeled "Liquid B," fill the second tumbler two-thirds of the way with Liquid B. Do not tell students what the liquids are. Place an ice cube in each of the tumblers. Ask students to share their observations and questions. Why is one ice cube floating and the other sinking? Is there a difference in the ice cubes? Is there a difference in the liquids? What is the density of the ice cube? What is the density of Liquid A and Liquid B compared to the density of the ice cube? What would you expect to happen to the ice cube if you mixed Liquid A and Liquid B together? What would happen if you placed the ice cube in a tumbler of concentrated salt water? What would happen if you place the ice cube in a tumbler of 90% IPA? (Note that some drug stores sell both 70% and 90% IPA).

Golf Ball in a Graduated Cylinder

Get a large graduated cylinder about 500 to 1,000 mL and wide enough to fit a golf ball inside it. Prepare a saturated salt solution using kosher salt flakes. Kosher salt flakes are good to use since they dissolve easily in water. Fill the graduated cylinder about one-third full with the salt solution. Now tilt the graduated cylinder on an angle and slide a golf ball (preferably a yellow or pink one) down the side of the cylinder. When you place the cylinder upright, the golf ball should float on top of the salt solution. If it doesn't, increase the concentration of salt in the solution and try again. With the ball floating on top of the salt solution, again tilt the cylinder on a side and slowly and carefully pour water down the side. Add enough water to equal the amount of salt solution. Place the cylinder upright and the golf ball should appear to be floating in the middle of the graduated cylinder. Because the solutions are immiscible, the students will not be able to see the division between the salt solution and the water. Ask students to share their observations and questions. Why is the golf ball floating in the middle of the graduated cylinder? What do you know about the density of the golf ball compared to the density of clear solution? Ask if any of the students play golf. What happens when they hit a golf ball in the water? Where does the golf ball go? Students will ask if the golf ball is a fake. Tell them it's a regular golf ball and nothing is tricky about it. Urge students to make speculations and

assumptions about the phenomenon. Encourage them to provide supporting evidence for their accusations.

Coke/Diet Coke and Smaller Sizes

Many teachers have done the classic Coca-Cola/Diet Coke demonstration in their classes (Galus, 2003). Students always seem to engage with the discrepancy. To add a new twist to the activity, consider adding another variable that can enhance students' understanding of density. Begin the activity in the usual way. Fill a 10-gallon aquarium with warm tap water and place it in full view of the class. Hold up a can of regular Coke and ask students to predict what will happen when you place the can in the water. Before you place the can in the water, have students provide reasons for their predictions. Are all the predictions the same? How many students think it will float? How many think it will sink? Place the can of Coke in the water and observe the results. Whose prediction was correct? Now repeat the activity with a can of Diet Coke. Again have the students made a prediction before you place it in the water. Allow time for students to provide an explanation for the phenomenon. Many may know that the regular Coke is sweetened with corn syrup, which is much denser than artificial sweeteners such as aspartame. Next, repeat the activity using regular Coke with caffeine versus regular Coke without caffeine. Then try Diet Coke with caffeine versus Diet Coke without caffeine. Does the presence of caffeine alter the results? Why or why not? To challenge their understanding of density, repeat the demonstration using a 12-ounce size regular Coke with a smaller 7.5-ounce size. Are there some students that think the larger size will again sink but the smaller size will float? If so, have both sides present their prediction with supportive evidence and reasoning. Since most students have little experience with the smaller size cans, they will probably make a prediction based on similar understandings or on faulty reasoning. Think about how difficult it is for some students to undergo a conceptual change, even in light of observational evidence. Teachers can take this activity further by comparing similar cans of Coke and Pepsi. Or Diet Coke versus Coke Zero. Or Coke versus 7-Up, root beer, or orange soda. And if your school would allow such a demonstration, you can also test Bud versus Bud Lite! Just tell your principal it's in the interest of science.

Structured Inquiries

The traditional lab that was introduced a few pages back can serve as a basis for a structured inquiry. With some simple modifications, the lab can encourage more ownership on the part of the student and offer follow-up inquiries to investigate at its end. Consider first introducing the lesson with a discrepant event from the previous section. Then prompt students to design an investigation on how they might measure the densities of various rocks. The standard lab can also become more student centered by eliminating the data table and having students design their own method of recording and organizing the data collected. The lab can also have "going further" questions or guided inquiries as a follow-up. One example may include having students sequence the densities of five unknown rocks (this time including igneous rocks) and minerals from least to greatest density. Students can then use rock and mineral guides to identify the type and name of each of the unknown samples.

Guided Inquiries

Guided inquiries offer fewer directions for students. The example below shows one way the traditional rock lab (from above) can be modified into a guided inquiry.

Purpose

Measuring density is a basic science skill that cuts across all science subject areas: biology, earth science, chemistry, and physics. In this lab, you will calculate the densities of several unknown rocks samples and then use their densities and physical characteristics to determine each rock's type and name.

Question

How does the density of sedimentary rocks compare to that of metamorphic rocks?

Investigation

Use the text resources in the room and the Internet to find out how density is measured. Obtain a means to measure the density of an irregular shaped object, such as a rock. Decide what kinds of measurements you need to take to calculate the density of each rock sample. Also decide the kinds of materials and equipment you will need to make such measurements. Make a list of the supplies and equipment you will need. Then, design a procedure to calculate the density. Include any safety rules you will need to follow. Design a data table and make all notations and recordings in your science journal. Show all work for the calculations in your journal. Have the teacher approve the procedure before beginning.

Analysis

1. What is the density for each rock sample you measured?
2. From the density, color, and other observable characteristics, use a rock identification guide to classify the type (sedimentary or metamorphic) and name of each rock sample.
3. How did the densities of the sedimentary rock samples compare to the metamorphic rock samples?
4. Knowing that sedimentary rock can be transformed into metamorphic rock through intense heat and pressure, how could this account for the difference in densities between sedimentary and metamorphic rocks?

Now It's Your Turn

Using the example above, choose one or more of the following science areas and write a guided inquiry based on the application of density to that area of science. Include the purpose of the inquiry, the question to be investigated, suggestions to help the student design the investigation, and several follow-up questions to assist in the analysis of the findings. After you write your inquiry, share it with a colleague.

General Science

1. Write a guided inquiry where a student calculates and compares the densities of five different 1-inch balls (Styrofoam, rubber, wooden, glass [marble], and steel balls).
2. Write a guided inquiry where the student discovers how the concentration of salt in water affects its density. Use swimming in the Great Salt Lake as one example.

3. Write a guided inquiry where the student demonstrates how a life jacket saves someone from drowning.
4. Write a guided inquiry where the student investigates the question: Does the peel (or skin) of a fruit affect its density and ultimately whether it will sink or float? Use a banana, orange, grape, apple, kiwi, and so forth as examples.
5. Write a guided inquiry where the student measures the density of a whole 3 Musketeers candy bar. Then have the student cut the bar in half and make a prediction whether the density of the half pieces will increase, decrease, or remain the same. The student should provide supporting evidence to determine whether the prediction was correct or not.

Biology

1. Write a guided inquiry where the student determines the population density of an ecosystem for a specific species (plant or animal).
2. Write a guided inquiry where the student describes the human population growth rate and its impact on the population density of several highly populated countries in the world.

Earth Science

1. Write a guided inquiry where the student is given 10 rocks and the task of sequencing the samples from the least to the most dense.
2. Write a guided inquiry where the student investigates the relationship between air pressure and density. Include an explanation about what happens to the density of air as the elevation or altitude increases.

Environmental Science

1. Write a guided inquiry where the student simulates an oil spill in water and compares the densities of the two liquids. Relate the information to recent oil spills and to cleanup and recovery efforts.

Chemistry

1. Write a guided inquiry where the student compares the densities of different gases such as air, helium, carbon dioxide, and propane. Prompt the student to fill balloons with an equal amount of each gas and compare differences.

Physics

1. Write a guided inquiry where the student calculates and compares the densities of solids. Suggest that the student use different types of wood (balsa, cedar, pine, maple, and walnut).
2. Write a guided inquiry where the student calculates and compares the densities of liquids by pouring different liquids of different densities down a graduated cylinder. Liquid layers can be formed using corn oil, water, glycerin, and corn syrup.

Suggest that the student carefully drop several solid objects in the cylinder and see at which level they rest. Solid objects can include a steel bolt, a rubber stopper, a piece of plastic, and a small block of wood.

Self-Directed Inquiries

For self-directed or student-initiated inquiries, we now understand that the source of the question comes from the student. This is considered the uppermost level of inquiry since the ownership of the question is derived from and planned by the student. According to Hermann and Miranda (2010), with the help of encouragement from teachers, students can learn to formulate and carry out their own science investigations. By using an Inquiry Question Template, students learn to independently construct a question to investigate, design a procedure to test the question, and analyze the data collected during the inquiry. Hermann and Miranda (2010) divide their 15-step template into three parts: the prelab questions, the research question, and the experiment.

Step 1: During the prelab, the student observes a phenomenon and responds to the following questions and tasks:

1. List several observations and inferences that can be made from the phenomenon you observed.
2. From the observations and inferences you recorded, what variables can be identified and tested?
3. From the variables recorded from Step 2, choose one variable (the independent variable) to test.
4. Decide how you would measure the independent variable you choose.
5. What factors (the dependent variables) could be affected by the independent variable? Choose one dependent variable to include in your investigation.
6. Decide how you would measure the dependent variable.
7. What materials will you need to test the variables selected?

Step 2: During the formation of the researchable question, the student completes the following task:

1. Based on the variables selected in the prelab, write a question you can test. Include the independent and dependent variables in your response.

Step 3: During the formation of the experiment, the student completes the following questions and tasks:

1. Write the steps you will follow in conducting the experiment.
2. Gather the materials needed to complete the experiment.
3. Make a data table to record and organize the results of your experiment.
4. Plot a graph that shows the relationship between the independent and dependent variables.