A Dastardly Density Deed

by Mike Shaw

A good storyline used in conjunction with a classroom science activity piques curiosity, generates enthusiasm, and promotes long-term learning. I use a story about a burglary of a million-dollar necklace to enliven a lesson involving different densities of liquids. This activity (page 20) has never failed to generate excitement among my middle level students as they assume the role of detectives to determine who pulled off the heist.

After students read the story of the bungling burglars, they are given the task of layering three different colored liquids—red, blue, and yellow—in a graduated cylinder. With a bit of trial and error, students will be able to successfully layer the liquids. The sequence of the liquids in the cylinder is the evidence they need to determine which burglar made off with the diamond necklace.

Follow up and extensions

After the students have completed the activity, I reinforce the concept that liquids have different densities by giving students more practice making density calculations, I provide them with several mystery samples of liquids, pipettes, graduated cylinders, and a pan balance and ask them to determine the density of each sample. Once they have determined the densities of the samples, they consult a table (Figure 1) to identify the mystery liquids. As a safety precaution, I avoid using the methyl alcohol, kerosene, or benzene as the mystery liquids. Corn oil, distilled water, and glycerin provide a nice range of densities.

As a follow-up, I set out a variety of colored liquids (Figure 2) in labeled beakers and challenge students to predict the layering sequence the liquids would settle into if they were added to a graduated cylinder. To do so, they must first determine the density of each liquid. Then, they can add the liquids to the cylinder to test their predictions. Have each group add the liquids to the cylinder in a different sequence. Students will be surprised to see that the liquids will layer themselves the same way regardless of the order that they were added to the cylinder.

Conclusion

This activity shows students how the mass-to-volume ratio of a liquid determines its density. As they see the mass change while the volume remains constant, they begin to understand why the density increases. To analyze the data, students perform mathematical calculations, compare and contrast different liquids, and make accurate measurements. Participating in this hands-on, exploratory investigation, allows students to use a trial-and-error approach that stimulates their thinking and leads to long-term retention of learning. Activities such as this one successfully create interest, engage attention, promote involvement, and focus students' thinking. ■

Mike Shaw *is a science teacher at West Stokes High School in King, North Carolina.*

STUDENT MISCONCEPTIONS: DENSITY

In my secondary science methods course, the week following our discussion on student science misconceptions, a student shared that his wife's kinesiology professor had told the class that "a pound of muscle is *heavier* than a pound of fat." In a general science textbook, the students are presented with an activity which begins with the question, "If you had several solids and a container of water, what will you do to determine whether a solid is 'heavier or lighter' than water?" These examples illustrate how classroom and textbook presentations may either reinforce students' naïve conceptions, or lead to new misconceptions being adopted. Obviously, misconceptions about density abound at all levels.

Many students have difficulty distinguishing between mass, weight, and density. In individual interviews with a group of ninth graders, the majority of them told us that a folded piece of aluminum foil weighs more than an unfolded piece of the same initial size. Some high school and college students showed a more sophisticated understanding of the concepts of density and buoyancy, however the major distinction was their ability to use more sophisticated terminology, but still they lacked the understanding.

SCILINKS THE WORLD'S A CLICK AWAY

Learn more about density at *www.scilinks.org*. Enter code SS010302.

Many students reject explanations that are in conflict with their beliefs. In this context, things are compared as "heavier" or "lighter." They opt to retain a misconception that makes sense to them, rather than struggle to accommodate a new idea. Among factors that contribute to students either retaining their misconceptions or adding to them are innate feelings, and the lack of context or meaningful examples.

Density is an abstract concept. Because many of our students are at the concrete operational level, understanding may not develop unless teachers make deliberate use of concrete materials and simplify the concepts. Students may be able to give formulas and definitions, and teachers may accept that as a sign of understanding; but many students have difficulty applying these principles when asked to predict (and support their predictions) whether or not something will float or sink in water.

Joseph Stepans *is a professor of secondary education in the College of Education at the University of Wyoming in Laramie where he conducts research on student misconceptions in mathematics and science.*

Teaching to The Standards

The National Science Education Standards emphasize that all students be afforded the opportunity to utilize scientific inquiry in order to promote the self-development of critical-thinking skills. This activity uses a small-group environment and engaging story to serve as a framework within which thinking and learning occur. It addresses and encourages the development of those skills by incorporating the following research findings based upon science standards:

- Students are most productive when they feel a sense of curiosity about the questions they investigate.
- Students creatively solve problems and display their enjoyment of the inquiry process when they participate in meaningful activities.
- Students working in small groups develop confidence when they are afforded equal opportunity to participate in key roles such as planners, leaders, data collectors, and recorders.
- Students who are allowed to spend sufficient time in forming their own reasons for how the activity works as part of a developmental process, and who are given adequate time to reflect upon what they have discovered, are likely to retain the information for significantly longer periods of time.

FIGURE 1 **Table of densities**

Liquid	Density (g/mL)
Methyl alcohol	0.79
Kerosene	0.82
Benzene	0.90
Corn oil	0.93
Distilled water	1.00
Sea water	1.03
Unsaturated salt water	1.12
Saturated salt water	1.16
Glycerin	1.26
Corn syrup	1.38

FIGURE 2 **Liquids for layering activity**

Liquid	Density (g/mL)
corn syrup mixed with blue food coloring	1.38
glycerin mixed with red food coloring	1.26
salt water mixed with yellow food coloring	1.16
distilled water	1.00
corn oil	0.93
isopropyl alcohol with green food coloring	0.86

Who committed the dastardly density deed?

Teacher preparation and notes for activity

When conducting this investigation, I intentionally avoid making the red-colored liquid the densest because many of the students will pour it into the test tube first, anticipating that the burglar will be caught "red-handed." Comparing the color sequence in the tube that produces layering to the hand color of the crooks leads students to conclude correctly that cowardly Curly reached only into the yellow layer, Agar only into the red, but bold Bubba braved the blue to bring up the necklace. Your student detectives will be neither deterred nor deceived as they present proof based upon the density dependent depths of the liquids.

Materials

- three 1000 mL beakers
- 500 g kosher salt
- food coloring (yellow, red, blue)
- distilled water

Procedure

1. Add 1000 mL of distilled water to a 1000 mL beaker. Add 30 drops of yellow food coloring. Stir to dissolve. This creates a solution with a density of approximately 1.00 g/mL.
2. Add 950 mL of water to a second beaker. Add 30 drops of red food coloring. Add 200 grams of kosher salt. Stir to dissolve. This creates a solution with a density of approximately 1.12 g/mL.
3. Add 925 mL of water to a third beaker. Add 30 drops of blue food coloring. Add 300 grams of kosher salt. Not all the salt will dissolve because this will be a saturated solution. This creates a solution with a density of approximately 1.16 g/mL.
4. Place these liquids in a centrally located station in your classroom.

The crime

Three bungling would-be burglars named Agar, Bubba, and Curly decided to relieve a wealthy socialite, Mrs. Rollinginit, of her most valuable possession, a diamond necklace. After a brief stakeout, the trio entered her home while she was out. Unknowingly, of course, they tripped a silent alarm upon entry. The three located and unlocked the safe, from which they carefully removed a tall, clear canister containing three layers of colorless liquid.

Peering downward into the vessel, they saw the exquisite necklace sparkling on the bottom. The leader of the trio designated one of the others to reach down and snatch the necklace from its liquid bondage. The burglar, trembling with fear, managed to reach only into the first level of liquid before rapidly retracting his hand. Furious, the leader screamed for the second burglar to grab the priceless prize. The second would-be thief, shaking like a leaf, reached down as far as the second liquid layer before hastily pulling back his hand. The boldest burglar, giving up on his two timid cohorts, plunged his hand down to the bottom of the container and triumphantly withdrew the necklace.

At this instant, they heard the distant wail of a siren and stampeded from the house. As they were racing across the front lawn, a patrol car rounded the corner, freezing Agar, Bubba, and Curly in their tracks. As the officer approached, they raised their hands in the air and surrendered. The diamond necklace was also recovered on the lawn where one of the thieves had dropped it. It is now up to the police to determine which thief had actually snatched the necklace from the bottom of the canister.

At the station, the three were required to hold their hands under a special light that caused the liquids found in the container to glow different colors. Agar's hand was coated in a liquid that glowed red. Bubba's hand was coated in a liquid that glowed blue, and Curly's hand was coated in a liquid that glowed yellow. Fortunately, any liquid picked up in a higher layer of the canister was washed off in the next deeper layer, so the crime lab scientists were certain they could determine who reached into the bottom of the canister.

The crime lab separated the liquids from Mrs. Rollinginit's canister and added dye to indicate the color that they glowed under the light, but carelessly forgot to record the order in which the liquids were layered. Your job is to re-layer the liquids in the canister in the proper sequence to determine which thief stuck his hand all the way to the bottom to retrieve the necklace. That person will be charged with first-degree burglary while the remaining two will be charged as primary and secondary accomplices. Submit your evidence to the District Attorney, who will charge the criminals according to their degree of dastardliness.

Purpose

To determine which burglar—Agar, Bubba, or Curly—reached into the bottom of a canister to steal Mrs. Rollinginit's diamond necklace. You will do this by combining three different-colored liquids in the proper sequence so that no mixing occurs.

Materials

- 1 empty styrofoam egg carton
- 4 small plastic or glass test tubes
- 3 large pipettes (7–10 mL)
- 1 small pipette (1.0–1.5 mL)
- safety goggles
- small plastic cup capable of holding 5 mL of liquid
- pan balance or electronic balance

Procedure

1. Use a pencil or pen to create four holes in the lid of the egg cartons sufficient to accommodate the diameter of the test tubes. Insert four small test tubes into the egg carton (or test tube rack), placing them in an upright, vertical position.
2. When your teacher calls your group, bring your test tubes, rack, and pipettes to the station where the three colored liquids are being stored.
3. Using your large pipette, add 5 mL of yellow liquid to the first test tube.
4. Repeat step 3 using a clean pipette to add 5 mL of red liquid to the second test tube.
5. Repeat step 3 using a clean pipette to add 5 mL of blue liquid to the third test tube.
6. Now, carefully and slowly, use your small pipette to add 1.5 mL of each of these three liquids (approximately one-third of each test tube), one at a time, to the fourth test tube. Drizzle the liquids down the inside wall of the test tube to facilitate layering.
7. Examine the test tube to see if the liquids formed three distinct layers. If not, clean out the mixture and repeat step 6, but add the colored liquids in a different order. Continue experimenting with the liquids until they remain in distinct layers in the test tube.
8. When you determine the correct layering sequence, deduce which of the burglars should be charged with the most serious crime using the chart below.

Safety note

EYE PROTECTION

During this lab you will need to wear safety goggles at all times. Clean up any spills immediately. Do not taste anything during the lab.

Burglar	Layer reached (top, middle, bottom)	Criminal charge (first-degree burglary or accomplice)
Agar		
Bubba		
Curly		

Questions

1. List the correct sequence, beginning with the top layer.
2. Describe the appearance of the contents of the three tubes containing the red, blue, and yellow liquids. Use physical properties such as color, volume, and state. Recall that these types of observations are referred to as qualitative. They do not include a __________ in their description.
3. Other than color, what are the differences among the contents of the three tubes?
4. Determine the mass of a clean small cup using a pan balance. Then fill it with 5 mL of the yellow liquid and determine the mass of the cup and liquid. Finally, subtract the mass of the cup from the mass of the cup and liquid to determine the mass of the liquid alone. (For example, Mass of cup: 5 grams. Mass of cup and liquid: 9 grams. Mass of liquid: 9 g – 5 g = 4 g.) Repeat these steps for each of the other two liquids and fill out the chart below.

Materials	Mass (g)
Empty cup	
Cup and yellow liquid	
Yellow liquid	
Cup and red liquid	
Red liquid	
Cup and blue liquid	
Blue liquid	

5. You have just determined the _____________ for each of the three liquids. Are these quantities the same for each liquid?
   Did you mass equal volumes for each of the liquids? If the mass of each liquid is different for equal volumes, what is your explanation for the difference?
6. What term describes the relationship between the mass and volume of a liquid?
7. Examine your mass-to-volume ratio for the yellow liquid. It is _______/_______.
8. Fill in the chart below. Be sure to include your density units.

Liquid	Density
Yellow	
Red	
Blue	

9. Do the liquids used in this investigation have the same or different densities?
10. In your opinion, why does each colored liquid have a different mass for its volume?
11. If you place three liquids of different densities into a test tube, where will they go in relation to one another? Why do the liquids behave in this manner?