Summary
In this activity, students investigate how mass, volume, and shape affect the density of an object and its ability to sink or float in order to design a model water column with fish swimming at various depths.

Time Needed
Preparation: 20–30 minutes
Activity Time: one 1-hour class period
Analysis Time: one 1-hour class period
Extension: one 1-hour class period, plus preparation time to procure additional materials

Objectives
After completing the activity and participating in discussion, students will be able to:

- Ask a valid testable question about density.
- Make a valid hypothesis about the effects of changing one variable on buoyancy and how that relates to density.
- Test a single variable (mass, volume, or shape) while keeping all other variables constant.
- Make accurate qualitative and quantitative observations about density.
- Explain how at least one variable (mass, volume, or shape) affects density and the ability of an object to float in water.
- Relate the results of the investigation to a model water column and propose a design that allows fish to “swim” at various depths.
- Identify problems with the investigation and propose modifications to improve the investigation.

Materials List (total for all groups)

- six large buckets or deep plastic basins filled with tap water
- six sealable, watertight plastic containers, same size (plastic food containers work well)
- six sealable, watertight plastic containers, various sizes; all should fit easily into the bucket (Note: important to use very light containers so that the difference in mass will be minimal)
- about ten pounds of sand (Note: any other grainy solid, e.g., salt, sugar, or rice, will work)
- four large bowls (big enough to hold about two cups of sand each)
- four plastic scoops or one-cup measuring cups
- two packages molding clay (approximately one pound each)
- two dozen small twigs, popsicle sticks, or breakable pieces of wood
- six large, thick rubber bands or string (to hold together broken pieces of wood)
- six towels or enough paper towels for six groups
- mass balance or scale for demonstration
• large plastic sheet or tarp if doing the lab in a regular classroom
• Student Planning, Record Sheets, and Analysis Sheets

Preparation
Decide how many groups you will have. Ideally, there are 2–4 students in each group. There should be at least two groups investigating each variable.

1. Separate same-sized plastic containers into two groups of three containers each.
2. Separate different-sized plastic containers into two groups of three containers each.
3. Pour about one cup of sand into each of the four bowls.
4. Fill buckets or basins with water.
5. Set up workstations:
   a. Four workstations with a bucket of water, a towel, a bowl of sand, a scoop or measuring cup, and either three same-sized containers or three different-sized containers
   b. Two workstations with a bucket of water, a towel, and a package of molding clay

Background Information for Teachers
Students have had experience with differences in density, and most can recognize whether or not two different objects have different densities, but many mistake these differences for differences in weight. A rock feels heavier than a piece of plastic foam that is actually the same weight because the rock is denser. Density is related to the mass and volume of an object. It is a measure of how compact something is, or how closely packed the molecules are. Materials with closely packed molecules are denser than materials with loosely packed molecules. The density of an object is calculated by dividing its mass by its volume (density = mass ÷ volume). For example, 10 kilograms of feathers and 10 kilograms of bricks both have a mass of 10 kilograms and weigh about 22 pounds (on Earth), but 10 kilograms of bricks is more compact (has less volume) than 10 kilograms of feathers and therefore bricks have a greater density than feathers. Because density is an intrinsic property of many materials (it does not depend on the material’s shape or size), it can be used to help distinguish between objects and materials that have similar appearances. Gold, for example, is nearly four times denser than pyrite (fool’s gold). Gold feels heavier than pyrite because it is denser.

An object’s density affects its buoyancy and how well it will float or sink. Buoyancy also depends on the density of the liquid. Mass is generally measured in grams and volume in cubic centimeters, so the standard measurement for density is grams per cubic centimeter (g/cm³). Pure water has a density of 1 g/cm³. If an object’s density is greater than 1 g/cm³, it will sink in water. Conversely, if its density is less than 1 g/cm³, it will float. Objects that have a density of 1 g/cm³ are neutrally buoyant, meaning that they neither sink nor float but remain suspended in pure water. In this lab, students will be using buoyancy as a relative measure of density.
Engage
Read the following scenario aloud to the students while they follow along. Discuss the scenario with students and have them take notes on their handouts. (Note: if a similar actual scenario that students can relate to exists, present that instead.)

### Sink or Swim

*A research scientist is studying fish that live at various depths in the ocean. She is researching fish that live near the ocean’s surface, in the middle depths, and on the seafloor. To support her research, she needs to build a model that shows fish swimming at different levels in the ocean. In her model, some fish will need to sink to the bottom, some will need to float near the top, and some will have to “swim” in the middle of the water. How can she decide which objects to use for model fish at each different level? How can she figure out which will sink, float, or stay right in the middle of the water?*

Introduce the term *density* and explore what it means in a qualitative sense. Explain that denser objects feel heavier than less dense objects because they are more compact. Show students a piece of Styrofoam or plastic and a piece of wood or rock that have the same mass (you will have to weigh these beforehand). Pass them around the room and ask the students which object is heavier. Chances are they might think the rock/wood is heavier. Then weight both objects in front of the class to show them that they actually have the same mass. Explain that the reason the rock/wood feels heavier is because it is denser. For more advanced students, you may want to explain that an object’s density depends on its mass and volume and introduce the equation (density = mass ÷ volume). For the purposes of this activity, students will be observing relative mass and volume (more or less dense than pure water) rather than making absolute measurements. Explain the difference between relative and absolute (calculated) density. In the case of the model fish, the objects the scientist uses will have to vary in density so that they sink, float, or suspend at different depths in the water column. Tell students that objects that have a density less than that of water will float in water, objects that have a density greater than that of water will sink in water, and objects that have a density equal to that of water will neither float nor sink but suspend themselves somewhere in the middle (this is called neutral buoyancy.) From this, they will be able to infer the density of their test objects relative to the density of water.

**Assess Preconceptions and Activate Prior Knowledge:** Ask students what they already know about density and have them describe examples of relative density they have witnessed or experienced. This may be a difficult concept, so provide some examples to get them thinking. Have they ever used a kickboard, inner tube, or life jacket while swimming? Perhaps they have thrown stones into a river or a pond and watched them sink immediately. Or maybe they have noticed that when they add oil to water, the oil rises back up to the top. Ask them to hypothesize about why some objects float and some sink. Finally, ask the students if they have any questions about density, but don’t give away answers that will be addressed during the activity. Write these questions on chart paper or a board for latter reference. Let them discover the answers for themselves through investigation.
Introduce the Activity

Explain that each group will be investigating how a single variable—mass, volume, or shape—affects the density of an object. They will explore how density relates to the buoyancy of the object, or its ability to float in pure water. Discuss the concept of a fair test and make sure students understand that to accurately test the effect of a single variable, everything else must remain constant during the experiment.

Explore

Hand out the Student Planning Sheet and Student Data Sheet for “Sink or Swim” to each student. Review both sections carefully with the class, asking for questions, allowing time to complete the Planning Sheet, and discussing responses with students individually.

Demonstrate the procedures below, modeling how and where students are to make and record their observations. Use one of the workstations for the demonstration. Depending on which variable the students are investigating (mass, volume, or shape), they will follow slightly different procedures. To save time, demonstrate each procedure using only one container or shape. Have students work in groups of 2–4. If possible, assign at least two groups to investigate each variable. Since the procedures are slightly different, to avoid confusion remind each group which variable they are investigating. Less-Structured Option: Let groups figure out which variable they are testing based on which materials they find at their workstations. Have students complete the Student Planning Sheet to help them get started with the investigation.

Have students divide up roles: for example, one student measures sand and fills containers, one student places the container in the bucket, and another student records the results on the data sheet. All members of the group should make observations. After each group has investigated their assigned variable, have students switch stations and experiment with a different variable.

Variable: Mass

1. Use the measuring cup to scoop some sand from the bowl into each of the same-size containers.
2. Put different amounts (masses) in each container. For example, make one container full, one container empty, and one container somewhere in between.
3. Seal the containers.
4. Place a single container in the water and observe the results. Repeat for each of the three containers.
5. Record the results in the student data sheet. Relative masses are okay, such as heavy, medium, or light.
6. Experiment with changing the mass. Figure out how much is required to achieve neutral buoyancy, the minimum amount required for the container to sink to the bottom, the maximum amount allowed for the container to remain floating, etc.

Variable: Volume

1. Use the measuring cup to scoop the same amount of sand from the bowl into each of the different-size containers. Structured Option: Instruct students how much to use or fill containers beforehand. Less-Structured Option: Let students decide the amount they will
use based on the size range of the containers. (Note: Explain to students that because the containers are different sizes, they actually have very slightly different masses. Make sure they understand that, technically, each container should have identical mass in order to keep that variable constant. But because they are all are very light and close in mass, for the purposes of this experiment, they can be treated to have the same mass.) Seal the containers.

2. Place a single container in the water and observe the results. Repeat for each of the three containers.

3. Record the results in the student data sheet. Relative volumes are okay, such as large, medium, and small.

4. Experiment with changing the mass—making sure to change it in all the containers—and observing how that may change the results. Can you find the mass of sand that will make an individual container neutrally buoyant?

Variable: Shape
Note: Some groups can experiment with clay while some experiment with sticks, or each shape-investigating group can try both.

1. Mold the clay into a shape such as square, sphere, or cylinder.
2. Place the clay shape or stick in the water and observe and record the results.
3. If investigating clay, gently pat it dry and remold into a different shape.
4. Repeat steps 1–3, experimenting with a variety of clay shapes.
5. Repeat steps 1–3, experimenting with whole sticks and stick pieces bound together with string or rubber band so they have the same mass as the whole stick but are a different shape.

As students are conducting their investigations, make sure each group is doing the following, providing support where necessary:

- testing a single variable, holding other conditions constant
- collecting and recording data accurately (allowing objects to sink or float without pushing on them or influencing them)
- making qualitative as well as quantitative observations (when the container was half full, it sank at first but then floated about halfway to the bottom) and recording data on the Student Record Sheet
- making observations regarding the design of the investigation as well as the results of the investigation (is water getting into the containers?)
- thinking about how the investigation relates to ways to make model fish “swim” at different depths (fish could be constructed out of objects with different densities)
Explain

1. Have groups review their data and spend some time discussing the results.
   - How did changing the mass change how the object floated? How did changing the volume or shape change it? (the more mass, the quicker the container sank; changing shape had no effect on buoyancy)
   - Why does an empty container float? (The container is not really empty. It contains air, which has mass, but is not as dense as water. A container of air has less mass than a container of water.
   - What causes a container to neither sink nor float but stay in between? (when its density is the same as the density of water)
   - Does changing the shape of an object change its density? Why or why not? (no, because mass and volume remain the same regardless of shape)
   - Have students use what they learned to complete the Student Analysis Sheet.

2. Bring the class back together so that they can share and explain their results with the entire class. Pose and discuss the above questions to the class. Students should refer to their Student Record Sheets and support their claims with data and observations. Refer back to the questions students posed earlier that were recorded on chart paper or the board.

3. **Apply to the Problem:** Read the scenario to the class again.
   - Have students apply what they learned to the design of the model fish (e.g., that they can simulate fish “swimming” at three different depths by building model fish of three different densities).
   - Have students suggest ways to design the fish so they have different densities (they can be the same size but have different masses, they can be different sizes but have the same mass).

Elaborate/Extend

Try the investigation using salt water instead of freshwater. Investigate a single variable in a tub of salt water and compare the results to the same variable in freshwater. Students should conclude that objects of a given density are more buoyant in salt water than in freshwater. If the density of the object remains the same, why does buoyancy change? Students should think about how the density of the water has changed with the addition of salt. Results will probably be subtle, so students will have to pay close attention to differences.

You may also want to extend the lab by having students make quantitative measurements of mass and volume and then actually calculate density. Use a balance to measure mass. To measure the volume of an object, use the displacement method. (The displacement method involves completely filling an open container with water, submersing the object completely under the water, catching the overflow water, then measuring the amount of water displaced. The volume of water displaced is the same as the volume of the object.)
Evaluate

1. Have students evaluate their investigation.
   - Did the investigation help them understand why some things sink and others float?
   - What about the experimental design worked well? What didn’t work well? How might they change the design in the future? (For example, containers might not be watertight enough.) What didn’t the investigation tell them? What other variables could they test? (different materials, more shapes and sizes, different liquids, liquids instead of solids)

2. Use the Rubric to evaluate students’ progress toward achieving the objectives of the lesson.

Rubric

<table>
<thead>
<tr>
<th>Objective</th>
<th>Full Credit</th>
<th>Partial Credit</th>
<th>No Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IN GENERAL</strong></td>
<td>Mastery</td>
<td>Partial Mastery</td>
<td>Little or No Mastery</td>
</tr>
</tbody>
</table>

Ask a valid testable question about density.
- Student came up with a valid testable question related to density.
- Student’s question was not entirely testable or was not directly related to density.
- Student’s question was not testable or related to density at all, OR student did not pose a question

Make a valid hypothesis about the effects of one variable on density.
- Student’s hypothesis was reasonable based on the question and on prior knowledge.
- Student’s hypothesis was related to the question, but not entirely reasonable (did not demonstrate careful thought).
- Hypothesis had no bearing on the question and/or was wholly unreasonable given background knowledge OR student made no attempt.

Test a single variable (mass, volume, or shape) while keeping all other conditions constant.
- Student kept all conditions constant (as much as reasonably possible) while testing a single variable.
- Student tested a single variable, but did not always remember to keep other conditions constant.
- Student consistently varied more than one condition and did not show an understanding of the importance of controlled variables.
<table>
<thead>
<tr>
<th>Objective</th>
<th>Full Credit</th>
<th>Partial Credit</th>
<th>No Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make accurate qualitative and quantitative observations about density.</td>
<td>Student made accurate and appropriate general observations about density, and measured and recorded the relative densities of different objects carefully, accurately, and consistently.</td>
<td>Student made general observations about density, and measured and recorded relative densities but without adequate care or accuracy.</td>
<td>Observations made and data collected had no bearing on investigation OR student did not attempt to collect any data.</td>
</tr>
<tr>
<td>Explain how at least one variable affects density.</td>
<td>Student provided an explanation of the effect of the tested variable on density; explanation is reasonable given prior knowledge and the observations made.</td>
<td>Student provided an explanation of the effect of the tested variable on density, but the explanation is not consistent with prior knowledge or the data collected.</td>
<td>Student made no attempt to provide a reasonable explanation.</td>
</tr>
<tr>
<td>Relate the results of the investigation to a model water column and propose a design that includes fish swimming at various depths.</td>
<td>Student showed an understanding that the investigation modeled the problem in some way and proposed a solution that is reasonable given the results of the investigation.</td>
<td>Student tried to relate the results of the investigation to the problem, but did not show a complete understanding. Student proposed a solution, but one that is inconsistent with the results of the investigation.</td>
<td>Student did not attempt to relate the investigation to the problem or to propose a reasonable solution.</td>
</tr>
<tr>
<td>Identify problems with the investigation and propose modifications to improve the investigation.</td>
<td>(If applicable) Student described at least one problem with the investigation and proposed a reasonable solution.</td>
<td>Student described at least one problem with the investigation but did not propose a reasonable solution.</td>
<td>Student made no attempt to analyze the investigation design.</td>
</tr>
</tbody>
</table>

**Options and Suggestions for Differentiation**

*Quick Lab*: Use this activity as an introduction to the Virtual Lab *Dive Right In*. Have the whole class experiment with a single variable, such as mass. Compare how changing mass while keeping volume and shape constant affects the density of an object and whether it will sink or float in water.
**Extended Lab:** Do the investigation using same-size objects of different materials, such as wood, metal, or plastic. Observe the differences in buoyancy and interpret what that means about the density of each object. If they are all the same size, why do they have different densities? Students should conclude that some objects are more compact than others. Also try materials that may absorb water such as fabric and sponges. Discuss how absorption affects density by changing the mass and volume of the object (a sponge may expand as it absorbs water).

**Structured:** Instead of having students adjust the mass themselves by filling the containers during the activity, control that variable by filling the containers to set levels beforehand. Students may also benefit from completing the Virtual Lab *Dive Right In!* before being introduced to the hands-on lab.

**Open Inquiry:** Instead of providing students with the investigation materials and setup, have them brainstorm the materials they would need and design the setup on paper. Time permitting, once you have evaluated the designs and helped students think through the challenges, students will be able to build the setup themselves. Guide students in the design with questions like *What types of objects have the same volume but different masses, or the same masses but different volumes? What types of objects have equal mass and volume but different shapes? How could we change the mass of an object without changing its volume? How could we measure density or compare the densities of different objects? What type of equipment or materials do we need to observe relative density?*

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**Sink or Swim**  
**Student Planning Sheet**

<table>
<thead>
<tr>
<th>Topic of lab (what the lab is about)</th>
<th>density, relative density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables (things I can change)</td>
<td>mass, volume, or shape of an object</td>
</tr>
<tr>
<td>Testable question</td>
<td>How does the mass of an object affect its density?</td>
</tr>
<tr>
<td>Variable I will test (variable I will change to see what happens)</td>
<td>I will change the mass of the object.</td>
</tr>
<tr>
<td>Variables I will not test (variables I will keep the same throughout the investigation)</td>
<td>volume and shape</td>
</tr>
<tr>
<td>This is a fair test because</td>
<td>I am changing just one variable while keeping all other variables constant.</td>
</tr>
<tr>
<td>Hypothesis (what I think will happen and why I think so)</td>
<td>I think that the object with the greatest mass will sink to the bottom. I think this because I know that heavy objects tend to sink.</td>
</tr>
<tr>
<td>Procedures (list of the steps I will take to try to answer the question)</td>
<td></td>
</tr>
<tr>
<td>1. Use three containers of the same size.</td>
<td></td>
</tr>
<tr>
<td>2. Put different masses of sand into each container.</td>
<td></td>
</tr>
<tr>
<td>3. Seal the containers and place them in the water one at a time.</td>
<td></td>
</tr>
<tr>
<td>4. Experiment with how much (what mass) is needed to sink the container, allow it to float, or keep it suspended under the water.</td>
<td></td>
</tr>
</tbody>
</table>
5. Observe the relative masses of sand required to achieve each of these conditions.

### Student Record Sheet

**Variable to change:** mass

**Variables to keep the same:** volume and shape

<table>
<thead>
<tr>
<th>Test #</th>
<th>Value of variable</th>
<th>Observations</th>
<th>Density compared to water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Light</td>
<td>floated</td>
<td>Less dense than water</td>
</tr>
<tr>
<td>2</td>
<td>medium</td>
<td>Slowly sank</td>
<td>About as dense as water</td>
</tr>
<tr>
<td>3</td>
<td>heavy</td>
<td>Sank</td>
<td>More dense than water</td>
</tr>
</tbody>
</table>

### Student Analysis Sheet

How are mass and volume related to density and buoyancy? Objects with more mass than volume will sink in water. Objects with more volume than mass will float in water.

How is shape related to density? Changing the shape of an object does not change its density because the mass and volume remain the same.

How could the scientist design model fish so they would float at different depths? She could design fish of different densities so some would float and some would sink. She could do this by using different materials, or by making some “fish” have more mass than volume, greater volume than mass, etc.