2.1 DENSITY BAGS (DB)

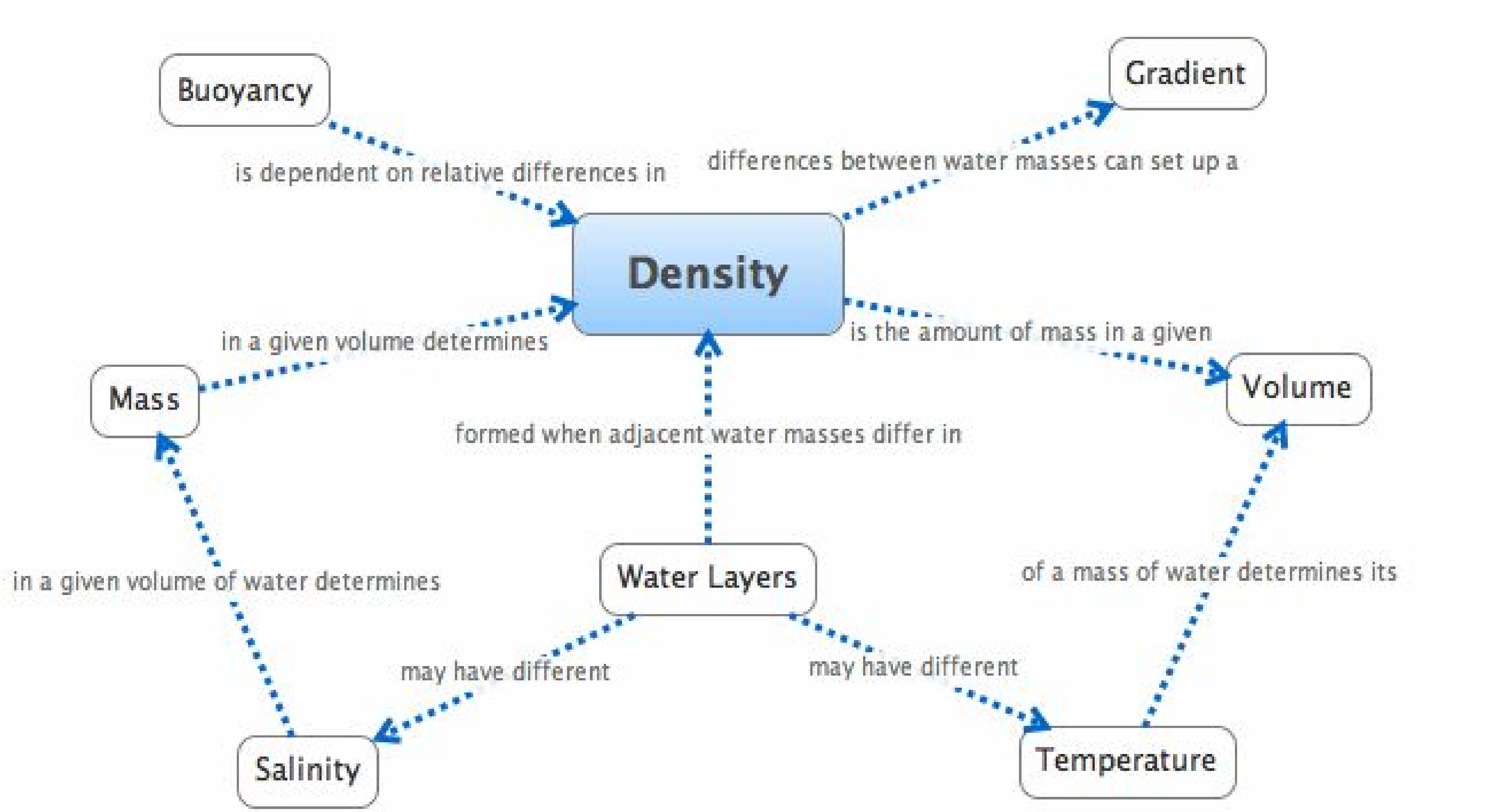

Image by Lauren Kaupp
T-DB Fig. 2.1 Density concept map

Goals

Students will…

1. Determine the effect of temperature on relative density.
2. Determine the effect of salinity on relative density.
3. Explain the relationship between floating, sinking, and relative density.
4. Apply density concepts to water layers.

Background and Introduction

In the ocean, movement of large masses of water is partially regulated by the density of these water masses. Density is defined as the amount of matter contained in a given volume.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Density is an *intensive property* of a substance, meaning that it depends on the type of substance rather than the amount of substance. Density can be expressed using a variety of units, depending on the substance's state of matter and overall volume. Common units are kg/m^3, g/cm^3, and g/mL. The density of water is dependent on the dissolved substances in the water and the temperature of the water. For liquid water, volume increases as water is heated and decreases as it is cooled. Although there are many substances dissolved in seawater, this activity only investigates the effect of salinity. Dissolved substances do not change the volume of the water in which they are dissolved, but they do change the mass. The more salts that are dissolved in a water sample, the greater the mass of the water sample, resulting in greater density. Table T-DB 2.2 shows how fresh water (0 ppt) and salt water (35 ppt) become slightly less dense when heated from 1 °C to 25 °C.

T-DB Table 2.2. Fresh water (0 ppt) and salt water (35 ppt) densities at different temperatures

Salinity (ppt)	Temperature (°C)	Density (g/mL)
0	1	0.999
0	25	0.997
35	1	1.028
35	25	1.023

Density differences between water masses that are only a few degrees different in temperature or have just slightly different salinities are small. However, these small differences play a major role in the formation of water layers in the ocean and in ocean circulation.

The activity in this topic explores two concepts related to density, *relative density* and *buoyancy*. Students do not make direct measurements of mass and volume or calculate density. Instead, they explore the relative density of water masses of different salinities and temperatures by looking at floating and sinking, which shows the density of one mass of water relative to another in terms of being more or less dense. Buoyancy is the force of a fluid that opposes the weight of an object in the fluid.

T-DB Table 2.3. Density, temperature, and salinity misconceptions

Misconception	Explanation
Size Big things are more dense, small things are less dense.	Density is a function of both size and mass. A large object can be less dense than a small object. For example, a hot air balloon is less dense than a book.
Size Big/heavy things sink, whereas small/light things float.	Relative density affects floating and sinking. A large iceberg is heavy, but it floats because it is less dense than water. A penny is small and light, but it sinks because it is more dense than water.
Size Objects float because the body of water is large (e.g. the ocean or the experimental container).	Relative density affects floating and sinking. The ocean is large, but objects that are less dense than seawater, like buoys, float and objects that are more dense than seawater, like rocks, sink.
Air Objects with air inside will always float.	The average density of an object affects floating and sinking. A sealed, glass bottle filled only with air will float. However, if that sealed glass bottle is filled halfway with sand, and halfway with air, it will sink even though there is air inside.
Water Water in the ocean has the same properties everywhere.	Ocean water properties vary on both big scales (e.g. shallow water verses deeper water) and small scales (e.g. between different tidepools along the coast).
Currents Density does not cause currents, only waves cause currents	The upward and downward movements of water masses of different densities are gravitational currents.

Additional misconceptions and confusions:

- Substances (e.g., salt/sugar) dissolved in water do not affect the overall weight.
- Confusion between density, buoyancy, and gravity.

References

Yin, Y., Tomita, M. K., & Shavelson, R. J. *Diagnosing and Dealing with Student Misconceptions: Sinking and Floating*. Science Scope April/May, (2008): 34-39.

Activity: Density Bags

T-DB Table 2.4. Suggested activity progression, if adhering closely to activity as written with no major modifications, assuming class periods of 40 minutes.

Day	Task
1	Introduction to activity
	Activity part A
	Class discussion on part A
2	Activity part B
	Class discussion part B
	Prediction part C
3	Activity part C
	Class discussion part C
	Assign activity questions for homework or discuss in class

Optional Introduction: Additional 20 min prior to introduction to activity

Optional Extension: Additional 20–30 min after final class discussion on activity

T-DB Table 2.5. Materials, if adhering closely to activity as written with no major modifications, assuming class of 32 students divided into groups of four (8 groups).

Materials	Quantity	Per	Class Total	Notes on Material Number or Material Modification
Small plastic bags*	6	Group	48	2"x2" suggested, but any size will work as long as bags can float unobstructed. Bags that are small will have a higher ratio of plastic to liquid and thus be more buoyant. Have extra bags on hand for breakages.
Scissors	1	Group	8	
Permanent marker	1	Group	8	
Labeling tape	30 cm	Group	240 cm	
Fresh water	750 mL	Group	6 L	Tap water can be used.
Beakers or large containers	4	Group	32	Any clear containers wide and tall enough for bags to float unobstructed can be used (e.g., 1,000 mL beakers). Containers must be able to hold hot water. Containers should be as standardized as possible to allow easy comparisons among groups.
Small cup	1	Group	8	
Tray	1	Group	8	Can also use a spare beaker or other wide container, towels, or newspaper to catch water
Tape	1 dispenser	Group	8	Clear tape to to seal leaks in bags
Towels	1–2	Group	8–16	Cloth preferred as can be reused.
Food coloring (optional)*	1	Group	8	Use dark food colors.
Salt water	750 mL	Group	6 L	Water should be at least 35 ppt. Making water even saltier will increase density differences. Salt water made ahead of time and allowed to sit will be less cloudy.
Heat source	1	Group *or* 1–2/Class	8 *or* 1–2	Number will depend on class materials available. Some options: beaker over hot plate, electric kettle or coffeemaker (without the coffee), pot on stove, heat in microwave Be careful not to heat water too much, hot water is a safety concern.
Ice bath	1	Group *or* 1–2/Class	8 *or* 1–2	Number will depend on class materials available.
Thermometer	1	Group	8	
Tongs	1	Group *or* 1-2/Class	8 *or* 1-2	Number will depend on heat source options.

*more details about this material in *Materials Details*

Materials Details

Small plastic bags

- Jewelry bags can be brought from drug stores, online, and in bulk from container distributors.
- Many plastic bags have small leaks at their seams due to the way the bags were heat sealed during construction. If these leaks are very small, they will not affect the experiment. If the leaks are from larger holes and from multiple locations, the bags are not an acceptable material.
- Leaking will vary based on brand and size. Different sized bags from the same brand may leak differently. It is important to test a few prior to buying or ordering large quantities to make sure they are acceptable.
- Test bags for leaks by placing a few bags filled with colored water in a container of clear water. If there are no leaks or only a very slow leak, the bags are usable.
- If the bags are leaking noticeably, but from just one location (e.g., the *same* spot near the seam), redo the test but place clear tape over the hole of a dry bag before filling with water. If this slows or stops the leak, the bags are useable. Tell your students where the bags leak, demonstrate how to cover the leak, and distribute clear tape as an additional material.
- Double-lock closures on the bags will help prevent leaks from the top of the bag, but bags may still leak from the sides.

Food coloring

- While food coloring will make bags more visible, it is not necessary.
- Dark food colors (e.g., green, blue, red) are more distinctive in water than light food colors (e.g., yellow). Consider giving all groups the same color of food coloring to limit issues with color as a variable.
- If students have concerns that food coloring is affecting the density of the liquid in the bags, redo the experiment without food coloring.

Activity Inquiry Prompts

1. How can you determine relative density?
2. What can you infer if the bag sinks? What can you infer if the bag floats?
3. Why are we using an ice bath rather than just putting ice directly into the water to cool it down (especially the salt water)?
4. Why does a bag on the surface just float to the surface and stop?
5. Why does a sinking bag stop sinking?

Planning with TSI

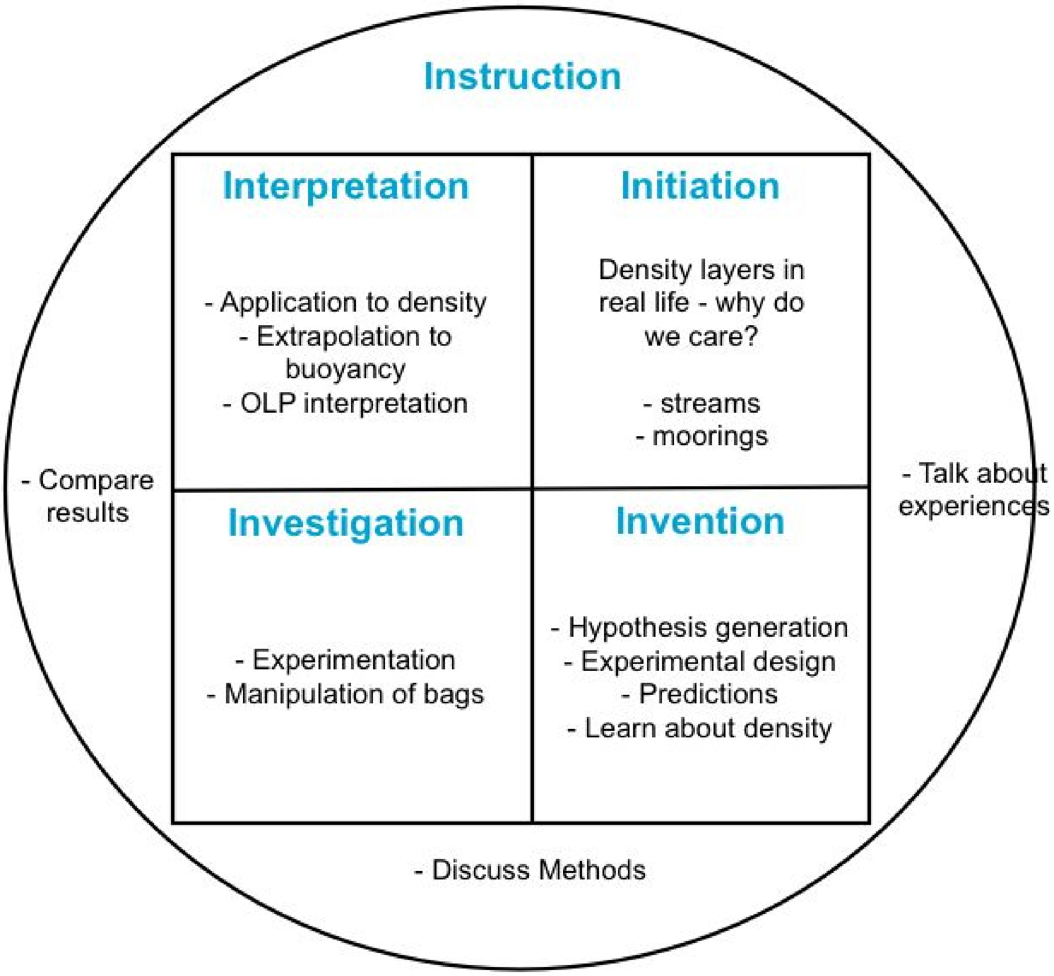

Image by Joanna Philippoff
T-DB Fig. 2.2. Planning *Density Bags Activity* through TSI phases

Focus Modes(s):

- Experimentation
    - Manipulation of bags of liquid in beakers of liquid to test hypotheses
- Replication
    - Class consensus on floating or sinking of bags based on multiple group observations
- Induction
    - Repeatedly observing cold and salty bags sink will lead to the generalization that cold water and salty water are more dense than hot water and warm water.

Notes:

- Students will circle through phase diagram three times, once with each procedure part.

Procedure

NOTE Figures and tables in this section refer to figures and tables in EOFE unless otherwise noted.

Safety Warning(s):

- Hot water can burn. Be aware of the temperature of the water, it should be very warm, not hot.
- Advise students to use tongs to handle the bags if the water is very warm.

Major modification(s) that may affect timing of the activity and/or supplies

- *Do full activity on one day or split parts over two or more days. Hot and cold water need to be prepared for Parts B and C, but Part A can be done on a separate day.*

A. Test the effect of salinity on the rising or sinking of bags of liquid.

1. For each combination of fresh water and salt water, make a prediction as to whether the bag will
    a. sink (the bag and liquid are more dense than the liquid in the beaker),
    b. float (the bag and liquid are less dense than the liquid in the beaker), or
    c. subsurface float (the bag and liquid are the same density as the liquid in the beaker).

   Record your predictions in Table 2.1.

Share predictions in a class data table, for example see "predicted" results in T-DB Table 2.6.

T-DB Table 2.6. *Example of how to set up a class table for sharing predictions of sink, neutral, or float for each condition. The tick marks represent the number of groups who shared a prediction (there are five class groups in this example). Options with no tick marks indicate no groups predicted this result. This table also included example results.*

Water in container	**Water in bag**	
	Fresh water	Salt water
Fresh water	Predicted *Sink I* *Neutral III* *Float I*	Predicted *Sink IIII* *Neutral I* *Float*
	Actual *Neutral (subsurface float)*	Actual *Sink*
Salt water	Predicted *Sink II* *Neutral I* *Float II*	Predicted *Sink* *Neutral IIII* *Float I*
	Actual *Float*	Actual *Neutral (subsurface float)*

2. Fill one 1,000 milliliter (mL) beaker with salt water and one 1000 mL beaker with fresh water. Label your beakers.

Modification: Prepare and distribute water to your students

- *Prepare solutions of each type of water in large containers prior to class.*
    - *Have four containers for each group. These containers should be labeled, e.g., "room temperature fresh" and "room temperature salt".*
    - *Students can fill their own containers from the large containers or water can be distributed to each student table.*

3. Observe as your teacher shows you how to fill the plastic bags for your experiment.
    a. Use a permanent marker to label an empty small plastic bag with the salinity of the water (fresh or salt) that will be poured into it.
    b. (Optional) Add a drop of food coloring to the empty plastic bag to make the liquid in the bag easier to observe.
    c. Fill the small cup with the same type of water that will be poured into the bag.
    d. Overfill the bag with water using the small cup. Do this step over a tray, spare beaker, or towel.
    e. Seal the bag so it does not leak or have air bubbles inside. Do this step over a tray, if done correctly liquid will spill out of the overfilled bag.
    f. Shake the bag to distribute the food coloring.
    g. Pat the plastic bag dry.
    h. Cut off the excess plastic of the bag above the closure.
    i. If at any point in this procedure the bag starts leaking, seal the leak with tape.

If the bags have not been used previously, cut the excess plastic above the zipper as close to the zipper as possible, without cutting the zipper. The small amount of plastic in the lip can trap air and affect the density of the bag.

4. Make a bag of fresh water and a bag of salt water.

Modification: This can be done for students prior to the experiment.

- *Label the bags with a permanent marker.*
- *Fill each bag as labeled.*

5. Place one bag into one beaker and record your observations in Table 2.1. Repeat this step until you have tested and recorded your observations for each combination of bag and beaker. Make sure to pat the bags dry before placing them in the beakers or when transferring them between beakers.

Ask students why they need to pat the bags dry when they transfer them between beakers.

6. Compare your results with those of your classmates.

Share results in a class data table; e.g., T-DB Table 2.6.

B. Test the effect of temperature on the rising or sinking of bags of liquid.

1. For each combination of fresh hot water and fresh cold water, make a prediction as to whether the bag will sink, float, or subsurface float. Record your predictions in Table 2.2.

Share predictions in a class data table.

2. Prepare hot water and cold water in 1000mL beakers. Make sure to use safety equipment and be careful with the hot water. Label your beakers.
    a. To prepare hot water, place a beaker of fresh water on a hot plate (Fig. 2.4 A), and heat to 50–70 degrees Celsius (˚C).
    b. To prepare cold water, place a beaker of fresh water in an ice bath until the water in the beaker reaches a temperature of –5˚C. Do not put ice cubes in the beaker (Fig. 2.4 B).
    c. The beakers can stay on the hot plate or in the ice bath during the experiment.

Modification: Prepare and distribute water to your students

- *Prepare solutions of each type of water in large containers prior to class.*
    - *Have four containers for each group. These containers should be labeled, e.g., “cold fresh” and “hot fresh”.*
    - *Students can fill their own containers from the large containers or water can be distributed to each student table.*
    - *For hot and color water, containers can be pre-filled and waiting in ice or hot water baths or in coolers. Create a hot water bath by heating a large beaker of fresh water to the desired temperature and placing the smaller containers in the beaker. Placing lids on containers and wrapping them with towels or other insulators help will prevent changes in temperature.*

Modification: Temperature can be measured quantitatively or described qualitatively, e.g. “hot” and “cold”, instead of using a thermometer.

3. Make a bag of hot water and a bag of cold water following the steps described in procedure 3 of Part A. Place each bag into each beaker and record your observations in Table 2.2. Repeat this step until you have tested and recorded your observations for each combination of bag and beaker.
    a. Pat the bags dry before placing them in the beakers or when transferring them between beakers.
    b. If the hot water is uncomfortably hot, use tongs to transfer the bags into and out of the water.

Modification: This can be done for students prior to the experiment.

- *Label the bags with a permanent marker.*
- *Fill each bag as labeled.*

- *Place the "cold" bags in an ice water bath. Place the "hot" bags in a hot water bath. Create a hot water bath by heating a beaker of fresh water to the desired temperature and placing the bags in the water.*

4. Compare your results with those of your classmates.

Share results in a class data table, T-DB Table 2.7.

T-DB Table 2.7. *Example results of the effect of temperature on the relative density of water in bags compared with water in beakers.*

Water in container	**Water in bag**	
	Cold water	Hot water
Cold water	*Neutral (subsurface float)*	*Float*
Hot water	*Sink*	*Neutral (subsurface float)*

C. Test the effects of both salinity and temperature on the rising or sinking of bags of liquid.

Modification: You may wish to split this experiment between groups. There are 16 possible combinations of temperature and salinity. Assign each group 4 of these combinations, but have all groups predict results for all combinations.

1. Examine Table 2.3.
   a. Fill in the boxes that you already completed in Part B (Boxes 6, 8, 14, and 16).
   b. Based on your results in Part A (salinity), make predictions as to whether the bags in boxes 2, 5, 12, and 15 will sink, float, or subsurface float. Fill in your predictions in Table 2.3.
   c. Based on your results in Part B (temperature), make predictions as to whether the bags in boxes 3 and 9 will sink, float, or subsurface float. Fill in your predictions in Table 2.3.
   d. Based on your knowledge of how salinity and temperature affect density, predict whether the bags in boxes 1, 4, 7, 10, 11, and 13 will sink, float, or subsurface float. Fill in your predictions in Table 2.3.

2. Examine your predictions in Table 2.3.
   a. Star (*) the predictions you are confident about.
   b. Circle the predictions you are unsure about. Write down why you are unsure.
   c. Discuss with your classmates which predictions they are confident about and which predictions they are unsure about.
   d. Decide which predictions you will test.

3. Prepare the beakers and bags you need to carry out your experiment. Record your observations.

4. Compare your results with those of your classmates.

T-DB Table 2.8. *Idealized averaged class data from the activity*

Water in container	**Water in bag**			
	Cold Salt	Cold Fresh	Hot Salt	Hot Fresh
Cold Salt	1 *Neutral (subsurface float)*	2 *Float*	3 *Float*	4 *Float*
Cold Fresh	5 *Sink*	6 *Neutral (subsurface float) (Part B)*	7 *Depends**	8 *Float (Part B)*
Hot Salt	9 *Sink*	10 *Depends**	11 *Neutral (subsurface float)*	12 *Float*
Hot Fresh	13 *Sink*	14 *Sink (Part B)*	15 *Sink*	16 *Neutral (subsurface float) (Part B)*

**Results from these combinations will depend on the salinity and temperature difference between the bags and the liquid in the beakers.*

Answers to Questions

1. How did your answers compare to your predictions?

Results will vary.

2. Explain why your classmate's results were the same or different for
    a. Part A (salinity).
    b. Part B (temperature).
    c. Part C (salinity and temperature).

Results will vary.

3. In Part C, which variable, temperature or salinity, tended to determine the behavior of the bag? Explain why you think this variable determined the results of your experiment.

Although actual results will depend on the salinity and temperature difference between the and the liquid in the beakers in your classroom experiment, in general, salinity has a greater effect *on density than temperature. This is because salt ions can fit into the spaces between the water molecules more tightly than water molecules can fit together, even when the water is very cold.*

4. Using the term density, explain how a bag of salt water can sink in a beaker of salt water. Where might this occur in the ocean?

If the salinity of the bag and beaker are the same, the density can only be different if the bag and beaker have different temperatures. If the bag of salt water is colder than the salt water in the beaker, it will sink because cold water is denser than warm water. This is because the volume of water decreases as it gets colder. As the temperature decreases, the same amount of mass fits into a smaller space, this means that the same volume of cold salt water has a greater mass.

Salt water sinks in nature where the surface waters get very cold due to cold air and wind, for example at the poles. The surface water at the poles becomes more dense and sinks.

5. If the temperature of the liquid in a bag and the liquid in a beaker were the same, under what conditions would the bag float? Where might this occur in nature?

That bag will float if it has a lower salinity. For the same volume, the lower the salinity, the less the mass in the bag.

In nature, where fresh water flows into the ocean, for example where a river empties into the ocean, the fresh river water layer will float on top of the salty ocean water.

6. Would fresh water flowing into the ocean sink or float on top of seawater? Explain your reasoning.

If the fresh river water is the same temperature as the ocean water, the river water will float. The same volume of river water has less dissolved substances and less mass than the ocean water, therefore the river water density is lower.

7. How might you use what you have learned in this activity to help explain the formation of layers in large bodies of water like lakes or the ocean?

As temperature or salinity change, the density of water changes. When temperature changes with the seasons, large bodies of water can warm up or cool down. Salinity can change in large bodies of water if there is a lot of rain. Salinity can also change if there is a lot of fresh water input near the shore due to rivers or glacier melting.

8. What do you think might happen to the liquid in the bags if the bags were not sealed? How could you test this?

The liquid in the bags would probably mix with the liquid in the beaker. You could test this by doing the same experiment, but leaving the bags open.

9. If a sealed bag of hot salty liquid is placed into a beaker of cold fresh water for 24 hours, what will happen to
    a. the temperature of the two liquids.

    They will equilibrate to the same temperature, since heat can move in and out of the bag.

    b. the salinity of the two liquids.

    The salinity will stay the same, since salt cannot move in and out of the bag.

    c. the density of the two liquids?.

    The liquid that gets warmer will become less dense and the liquid that becomes cooler will be more dense.

10. If you used the food coloring, do you think it affected the density of the liquids in the bags? How could you verify your answer?

Adding the food coloring increased the density of the water. Although food coloring is mostly water, it also has dissolved food dye, which increases the mass, but not the volume. This has the same effect as adding salt to water. If you increase the mass, but do not change the volume, you increase the density. To test this, you could do the same experiment with one set of food colored bags and one set of non-food colored bags.

Optional Introduction
Density demonstration

Goals
Students will…
1. Be provided with a visual representation of density.
2. Address common misconceptions about density, floating, and sinking.

T-DB Table 2.9. Materials for density introduction demonstration

Materials	Quantity	Notes on Material Number or Material Modification
Transparent box	1	The size of a small aquarium
Large beaker	1	Either 1 L or 2 L
Graduated cylinder (~300 mL)	1	To get volume of plastic bottles
20 oz (591 mL) Plastic bottles	6	Remove labels, fill according to Procedure 2
2 L Plastic bottle	1	Remove labels, fill according to Procedure 2
Balance	1	
Fresh water	Enough to fill aquarium, beaker, and 1 20 oz bottle	
Sand	Enough to fill ~2.5 20 oz bottles	
Calculator (optional)	To assist with calculations, either one just for the teacher or one for each student.	

Procedure

Preparation:
1. Fill aquarium tank and beaker with tap water.

2. Prepare bottles as in T-DB Table 2.10:

T-DB Table 2.10. Preparation of bottles for density, temperature, salinity demonstration

1	20 oz bottle	Filled with air
2	20 oz bottle	Filled with water
3	20 oz bottle	Filled with sand
4	20 oz bottle	¼ filled with sand
5	20 oz bottle	½ filled with sand
6	20 oz bottle	¾ filled with sand
7	2-L bottle	Filled with air

3. Approximate the total volume of one of the 20 oz bottles by filling one bottle to the very top with water and then measuring into the graduated cylinder to allow the calculation of density in the demonstration.

Demonstration:

Demonstrate this activity following a question, predict, observe, explain model: (1) pose each question to the class, (2) ask students to make a prediction (individually, in groups, or as a class), (3) have students observe and/or assist with the demonstration, and (4) finally have students explain or lead students to an explanation of the demonstration.

1. **Question: How does material affect density?**
    a. Predict: Rank the density of 591 mL soda bottles filled to the top with air, water, and sand.
    b. Observe: Use a balance to take the mass of each. Divide by the total volume of each. Calculate density.
    c. Explain: The sand bottle is the most dense, sand is a solid. The water bottle has "medium" density, water is a liquid. The air bottle is the least dense, air is a gas.

2. **Question: How does density affect floating?**
    a. Predict: Which bottles (air, water, sand) will float or sink?
    b. Observe: Put bottles 1, 2, and 3 into the aquarium.
    c. Explain: The sand bottle is more dense than water, so it sinks. The air bottle is less dense than water, so it floats. The water bottle is approximately the same density as the water, so it floats at or near the surface.

3. **Question: Does air always make objects float?**
    a. Predict: Will a bottle float if it has any amount of air in it?
    b. Observe: Put air and sand bottles (bottles 4, 5, and 6) into the aquarium. Explain: Air does not always make an object sink. The overall density will determine if it floats or sinks in water. The more sand and less air in a bottle, the greater its overall density.

4. **Question: How does size affect mass?**
    a. Predict: Which has more mass, a 2 L soda bottle or a 591 mL soda bottle? Both are made of the same material.
    b. Observe: Use a balance to take the mass of both. The 2 L bottle has more mass.
    c. Explain: The 2 L bottle is bigger and therefore has more matter (or stuff).

5. **Question: How does size affect volume?**
    a. Predict: Which has more volume, a 2 L soda bottle or a 591 mL soda bottle? Both are made of the same material.
    b. Observe: Read the volume from both bottles. The 2 L bottle contains 2 L, and the 591 mL bottle contains 591 mL. This is the amount of soda they contain, so both have an actual volume that is slightly larger than the amount of soda they contain.
    c. Explain: The 2 L bottle is bigger and therefore has a greater volume (takes up more space) than the 591 mL bottle.

6. **Question - How does size affect density?**
    a. Predict: Which has greater density, a 2 L soda bottle or a 591 mL soda bottle? Both are made of the same material.
    b. Observe: Put both bottles in the aquarium tank. Both float at the same level.
    c. Explain: Density depends on both mass and volume. Since both bottles are made of the same material and are full of the same material (air) they have the same density. Density is a ratio so the size or amount of materials does not affect density.

7. **Question - How does size of the container of water affect density?**
    a. Predict: Will the same bottle float in a smaller container of water?
    b. Observe: Put the smaller bottle into the beaker of water.
    c. Explain: Only the material affects density. As long as the material in the beaker is the same as the material in the aquarium, it does not matter how much there is.

8. Summarize what factors affect density (mass, volume) and what factors affect floating (density of object compared to water).

Optional Extension
Summative density demonstration or assessment

Goals
Students will…
1. Verify their understanding of density and salinity *or*
2. Be assessed on their understanding of density and salinity

T-DB Table 2.11. Materials for density extension demonstration

Materials	Quantity	Notes on Material Number or Material Modification
Transparent Graduated cylinders	2	500 to 1000 mL
Food coloring	1	A dark color (e.g. blue or green)
Ice	Enough to fill each cylinder with ~200 mL of ice	
Fresh water	Enough to fill one graduated cylinder	
Salt water	Enough to fill one graduated cylinder	

Procedure

Preparation:
1. Make ice, if not purchasing already-made ice

2. Prepare two transparent 500–1000 mL graduated cylinders
    a. Fill one with fresh water
    b. Fill the other with salt water (for best results, prepare salt water the day before so it is not cloudy and cannot be visually distinguished from the fresh water)

Demonstration:
1. Tell students that one of the containers has fresh water and one of the containers has salt water. Both the fresh and salt water should be at room temperature. These containers should be labeled.

2. Tell students you will be adding ice (made with fresh water) to each container. Have students predict if the ice will melt faster in the salt for fresh water container based on what they know about density.

3. Add about 200 mL of ice to the top of each cylinder and observe what happens. Do not stir or disturb the ice during this time. Observe what happens for as long as your students can remain attentive—aim for at least five minutes.

4. Have students formulate a hypothesis explaining their observations. At this point, many students will not be able to explain their observations.

5. Repeat procedures 1–3, but this time add 5–6 drops of food coloring to the ice in each cylinder and observe what happens.

6. Lead a class discussion on what is happening in the containers and have students revise their hypotheses explaining their observations.

Challenge: Do not label the container in procedure 1. Have students predict how ice will help them determine what water is in what container.

Explanation for the observation:
Ice melts faster in fresh water than in salt water.

Ice in fresh water (T-DB Fig. 2.3 A)
Water from melting ice is cold and fresh. It is more dense than fresh water at room temperature (remember that as temperature decreases water density increases). The denser cold water from the melting ice sinks to the bottom of the cylinder. Food coloring mixed with the melting ice water will also sink to the bottom of the cup.

When the dense cold water sinks to the bottom of the cup, it displaces water at the bottom of the cup. The room-temperature water at the bottom of the cup has to go somewhere when it is pushed out of the way by the sinking cold water. The displaced room-temperature water from the bottom of the cup moves up toward the surface. Eventually, the movement of dense cold water sinking and room-temperature water being displaced mixed the food coloring throughout the cup.

The result of this mixing process is that the ice is always being surrounded by new room-temperature water as the dense cold water sinks and less dense room-temperature water is pushed upward. Therefore, ice melts faster in fresh water.

Ice in salt water (T-DB Fig. 2.3 B)
Water from melting ice is cold and fresh. Fresh water is less dense than salt water no matter what the water temperature is (remember that water density decreases as salinity decreases). Since the cold water from the melting ice is less dense than the salt water, it floats on the top of the salt water. This is why the food coloring forms a layer at the top of the cup. The layer of cold water from the melting ice “insulates” the ice. In other words, the cold, fresh water from the melting ice helps keep the ice cold. Therefore, the ice melts more slowly in salt water.

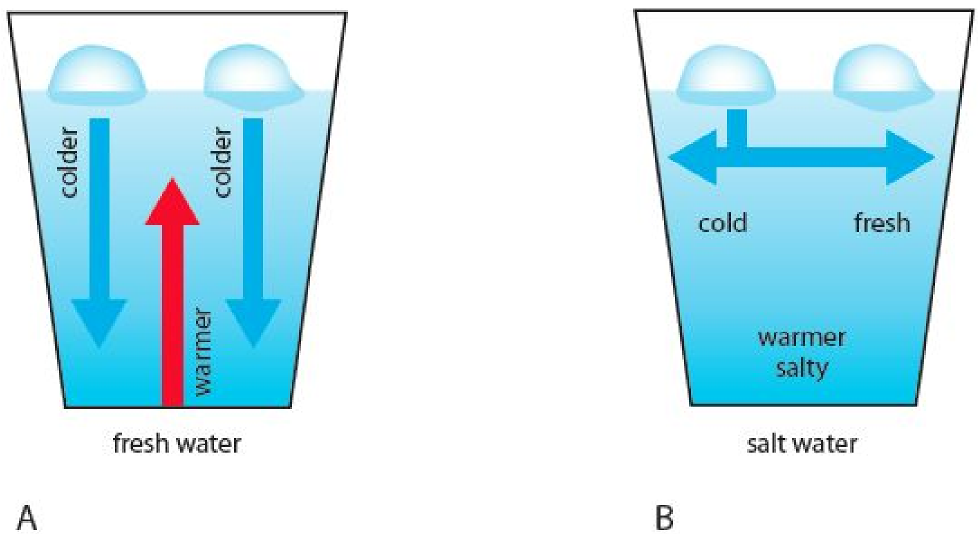

Image by Byron Inuoye
T-DB Fig. 2.3 (**A**) Ice melting in room temperature fresh water (**B**) Ice melting in room temperature salt water

<u>Further Investigations: Density, Temperature, and Salinity</u>

1. Simulate layers of water formed by differences in temperature and salinity.
    a. Prepare two 100 mL water samples, one of cold salt water and the other of warm fresh water. Add a different color of food coloring to each.
    b. Place the cold salt water into a beaker. To prevent mixing, slowly pour about 20 mL of the warm fresh water down a stirring rod or down the back of a spoon onto the cold salt water in the beaker (Fig. 2.7). Look for evidence of layering.
    c. Test different combinations of water temperature and salinity.
    d. Try to create three or more water layers in your beaker.

This can be done with the same materials used in the activity.

2. What do you think the relative density of the bag alone (empty of liquid) is in the *Density Bags Activity*? How might the density of the bag affect the results? Design an experiment to test your hypothesis.

The density of the bag is slightly less than water because the bag by itself will float on water. This would cause all of the filled bags to be slightly less dense overall than the water in them. However, there is much more water than bag, both by mass and volume, so the effect of the density of the bag is small.