How Does the Density of Water Affect Ocean Currents?

Student Activity Sheet

Name ________________________________ Date ______________ Class ____________

You've probably been to an ocean beach in the summertime and stood neck-deep in the water. While you're standing there you suddenly feel cold water flowing over your lower body. From your feet to your knees the water feels icy cold and from your knees to your head the water feels warm. You probably wondered what causes this to happen. What you felt were warm surface currents and cold deep currents. Changes in the ***density*** set these currents in motion.

Some ocean currents are set in motion by the wind. Other ocean currents are created by something you can't see or feel. Differences in the density of water can also cause currents to form and move. Density is affected by temperature and ***salinity.*** Cold water or water with dissolved salts (higher salinity) is denser than warm water or water without dissolved salts (low or no salinity). For example, at the same temperature (20º C) the density of salt water is 1.025 g/ml and fresh water 0.998 g/ml.

Density	Water Properties
More dense (higher density)	Cold water, Salt water
↕	↕
Less dense (lower density)	Warm water, Fresh water

A less dense substance will always lie above a more dense substance. When you have water of two different densities meeting, the lower density (less dense) water will move on top of the higher density (more dense) water. The different densities actually cause the water to move, forming a density current. In the oceans, the deep,bottom currents are colder and saltier than the surface currents.

How did scientists ever figure out that this is how some currents were formed? A seventeenth century scientist named Marsigli went to Constantinople to settle a dispute between fisherman about a deep current in the Bosporus. The Bosporus is a ***strait*** that flows between the Black and

Mediterranean Seas. Marsigli observed the Bosporus and concluded that there was a surface current that flowed into the Mediterranean Sea from the Black Sea.

Marsigli designed an experiment to test his idea. He placing a rope deep enough in the water so that both the surface and deep currents touched it. The rope wouldn't stay straight but became tangled as if pulled in two directions. Marsigli's observations led him to believe there was a surface current and a deep ***undercurrent***.. The upper or surface current pulled the top of the rope in the direction of the Mediterranean Sea. The lower part of the rope went in the opposite direction towards the Black Sea. Marsigli determined that the current changed directions about 8 to 12 feet below the surface. He theorized that there were density differences between the two seas causing an countercurrent to develop.

Marsigli set out to prove his density theory by taking water samples of the Mediterranean and Black Seas. Marsigli found that the Black Sea had a lower salinity than the Mediterranean Sea. Marsigli thought that the lower salinity in the Black Sea was because so many rivers flow into the seas, diluting the salt water with fresh, river water**.** Marsigli then measured the density of the surface and deep water from the Bosporus. The surface water had a lower density than the deeper water. Marsigli performed another experiment to prove his point. He created a box that was divided in half and the divider had two holes in it- one at the top and one near the bottom of the divider. He filled one side of the box with dyed water from the Black Sea. In the other side of the box he placed water from the Mediterranean Sea dyed a different color. When Marsigli opened the holes in the divider he noted that the water from the Mediterranean flowed through the lower floodgate and that the water from the Black Sea flowed through the top floodgate. The Black Sea water was less dense and had a lower salinity and so it flowed over the saltier, more dense Mediterranean water. This caused an upper current and a lower current similar to that of the Bosporus.

In this kit activity, you will use Marsigli's box to observe how differences in salinity and temperature cause currents to form in the ocean and seas.

Objectives:

- Examine the effect temperature and salinity have on the density of water.
- Observe density currents.
- Learn that the mixing of primary colors creates secondary colors.
- Discover that different densities of water will stratify to form layers.

ACTIVITY A: TEMPERATURE EFFECTS ON WATER DENSITY

Materials:

Marsigli's Box	2- Plastic gallon bottles
Ice (Teacher supplied)	Stop watch or timer (Teacher supplied)
Cold and hot tap water	Grease pencil or magic marker
2-Thermometers	Food coloring (red, blue, and yellow)
Spoon	

Procedures:

1. Look over Marsigli's box so that you are familiar with its parts. Close the floodgate in the box's divider so that both holes are covered.
2. Fill one plastic bottle with hot tap water and the other plastic bottle with cold or iced tap water.
3. Fill one side of the Marsigli's box with the hot water and the other side with the cold water. Add the water to each side at the same time. This is easy to do if have two students **each** pouring one of the gallons of water into one side of the box. Pour the water in until both flood holes are covered.
4. Add a few drops of yellow food coloring to the side with the hot water. Stir with the spoon until the color is evenly mixed throughout the water. Record the water temperature in that side (hot water).
5. Make sure the water level on both sides is equal. Add a few drops of blue food coloring to the cold water on the other side of the Marsigli's box. Stir until mixed. Record the water temperature of the cold water.
6. Have a person ready with the stopwatch to measure the time it takes for the two sides to adjust. The floodgate separating both sides will be removed next. Make a prediction about what you think will happen to the yellow and blue water when the holes are both opened. Write your prediction on the Predictions and Observations Table. Start the stopwatch at the same time you remove the floodgate. Stop the watch when all water motion ends.
7. Record the length of time it took both sides to adjust themselves and your observations of what happened to the water under Observation 1. Make sure you note what color water moves through each (upper and lower) of the holes in the divider.
8. Close the floodgate once all water motion stops in the box.
9. Use the spoon to stir the water in **one** of the sides of the box. Leave the other side undisturbed. Record your observations (Observation 2) about what happens in the side of the box that you stirred, especially the color of the water.

10. Add three drops of red food coloring to the side you just mixed. Stir the water. Record what color the water turned and the temperature of this mixed water on the data table (Observation 3).
11. Have a person ready with the stopwatch to start timing when the floodgate is raised up again. Make another prediction about what you think will happen when the floodgate is removed. At the same time, start the stopwatch and remove the floodgate so that both gateways are open. Stop the watch when the water motion in the box stops.
12. Record the end time and what happened to the water under Observation 4 on the data table. Rinse and dry all the equipment so that it is clean before you start Activity B. Answer the discussion questions.

Observations and Predictions		
Start Temperatures	**Hot water (yellow side)**	**Cold water (blue side)**
Prediction 1		
Observation 1	**Start Time:** **End Time:**	**:**
Observation 2		
Observation 3 **Temperature**	**Mixed side:**	
Prediction 2		
Observation 4	**Start Time:** **End Time:**	

Discussion Questions:

1. What happened when you opened the floodgate in step 6?

2. Which side, warm (yellow) or cold (blue), has the more dense (higher density) water?

3. How did you decide that the side you picked in question 2 was more dense?

4. What happened during the period of adjustment in Steps 7 and 8?

5. Why do you think this adjustment happened?

6. What happened when you stirred one side in Step 9? What happened to its density?

7. What happened when you added a few drops of red dye to the mixed water?

8. What happened when you opened the floodgate the second time? Why?

ACTIVITY B: SALINITY EFFECTS ON WATER DENSITY

Materials:

- Marsigli's box
- Tap water (Teacher supplied)
- 1 Box of salt
- Spoon
- Weighing balance (Teacher supplied)
- 2- Plastic gallon bottles
- Food coloring (red, blue, and yellow)
- Stop watch or watch (Teacher supplied)
- Weighing boats

Procedures:

1. The directions for this procedure are exactly the same as for the cold and hot water density activity (Activity A). Close the floodgate in the Marsigli's box to cover both flood holes.
2. Fill one plastic bottle with freshwater from the tap (bottle 1).
3. Weigh out 44 grams of salt into a weighing boat. Add the salt to the plastic bottle (bottle 2) and fill the bottle with tap water. Mix by shaking until the salt is completely dissolved.
4. Fill one side of the Marsigli's box with the fresh water (bottle 1) and the other side of the box with the salt water (bottle 2) you've just made. Add the water to each side at the same time. This is easy to do if have two students **each** pouring one of the gallons of water into one side of the box. Pour the water in until both flood holes are covered and the water level on each side of the divider is equal.
5. Add a few drops of yellow food coloring to the salt water in the box and stir until mixed.
6. Add a few drops of blue food coloring to the fresh water in the other side of the box and stir until the color is mixed.
7. Have a person ready with the stopwatch to measure the time it takes for the two sides to adjust or become even after you remove the floodgate. Make a prediction about what you think will happen when the gateways (holes) are both opened. Start the stopwatch at the same time you remove the floodgate. Stop the watch and close the floodgate once the water stops moving in the box.
8. Record the length of time it took both sides to become level after you opened the divider. Also record your observations about what happened to the water on each side under Observation 1 on the data table. Mention what color of water flowed through the upper and lower holes and the direction the water took. Note what the water looks like on each side of the tank after all the colored water has stopped moving?
9. With the spoon, stir one of the sides until the layers of colored water are mixed. Make sure you note on the data table what color the water turned after mixing (Observation 2).
10. Add three drops of red food coloring to the side you just mixed and stir. Note the changes you see under Observation 3.
11. Have a person ready with the stopwatch to time the next part of the activity. The floodgate is going to be opened again so predict what you think will happen (Prediction 2). Start the stopwatch and remove the floodgate **at the same time**. Both holes should be open for the water to flow through. Stop the watch when the water motion in the box stops.
12. Record your observations (Observation 4) and the time on the data table. Clean and dry all the equipment before you put it back into the kit. Answer the discussion questions.

Observations and Predictions	
Prediction 1	
Observation 1	**Start Time:** **End Time:**
Observation 2	
Observation 3	
Prediction 2	
Observation 4	**Start Time:** **End Time:**

Discussion Questions:

1. What happened when you first opened the floodgate in step 7?

2. Which has the highest density- the salt water or the fresh water?

3. What made you decide which was denser?

4. What happened when the water level was adjusting after you opened in the floodgate in Step 7?

5. Why do you think this adjustment happened?

6. What happened when you stirred the one side in Step 10? What happened to the water density in the mixed side?

7. What happened when you added a few drops of red dye to the mixed water and stirred it?

8. What happened when you opened the floodgate the second time? Why?

Vocabulary

Density: The mass per unit volume of a substance [Density = mass/volume]. You can also think of density as how closely packed the atoms or molecules are in a material.

Salinity: A measure of the amount of dissolved salts in water, usually given in units of parts per thousand by weight (ppt). The salinity of seawater averages 35 ppt but seawater's salinity is usually anywhere from 30-37 ppt.

Strait: A narrow strip of water connecting two large bodies of water.

Undercurrent: A current flowing in a direction opposite the surface current above it. The undercurrent can be separated from the surface current by temperature or salinity differences in the water in each current.

Teacher Strategies

Background:

Prepare your students for this activity by talking about the water cycle. Explain how freshwater flows from the land to the ocean as runoff. Let them know that most of the runoff in cities flows into sewers. After storms, many coastal cities dump raw sewage into the ocean when their treatment facilities cannot handle the overflow. Rivers also discharge fresh water into the ocean. Regardless of its source, fresh water doesn't mix with the ocean's salt water, but has a tendency to lie on top of the salt water. Two layers of water are formed. This is very typical of what happens in estuaries. Even small differences in the degree of saltiness or salinity of seawater will cause the denisity to be different. After all, the difference between fresh and salt water densities is very small-0.998 and 1.025 g/ml. Areas far from any large fresh water source can still have layers that form because one layer is more salty than the other. Density separates the layers because the more salt the water has in it, the more dense it is.

Layers of water also form when warmer, less dense water meets cold, denser water. The cold water sinks and the warmer water 'floats' over the top of it. The coldest water in the ocean is very deep and the warmest is at the surface. In fact, worldwide, the deep water of the oceans is very similar in temperature. The cold, deep water flows beneath the warmer, surface water, forming cold water currents. Again, density is what separates the two layers of water.

It is really the combination of salinity and temperature effects on density that cause both deep and surface ocean currents. Your students should also know that other factors, such as wind and the Coriolis effect, also influence currents. Figures have been included which show the global surface and deep water currents. These may help your students understand what it is this activity explains. It will probably be helpful for you to demonstrate the concept of density. You could use different liquids, such as oil, colored water, or colored alcohol to demonstrate the density of liquids. Floating an uncooked egg in water of various salinities is an easy way of showing the effects of increasing density.

Instructional Hints and Strategies:

You may do this activity like a demonstration but involve your students. Rather than doing all the procedures yourself, assign specific tasks to your students. These are several 'job' suggestions: observer, salt weigher, data collector, water pourere, and timekeeper. The actual procedures are the same for both parts of the activity but the materials you use in the Marsigli's box have different densities (salt versus fresh water or hot versus cold water). Use ice water for a more dramatic demonstration. A data table has been included in both Activities A and B so that your students can write down their individual observations. This information will help them to answer the discussion questions and will also help them to realize that a large part of science involves careful observing and recording of experiments.

What happens in both parts of this activity is that the denser water flows through the lower hole in the divider while the less dense water flows in the opposite direction through the upper hole (like an undercurrent). Both sides will reach equilibrium after a short time and three layers should be formed. You will have the denser layer on the bottom of both sides with an intermediate mixed or green colored layer in the middle and the less dense layer on the very top. In Activity A, the surface layer will be yellow, the middle layer green, and blue layer on the bottom. You have increasing density from top to bottom. In Activity B, the surface less dense layer is colored blue, an intermediate layer of green, and a bottom most dense layer of yellow. If you think switching the color of the less and most dense water in Activity B will confuse your students, simply change the instructions so that the densest water in each activity is the same color.

Make certain that your students realize what is happening with the color changes: when two primary colors are mixed, a secondary color results that is the combination of the two primaries. When adding the food coloring to the water, make sure to add enough to make the color very dark. The students can see the two colors interact better that way. Make certain the white background is on the back of the Marsigli's box. The colors are better seen against the white background.

Answers to Discussion Questions for Activity A:

1. The blue, cold water flowed from one side to the other through the bottom opening/hole. The yellow, warm water flowed through the top opening.
2. The blue, cold water was denser.
3. The blue water is denser because cold water is denser than warm water and the blue water stayed on the bottom.
4. The yellow, warm water moved to the top of the other side and after the adjustment it filled the top half of both sides of the box. The blue, cold water moved to fill the bottoms of the both sides of the box.
5. The adjustment occurred because the denser water moved under the less dense water when the two met. Equilibrium was reached when the water on each side had moved from one side to the other to form equally deep layers of color.
6. You mixed the lower and higer density color layers to come up water that has a medium density because the temperature is now a mixture of hot and cold. You created a new green colored mixture when you mixed blue and yellow colored water together.

7. The water mixture turns brown when the red dye is mixed in with the green colored water.
8. The brown colored water moved to the other side through the lower hole. The brown colored water moved up along the divider to flow in between the blue and yellow layers on the other side. The yellow layer was forced up and through the upper hole to flow to the top of the other side of the box while the blue water flowed through the lower hole to the bottom of the opposite side. When the layers were the same thickness on each side of the box the colored water stopped moving. The brown water moved between the blue and yellow layers because its density is intermediate between the hot and cold water.

Answers to Discussion Questions for Activity B:

1. Yellow water flowed from one side to the other through the bottom opening. Blue water flowed from through the top opening to the other side.
2. The salt water was denser.
3. The yellow salt water formed a layer on the bottom so it must have been the more dense liquid.
4. The blue fresh water moved opposite side and after adjusting, filled the upper half of both sides. The yellow saltwater filled the bottom half of the box on both sides. There was a layer of green between the blue and yellow layers.
5. The yellow colored salt water was higher in density than the blue colored freshwater so when the two colored water's met, the more dense salt water moved underneath the less dense fresh water. When the layers of each color were equal sizes on both sides did the water stop moving.
6. You mixed salt and fresh water to come up a new mixture that was half of each. That kind of water is called brackish water and it turned green because mixing blue and yellow produces green. The green water should also have a density somewhere in between the blue and yellow water.
7. When the red dye is mixed in with the green water, the resulting water mixture turns brown.
8. The brown mixture moved to equilibrium by settling between the yellow and blue layers on the opposite side. The blue water was forced upwards and through the upper hole to form an even layer across the top of the box. The blue water moved through the lower hole to form an even layer across the bottom of the box. The brown water forms a layer between the yellow and blue, so that you have three layers now. Why? The density of the brown water is between that of the fresh and salt water's densities.

Approximate Time Required: One class period should be plenty of time unless you wish to spend more time introducing the concept of density.

Target Audience: Science.

Extensions:

Grades 4-6

1. To demonstrate the concept of density, use a glass test tube or other clear container and fill with liquids of varying densities. Students will observe how these liquids float on top of each other. Possible choices of liquids are corn syrup, vegetable oil, vinegar, water. Color any or all with food coloring to make seeing the layers formed easier.
2. In a large aquarium, you can demonstrate density currents. Fill the bottom of the aquarium about a third of the way with very cold water. Use food coloring to die it blue. Start stirring the water in a slow systematic pace. Once a current develops, slowly add the hot water that you have died red to the tank. Continue stirring at the same rate. Students should see how the hot water floats on top of the cold water because it is not as dense. The molecules in the hot water move further apart and become less dense as it cools down. You have a density current formed.

Grades 9-12

1. Assemble common laboratory salts, such as NaCl, KI, $NaHCO_3$, or $MgCl_2$. Your students should each weigh a 250 ml beaker to the nearest 0.01 g. Have students prepare 100 ml of 1 M solutions of the salts you have selected. One hundred ml of the salt solution should be placed into the beaker, reweighing the filled beaker. Record the weights. The density of the solutions should be determined using the formula D=M/V. Students should record densities of the salt solutions in a data table. Give hydrometers to your students so that they can determine the specific gravity of the liguids. They will then convert the specific gravity to density. Results should be recorded. Students should also determine the density of vegetable oil using the two methods.

   Questions:

   a. Which method of determining density do you believe to be most accurate? Why?

   b. If various salt solutions and vegetable oil were placed in a container, how would the solutions arrange themselves? Why?

c. What are the dissolved substances found in the Atlantic Ocean? How are their densities different? Which would tend to be closest to the surface? Which would be found in deepest waters?

2. Carry out the activity as written except vary the concentration of the saltwater. Instead of the 22 g of salt, use the amounts below. Run a trial for each concentration and time the diffusion of the liquids.

Example:	Trial 1	5 g NaCl in 2 L water
	Trial 2	10 g NaCl in 2 L water
	Trial 3	22 g NaCl in 2 L water
	Trial 4	40 g NaCl in 2 L water

Have students graph the results. Plot concentration (g of NaCl/ 2L) versus time (seconds or minutes). You may need to explain the concept of molarity to the students. Have them determine the molarity of the 5 g, 10 g, 22 g, and 50 g solutions of NaCl in 2L water. Your students can then graph molarity of NaCl versus time.

3. Close the floodgate and change the amount of water on each side, making side A higher than side B or vice versa and study the results.