Learning through Experimentation
Ice Cubes, Density, Currents

Adapted from Lawrence Hall of Science GEMS
"Ocean Currents: Marine Science Activities for Grades 5-8"
Activity 5: Ice Cube Demonstration, p 85

OBJECTIVES

- ❖ Compare various approaches to student inquiry
- ❖ Give the students a chance to experiment and observe a phenomenon that may be surprising to them.
- ❖ Reinforce what they know about how salinity, temperature, and density relate to the formation of ocean currents.
- ❖ Connect what they have learned to polar waters.

CONTENT STANDARDS

<u>Sixth Grade</u>
Energy in the Earth's System: 4a, b, c, d, e
Investigation and Experimentation: 7a, b, c, d, e

<u>Seventh Grade</u>
Investigation and Experimentation: 7a, b, c, d, e

<u>Eighth Grade</u>
Motion: 1a, b, c, d, e, f
Density and Buoyancy: 8a, b, c, d
Investigation and Experimentation: 9a, b, c, d, e, f

<u>Ninth through Twelfth Grade</u>
Chemistry: Chemical Thermodynamics: 7a, b, c, d
Earth Science: Energy in the Earth System: 5a, b, c, d, e, f, g & 6a, b, c, d

MATERIALS

Copies of each of the 3 student instructions: "Problem Solving/Challenge," "Open-Ended Exploration," and "Structured Activity"
Clear plastic 10-ounce cups (2 per set-up)
Enough fresh water to provide 8 oz (250 ml) per set-up
Enough salt water to provide 8 oz (250 ml) per set-up
(3-4 Tbsp salt per quart of water is approximately the salinity of open ocean seawater – 35-36 o/oo (parts per thousand), or 3.5-3.6 %.)
Kosher salt is preferred because it makes a clearer solution than regular table salt.
Fresh water ice cubes (all made from the same volume of fresh water), 4 per set-up, in a separate container
Food coloring (not yellow; use a dark color); 1 drop-control vial *or* 1 bottle & an eye dropper per setup
paper for students to take notes and draw diagrams

pens and pencils
paper towels for spills

Set-up for each station:
1 set of instructions
2 clear plastic 10 oz cups
    One containing 8 oz (250 ml) fresh water *
    One containing 8 oz (250 ml) salt water *
        * Both should be at the same temperature (room temperature is fine)
4 ice cubes
spoon
1 vial *or* 1 bottle & eye dropper of food color

The only difference in the set-up between stations is that you should label the cups "salt water" and "fresh water" **only** for the set-ups with the instructions for "Open-Ended Exploration" and "Structured Activity." The "Problem Solving/Challenge" setup should have unlabeled cups.

INSTRUCTIONS
1. Divide your students into groups of about 4 students.
2. Provide each group with one setup of materials.
3. Give each group a different set of instructions (there are 3 sets of instructions, so you may need to repeat – you might put two groups at the same table with the same instructions).
4. Let them experiment. No tasting allowed!
5. Students should take notes during the process, recording their questions, predictions/hypothesis, procedure/set up, results, and conclusions.
6. As you walk around and observe your students, you can give them hints to steer them to think about about temperature and density.

DISCUSSION QUESTIONS FOR AFTER CONDUCTING THE EXPERIMENT
1. Does ice melt faster in fresh water or salt water?
2. When there is warm water and cold water in a cup, which ends up on the bottom?
3. When there is salt water and fresh water in a cup, which ends up on the bottom?
4. How does this knowledge help you explain why the ice cubes melt faster in fresh water than in salt water?

EXPLANATION
The ice cubes melt faster in fresh water. Adding salt to water does lower its freezing point, but in this experiment, the ice cube melts faster in the fresh water because the density of the water already in the cup is different from the density of the water melting off the ice cube.

In the cup of fresh water, the water released from the melting freshwater ice cube is colder than the rest of the water in the cup. Because the density of fresh water increases as it gets colder, the colder melt-water sinks to the bottom of the cup.

You should be able to see this if you put a few drops of dye on top of the ice cube. After a while, the food coloring in the cup will disperse as the all the water in the cup reaches the same temperature.

In the cup of salt water, the fresh water melting off the ice cube stays at the surface and surrounds the ice cube. This is because the melt-water is less dense than the salt water that fills the rest of the cup, even though it is colder than the salt water. The ice cube is 'insulated' from the warmer salt water by the just-melted water from the ice cube. This means that the ice cube melts slower than the ice cube in fresh water. The fresh water layer formed by the ice cube melting can be seen by adding a few drops of food coloring on top of the ice cube.

After waiting the same amount of time as for the fresh water cup, the dye in the salt water cup should still be only in the fresh water layer and remain separate from the salt water.

RELATING CONCEPTS TO THE REAL WORLD

You can relate these ideas to the formation of deep sea currents in Antarctica.

As surface sea water freezes in the polar ocean, salt is squeezed out of the ice as it forms and is trapped in pockets within the ice. The increasing salinity of the water trapped within the honeycomb of ice prevents this water from freezing. Being extremely dense, it slowly drips out of the ice matrix and sinks to the sea bottom. This creates a density-driven current, also called a thermohaline current (*thermo*- for heat and *-haline* for salt). When it reaches the ocean floor, it is called Antarctic Bottom Water. It moves very, very slowly north. It is estimated that it may take this water 1,000 years to reach the North Pacific basin.

Thermohaline circulation is a major part of the oceanic convective system, which distributes heat energy from the equatorial oceans to the polar regions. This **ocean conveyor belt** has a large impact on the climate of our planet. A breakdown of this circulation system probably would cause major changes in local climates throughout the world.

Thinking questions for your students

1. What is an ocean current?
2. Why do you think ocean currents are important?
3. What sets water in motion and causes ocean currents to form?
4. What might happen to ocean currents if all the glaciers in Antarctica melted and flowed into the sea?

Setup Number 1
Problem Solving/Challenge

There are two containers of water on the table. One contains salt water, the other fresh water. Using only the materials at the table, can you devise an experiment that you can perform right now that will reveal which is the salt water?

Record your experiment (design, procedures) and the results. (Write on the back of this paper if necessary.)

Describe the evidence that you collect and how it supports your determination of which is the salt water.

Oh, and by the way, no tasting allowed!

Setup Number 2
Open-Ended Exploration

Examine the materials on the table. Using only those materials, design experiments you can perform to learn as much as you can about:

- the characteristics of warmer vs. cooler water;
- the characteristics of salty vs. fresh water;
- the relative densities of different temperatures and salinities of water;
- density-driven currents in the ocean.

And remember, this is a science classroom—no tasting!

Setup Number 3
Structured Activity

Follow the procedures described below:

1. Find two cups of water on the table. One is labeled "salt water," the other is labeled "fresh water."

2. If you placed one ice cube in each cup at the same time, which do you predict would melt faster?

   ____

   Why?____

   ____

3. Now use the spoon to place 1 ice cube in each cup of water. Observe both for 90 seconds.

4. Which ice cube melted faster? ______________________________________

5. Do you have any further explanation to match your observation?

   ____

   ____

   ____

   Gently add 4 drops of food coloring to each beaker. Describe your observations.

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6. Can you explain what is happening? ______________________________

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Questions to Activate Related Prior Knowledge:

- Why might kids in Arizona/Tahoe/etc. benefit from studying the ocean?
- Describe a memorable experience that you have had related to the ocean.
- Can you think of anything you've heard or read lately in the news about the ocean?
- What do you know about the densities of different water masses in the ocean?
- What do you know about how water moves in the ocean or about ocean currents?
- If the ocean's current patterns change, what are some changes that might occur in your local climate?

Density Driven Circulation and Water Masses

How do density differences in seawater drive deep ocean circulation?

Temperature and salinity are two of the most important properties of ocean water; together they govern the density (mass per unit volume) of seawater. Density differences drive the vertical and horizontal circulation of about 90% of the ocean. Surface seawater that is made denser by cooling, increased salinity, or mixing, sinks to depths where its density is the same as the surrounding water. From there the water spreads horizontally to great distances, layering between waters of lesser density above and greater density below. It continues spreading outward, at a very slow pace compared to surface-ocean currents, as more water of the same density sinks from above.

The tendency of seawater to seek its own density level leads to the formation of distinctive water masses. A **water mass** is a body of seawater that is relatively uniform in density and is identifiable based on its temperature and salinity. The subsurface movement of water masses is called **thermohaline circulation**. Heat transport by moving water masses, likened to huge conveyor belts, is an important control of global climate.

Water masses of different densities tend not to mix. This lack of mixing means that each water-mass layer retains its original properties, including temperature, salinity, percent of dissolved gasses and trace elements, which in turn can be used to identify and track the water mass.

When compared to the approximately 1.0 km per hour speed of most wind driven surface currents, the velocity of a density driven deep ocean current is much slower, typically moving about 1.0 m per hour. The circulation of the deep ocean is driven by the increase in density of surface water due to changes in its temperature and/or salinity. At high latitudes (the polar regions) seawater density is increased by cooling and at any latitude the density of surface water can be increased by net evaporation.

The Ocean's Influence on Climate:

Water's exceptional capacity to store heat has important implications for weather and climate. A large body of water (such as the ocean or the Great Lakes) can significantly influence the climate of downwind localities. The most persistent influence is on air temperature. Compared to an adjacent landmass, a body of water does not warm as much during the day (or in the summer) and does not cool as much at night (or in the winter). In other words, a large body of water exhibits a greater resistance to temperature change, called **thermal inertia,** than does a landmass. Air temperature is regulated to a great extent by the temperature of the surface over which the air resides or travels. Air over a large body of water tends to take on temperature characteristics similar to the surface water. Places immediately downwind of the ocean experience less contrast between average winter and summer temperatures. So in Santa Monica, California, it will stay warmer in the winter and cooler in the summer than it will in Monterey Park, California which is 24 miles inland from the coast. These coastal areas are said to have a **maritime** climate.