Session 1: Observing Convection in Water

Overview

In this session, your students conduct three experimental trials, each involving a drop of food coloring moving through water. Observing how the colored currents move in relation to a heat source enables students to see different segments of a convection current. The students record their observations from each test on a separate data sheet and share their results in a class discussion. The primary objective of the first session is to involve your students in accurate observing, recording, and comparing.

What You Need

For the class:
- □ 4 pitchers, bottles, or jugs (at least 1 liter)
- □ 1 electric water heater, or another way to provide one gallon (4 liters) of hot water near the boiling point (hot tap water is usually not hot enough).
- □ paper towels
- □ 2 1-oz. bottles of blue or green food coloring
- □ chalk and chalkboard

For each group of 3–4 students:
- □ 1 6-oz. wide-mouthed cup (paper or plastic)
- □ 1 8" diameter pan made of clear, thin plastic (used under potted plants). Aluminum pie pans may be substituted if clear plastic pans are unavailable.
- □ 1 medicine dropper
- □ 4 6-oz. styrofoam cups
- □ 2 sheets of white paper
- □ 1 cafeteria tray
- □ 1 deep basin, large bowl, or bucket for collecting used water

For each student:
- □ 3 “Convection Observations” data sheets (master included, page 11)
- □ 1 pencil
Getting Ready

Before the Day of the Class:

1. Purchase pans about 8" in diameter, made of thin, clear plastic. Inexpensive pans are sold in plant nurseries and large variety stores for use under potted plants. Do not use pans with bottoms that have ridges in concentric circles. Radial ridges are acceptable. If clear plastic pans are unavailable, aluminum pie pans can be substituted. Smooth-bottomed pans are best.

2. Duplicate four "Convection Observations" sheets for each student, using the master on page 11. Three of the sheets will be used in the first session; one will be used in Session 2.

3. Conduct Trials A, B, C, and D, as described in the first two sessions, so you can confidently demonstrate the procedures and be able to anticipate problems that your students might encounter.

The Day of the Class:

1. Fill the pitchers or jugs with water at room temperature, and place them in a centrally located area.

2. Set up a coffee pot or other source of about one gallon of very hot water, close to boiling.

3. Put a full dropper of food coloring and one medicine dropper into each wide-mouthed jar or cup. It is best to allow the students to use the food coloring themselves. However, if you are concerned about spills that can create stubborn stains, you may prefer to go around to each lab group yourself during the experiments, and place the drops of food coloring in the pans.

4. On cafeteria trays, assemble the following materials needed by each group of 3-4 students: 4 styrofoam cups, a wide-mouthed container with food coloring and medicine dropper, two sheets of white paper, and a clear plastic pan.

5. Arrange desks or tables and chairs so groups of 3-4 students can work together.
6. Place one large basin, bowl, or bucket near where each team will conduct its experiments.

Introducing the Activity

1. Ask your students to imagine they are in a submarine that is stuck at the bottom of an ocean. The submarine has no power to move itself up or down, but can propel itself horizontally. The class needs to figure out where to find the upward ocean currents so the submarine can rise safely to the surface.

2. Tell the class they will conduct several experiments using food coloring to trace the currents that are formed when water is heated unevenly. These experiments will help them solve the problem of the stranded submarine.

3. Show your students how to set up the test apparatus as illustrated on the data sheets:
   
   a. Line a cafeteria tray with a white sheet of paper.
   
   b. Place three styrofoam cups upside down on the paper.
   
   c. Place the pan on top of the cups.
   
   d. Fill the pan one-half to two-thirds full of water at room temperature, from a jug, bottle, or pitcher.

4. Demonstrate how to place a drop of food coloring in the bottom of the pan of water with the medicine dropper. Emphasize the following points:

   a. The water in the pan should sit for a minute or so before a drop of color is added to be sure there are no initial currents in the water.
   
   b. Dip the medicine dropper into the food coloring and draw a very small amount into the dropper.
   
   c. Move the dropper straight down in the pan of water, slowly, to minimize stirring up the water.

If you don't have enough buckets or basins for each group to have one at its work area, place several large containers in several locations in your classroom. This will reduce the need for your students to be carrying containers of water around the room.
If you think your students will be tempted to add a lot of food coloring rather than the tiniest possible drop, you might want to demonstrate the result of too much food coloring.

d. The tip of the medicine dropper should touch the bottom of the pan before you squeeze out the drop.

e. For best results, release the smallest possible drop and remove the dropper slowly.

f. Keep the food coloring container on the table or desk at all times to avoid spills.

g. Hold a white sheet of paper behind the plastic pan in order to see the food coloring better when viewing the pan from the side.

5. Between trials, students should stir the water gently, to disperse the remnants of the food coloring, then wait a minute or two for the water to become still. Demonstrate how to empty the water into the bucket and replace it with fresh water from a pitcher, should the old water become too dark with food coloring. Caution your students NOT to try to carry a pan full of water across the room. Tell them to bring the pitcher and the bucket right to their water pans and empty the pans there.

6. Distribute data sheets to each student and tell the class to record their observations by drawing arrows on their sheets to indicate in which directions the food coloring moves. Student should also describe the motion in words on their data sheets. Emphasize that each student should record her own observations.

Conducting the Trials

1. Divide your class into groups of 3–4 students. Each group will conduct three experimental trials. Explain that groups may work at different rates. They may wish to repeat trials that were invalid because the water was turbulent, or the drop was not carefully placed. If they finish a trial early, they may repeat it, or observe the experiments of other groups.
2. Ask one person from each group to pick up a tray of equipment (pans, styrofoam cups, food coloring, and medicine droppers). Have them set up the apparatus as demonstrated, and as pictured on the data sheets. Have one or two students go around with the water pitchers or jugs and fill pans two-thirds full with water for all of the groups.

3. Briefly explain the first trial and have the students begin conducting Trial A:

**Trial A:** Observe the movement of a drop of food coloring in still water (with no heat source). The drop should be placed at the center of the pan, right on the bottom. Circle “TRIAL A” on the data sheet. Draw what happens to the food coloring as you look at it from the top and from the side view, and write a brief description of what you see.

4. Go from group to group to offer help and suggestions as needed. When most of the students have completed the first trial, explain the second trial and have them begin:

**Trial B:** Have one person from each group get a styrofoam cup of hot water. Do NOT fill the cup all the way to the top as the danger of scalding spills is too great. Carefully slide the cup under the center of the pan. Place a drop of food coloring at the bottom of the pan, over the heat source. Record your observations on a new data sheet, circling Trial B. Use arrows to show movement.

5. When most of the students have completed Trial B, explain the next trial, and have them begin:

**Trial C:** With the heat source under the center of the pan, place the drop of food coloring on the bottom of the pan, about halfway between the center and side. Record the motions of the food coloring on a third data sheet.

6. Have the students clean up and return all equipment to the assigned areas. Remind your students not to carry a pan full of water across the room, but to empty the water into the bucket near their work area.

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If you have time or if you are interested in devoting another session to experimenting, you might want to have your students try the following trials:

- Place a cup of ice water under one side of the pan, and see how it affects the movement of the food coloring.
- Place a drop of food coloring on the surface of the water, directly over the heat source.
- Place a drop of food coloring on the surface of the water, halfway to the edge of the pan.

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Diffusion: the process by which one substance gradually spreads out or scatters widely in a second substance.

Discussing the Results

1. On the chalkboard, draw a large overhead view and a side view of the plastic pan. Select one team to share its observations of Trial A with the class. Have them describe what they saw and invite one of the students to draw his team's observations on the chalkboard.

2. Ask if there are other teams who have observations that they wish to share regarding Trial A.

3. Summarize the observations for Trial A as follows: If the water is still to begin with, the drop of food coloring expands and grows “fuzzier-looking.” This process is known as diffusion, in which one fluid gradually spreads out and mixes with a second fluid.

4. Select a different team to share its observations of Trial B. Have them proceed as before, describing and adding information to the drawing on the chalkboard. Ask the rest of the class to add other information, descriptions, or observations.

5. Summarize the results of Trial B as follows: The food coloring goes up from the bottom of the pan toward the surface of the water and then spreads outward to the sides. In some cases, you can see the food coloring descend in the outer areas of water.

6. Select a different team to present its observations of Trial C. Invite the other students to make additional comments. Summarize the results of Trial C as follows: The food coloring creeps along the bottom of the pan to the heat source. The food coloring then rises in the water directly over the heat source (as in Trial B).

7. Tell the class that in the next session they will do one more experiment and then apply what they have learned to bring the submarine safely to the surface.
Observations

Overhead View

Circle which trial you are doing:

Trial A: No heat • Drop in center
Trial B: Heat in center • Drop in center
Trial C: Heat in center • Drop halfway to edge
Trial D: Heat in center • Drop in center and halfway to edge

Equipment Arrangement:

Side View

Describe (in words) what is happening:
Session 2: Getting the Whole Picture

Overview

Through a series of discussion questions, the students describe a complete convection current. They apply this knowledge to guide an imaginary submarine through ocean currents generated near a hot volcanic vent. Then your students test their predictions by putting “submarines” (drops of color) at various places in their pans of water and observing what happens. The goal of this session is for your students to learn and apply the concept of a convection current.

What You Need and Getting Ready

The students will use the same materials and equipment set-up as they did in Session 1. Follow “Getting Ready: The Day of The Class,” steps 1–6, page 6. One copy of the “Convection Observations” data sheet is needed for each student.

The Convection Current as a Whole

1. Remind the students that in the last session they did experiments to discover how water moves near a heat source. This session will help them explain what they saw and apply what they learned to navigate an imaginary submarine through ocean currents. Tell them they will also do an additional experiment.

2. On the chalkboard, draw a side view of the pan with a cup of hot water under it, as in the experiment. Help your students describe the complete convection current by asking the following questions, and recording their answers by drawing arrows in the diagram.

   a. Which way does the water move over the heat source? [Up.]

   b. What happens to the water when it reaches the surface? [It moves toward the edge of the pan.]

   An explanation for why convection occurs has not been included in the class discussion. If your students understand the concept of density, you may want to provide an explanation as to why convection occurs. See “Behind the Scenes,” on page 30 for a more detailed description of convection.
Many students conclude that "warm fluids rise." This is because the warm fluid is pushed upward by the cooler, denser fluid that surrounds it.

c. What happens to the water when it reaches the edge? [It moves down. Some students may have observed this; others may not.]

d. Which way does the water move along the bottom of the pan? [Toward the center.]

3. Summarize the results again, but this time in the context of the temperature changes that occur. Explain that the kind of movement the class has observed takes place whenever liquids are heated unevenly. The heat source under the center of the pan heats the water over it. This hot water rises to the surface, and spreads out toward the edges of the pan. As it moves farther from the heat source, the water cools and sinks toward the bottom of the pan. As the cooler water moves toward the heat source along the bottom of the pan, it becomes warmer, and rises to the surface again.

4. Tell your class that their observations describe one way heat moves, called convection. Explain that the path of the motion is called a convection current. Show how the sketch on the board makes two circles. Each of these circles is a convection current. (More advanced students may be able to understand that the convection currents in the whole pan would form a doughnut-shaped pattern when visualized in three dimensions.)

5. Ask your students to remember the submarine stuck at the bottom of the ocean. Draw a sketch on the board showing the ocean bottom with a hot volcanic vent. Explain that such vents do exist in nature, and that they were discovered and explored by submarines, miles deep in the ocean. Draw a tiny submarine far from the vent.

6. Explain how this situation is similar to the pan of water: the ocean vent is very hot and acts like the cup of hot water under the pan. Ask the students to predict the direction of the ocean currents that the submarine will encounter as it approaches the vent. How can the submarine and its crew be saved? Draw the students' ideas with arrows on the board.
Conducting Trial D

1. Tell the class that they will now conduct another trial, like the trials they did in Session 1. This time you’d like them to imagine that the drops of color are submarines with their engines turned off. They’ll be able to find out if their predictions as submarine pilots were correct. Explain Trial D to your students.

   Trial D: Refill the hot water cup, and again place it under the center of the pan. Place one “submarine” (drop) on the bottom of the pan in the center, as in Trial B, and one “submarine” (drop) on the bottom of the pan halfway to the edge, as in Trial C. Draw and write a description of what happens to the two “submarines” on a fourth “Convection Observations” data sheet.

2. Before the students begin, have them predict what will happen to the two “submarines.” Record several predictions on the board.

3. As in the last session, ask one person from each group to pick up a tray of equipment and to set up the apparatus. Have one or two students go around with the water pitchers or jugs and fill pans two-thirds full with water. Have students begin conducting Trial D.

4. When all groups have had a chance to complete Trial D, have them empty their pans and return their equipment on trays to the front of the room.

5. Have one group present its results as you sketch them on the board. Invite other students to comment. Summarize the results as follows: As you might have expected, the “submarine” in the center moved like the drop in Trial B—it rose to the surface and went toward the edge of the pan. The “submarine” off to the side moved like Trial C. It crept along the bottom, heading toward the heat source.

6. Ask your students to summarize what they have learned so far about convection.
Magma Convection Worksheet

Draw arrows to indicate how the magma flows.

Will the distance between North America and Europe increase, decrease, or stay the same? ___________________________