Convection

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

In this 1-2 day activity, students use drops of dye to explore currents in two trays of water. One tray is subjected to heat and cold at opposite ends, and the other is of uniform temperature throughout. Students first compare the behavior of dye drops in the hot end of the unevenly-heated tray with the behavior of dye at one end of the uniform temperature tray. Afterward, they predict the behavior of dye at the cold end and try it, and make detailed observations. Finally, they predict how different colored dyes at the hot and cold ends will move in relation to one another, try it, and make more observations. The teacher wraps up the activity by introducing the terms "convection" and "current." At this point, the idea that the dye is tracing currents in the water is reinforced. Students then conduct a culminating activity that relates these terms to uneven heating, mixing, and the movement of heat through water.

Objectives

Students work with the following ideas and content:

- Heat and cold (different temperatures) in a fluid cause the fluid to move and mix.
- Heat makes some of the fluid rise.
- Cold makes some of the fluid sink.

Students demonstrate understanding of these ideas by:

- Predicting the motion of fluids subjected to heating and cooling,
- Explaining that for fluids to move in response to heat, different areas of the fluid must be at different temperatures.

Correlations to NC Science Standards

5.P.3.1 Explain the effects of the transfer of heat (either by direct contact or at a distance) that occurs between objects at different temperatures. (conduction, convection or radiation).

Brief Science Background

Convection is all around us. It is the evening breeze, ocean currents, and steam rising over a stove. Any time a liquid or gas is heated more in one place than in another, convection causes currents that move the heat around in it. The reason for convection is not appropriate to teach to fifth graders. However, (for teacher background only) it happens because a liquid or gas takes up more space when it is warmed, and it takes up less space when cooled. Whether warm or cool, the liquid or gas still weighs the same, but heating or cooling makes it expand or contract. The not-so-obvious result is that the stuff that takes up more space rises and the stuff that takes up less space sinks, even though its weight is unchanged. It's like what happens when you shake up a jar containing large and small beans. Even if all the beans weigh the same, the large ones move toward the top and the small ones move toward the bottom. As things rise and sink, they produce currents. We experience those currents in the air as a breeze, or as smoke rising above a fire. In the Atlantic Ocean, we experience convection currents as the Gulf Stream flowing past the Eastern Seaboard.

Materials

Materials for the whole class or the teacher

- 24 deli trays (4” x 6”)
- 16 small foam cups
- a permanent marker
- 2 dishpans
- 8 32-oz plastic containers
- a hotpot
- a thermos
- two ice cube trays
- two dye dropper bottles, one red and one blue
- 8 digital thermometers
- (optional) white paper

Materials for groups of 4 students

- three 4 x 6 deli trays containing room temperature water
- one small foam cup labeled “C” containing ice water
- one empty small foam cup labeled “H”
- a digital thermometer

Preparation

1. A day before the activity, set out the eight 32-oz containers filled with water to come to room temperature. Have these available on the day of the activity for students to replenish water in their trays. Also, fill the ice trays and freeze them.
2. On the day of the activity, fill two trays for each team with room temperature water to the shoulder of the tray (about ¼ inch from the top).
3. On the day of the activity, heat water in the hotpot, pour it into the thermos, and adjust the temperature to about 130° F. Three full hotpots fill the thermos. During the activity, you will pour hot water from the thermos into the small foam cups at each team’s station.
4. Place the two dishpans where teams have access and a little spillage will do no harm. Teams dispose of used water in these between parts of the activity.
5. Use the permanent marker to label small foam cups “C” and “H,” one each per team. Just before the activity, fill the “C” cups with ice and add water to the brim so that ice protrudes above the lip. Place these full ice water cups and the empty “H” cups in the empty trays as shown in BLM 1.
6. Set up the student workspaces (see materials for groups of 4 above and the diagram under procedure below) with both trays of room temperature water on the table top. Students see results more easily when the setup is over a white background. If your tables are dark, put white paper under the setup.

Preparation cont.

7. Set up the student workspaces (see materials for groups of 4 above and the diagram under procedure below) with both trays of room temperature water on the table top. **Results are clearer over a white background. Place white paper under setups if tables are dark.**

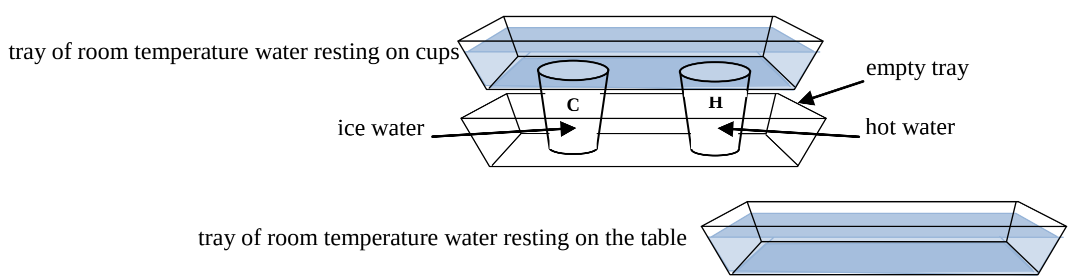
Procedure

1. Explain that each team will explore what happens to drops of dye placed in two different trays of water. Ask them to carefully observe both trays and to especially note what is different about the two trays.

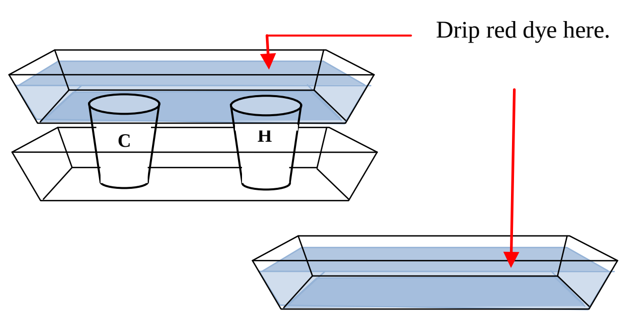
2. Show how to turn on thermometers and set them to ˚F (˚F provides a finer measure). Explain that if thermometers automatically turn off, to just turn them back on. Ask students to measure and record water temperature in both trays.

3. Circulate around the room to pour hot water into the cups labeled H. **Pour to near the top but not to the brim. In contrast, the cold cup labeled C should be full to the brim with water containing ice so that some ice protrudes above the top of the cup. You might need to add a little water to the cold cup.** Ask students to record water temperatures in both cups (H and C) and record these in their notebooks as “beginning temperature H” and “beginning temperature C.”

4. Project BLM 1 and ask students to set up their stations as in the diagram. **When teams place the tray of room temperature water on the cups, a little water should spill from the cold cup into the empty tray below. Ice in the cup should touch the tray resting above it.** After this, ask teams to let the setup rest undisturbed for 2 minutes. Ask them not to touch the table or the setup throughout the activity. While setups rest, ask students to predict (as class discussion) what they think will happen when you drip dye in over the cup labeled H.



5. After setups settle, circulate among teams with the red dye dropper to add 3 drops of dye to the tray of water resting on the cups. Drip near the surface but not touching, <u>directly over the center of the “H” cup</u>. In the tray on the table top, drip the dye <u>at the same relative location</u>.



Procedure Cont.

Allow about 3-4 minutes to observe the movement of the dye. When teams finish observing, ask them to respond to the following notebook prompt.

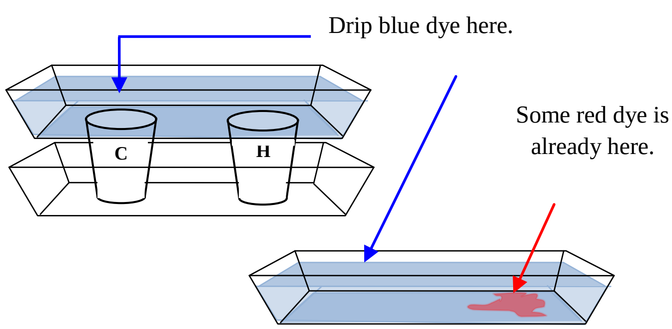
Notebook Prompt: Describe how the dye moves in both trays and compare them. Include a sketch of the pattern of dye in both trays.

6. Conduct a whole-class discussion to bring out observations about differences in the pattern of dye in the two trays. Ask students to speculate about reasons for the differences. **Accept all ideas. Do not correct misconceptions or teach about convection now.**

7. Explain that the class will repeat what we have just done, only this time, add dye over the middle of the "C" (ice water) cup and on the other side of the tray on the table top. Hold a class discussion about what students think they will see both trays. Get as many predictions as possible.

8. Ask students to leave the tray on the table top in place, and carefully take the tray that is resting on the cups, empty it in one of the dishpans, and refill it from one of the 32-oz room temperature water containers. Ask them to measure the temperature of the refilled tray, then place it on the cups as before. Ask them to let the tray rest for 2 minutes.

9. As teams are ready, circulate with the blue dye dropper to drip 3 drops into trays resting on the cups directly over the center of the "C" ice water cup. Also drip 3 drops at the same relative location in the tray on the table top. Ask students to observe for 3 minutes.



10. Hold a class discussion and ask the following:
    - Describe how the blue dye moved in both trays.
    - How do results compare to our predictions?
    - How might you explain the movement of the blue dye?

11. Ask students to leave the tray on the table top untouched (now with blue and red blobs at opposite ends). Ask teams to empty the tray that was sitting on the cups, and replace the water with clean room temperature water as before. Ask them to put the refilled tray back in place on the cups again.

12. Explain that we saw how dye moved from the hot and cold cups separately. Ask the class what they expect to see if we put dye over both cups at the same time? Bring out ideas. Some students might need to draw on the board, or have you draw for them.

Procedure Cont.

13. Circulate among the teams with both dye dropper bottles and drip 3 drops of red over the "H" cups and 3 drops of blue over the "C" cups. Since there is already dye at both ends of the tray on the table top, no more dye needs to be added to that tray. Ask students to observe. After they have observed for 3-4 minutes, give out BLM 2, project the notebook prompt, and ask students to respond to it.

    Notebook Prompt: Describe the movement of the red and blue dye. Give possible reasons for what you saw. Use the handout to draw how the dye moved.

14. When students finish describing and drawing, ask where the most mixing occurred, and why they think this might be.

15. Ask teams to measure temperature of the bottom of the tray directly over the center of the C cup, the H cup, and midway between them, and record all three temperatures in their notebooks.

16. Ask teams to remove the tray from the cups, set it aside, measure water temperature inside the C and H cups, and record these labeled as "final temperature H" and "final temperature C."

Content Wrap-Up

1. Ask students to explain their ideas about the function of the dye. Ask students for temperatures they measured in the tray over the cups. The two colors followed the movement of different temperatures of water. Explain that we call water or air that is moving in the same direction a "current." The dye traced currents. Ask students for places they have come across currents (e.g. a stream, the beach, or air currents in a house from HVAC). Write "current" for all to see, and ask students to write it, and define it in their own words in their notebooks.

2. Remind everyone of class discussions about the currents in the trays. Recall discussion points about heat and cold making currents. Explain that currents in water or air caused by one place being warmer than another are called "convection" currents. Write this term for all to see, and ask students to define it in their own words in their notebooks. Ask what direction the currents moved (both vertically and horizontally).

3. Ask students to calculate the change in water temperature in the H and C cups from beginning to final (with a plus for increase and minus for decrease). You might need to tell them to subtract the final from the beginning temperatures that they have recorded. Put results up for all to see. In general, all of the H cups lost temperature, and all of the C cups gained. Explain that convection currents move heat from hot places to cool ones. The current moved heat from the hot cup to the cold one.

Notebook Prompts:

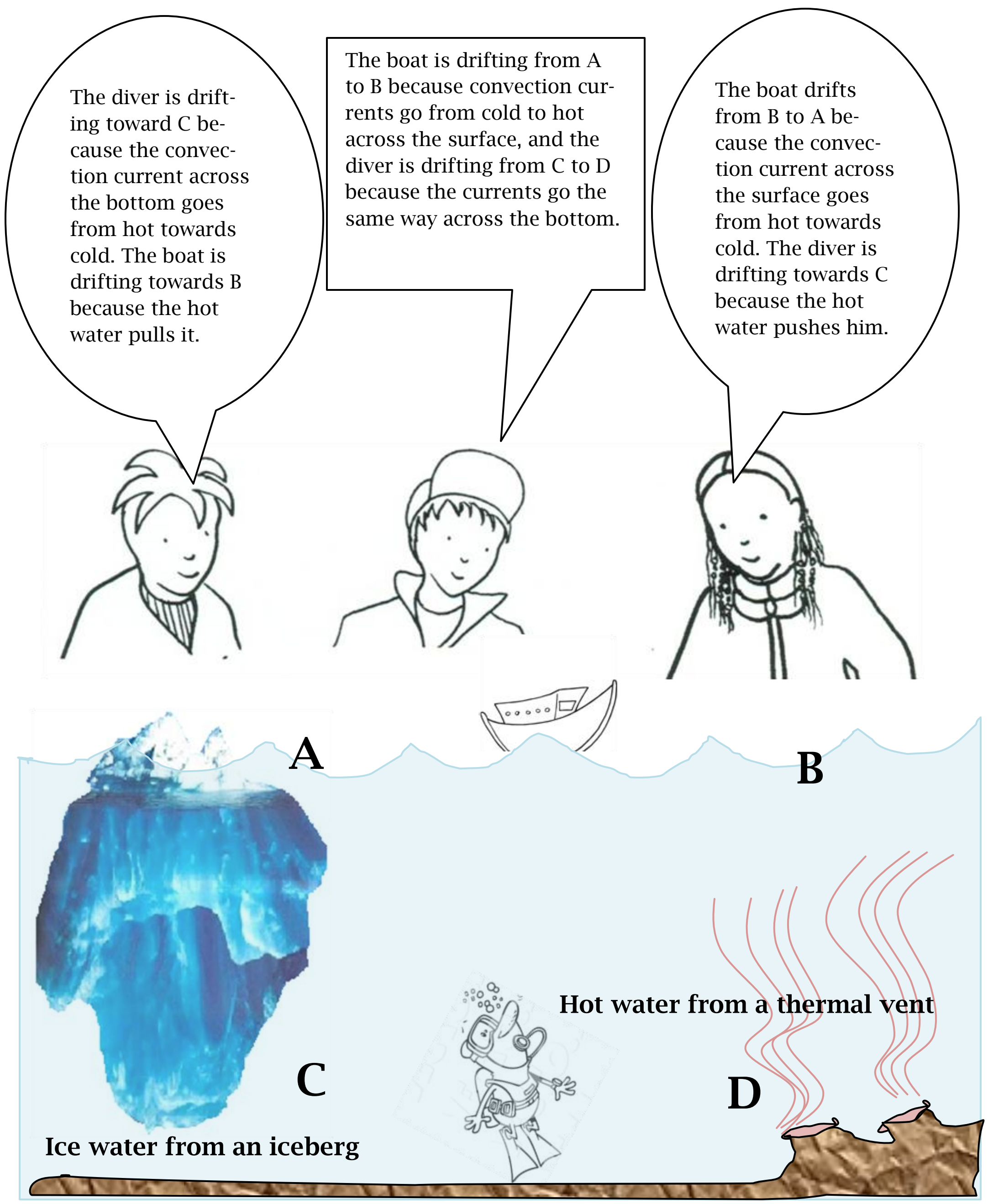
- A new student has come into the class, and you are trying to catch that person up on what's been going on. Explain what we have done and use the terms "current" and "convection" to describe what you saw. Also describe how heat moved.

- Describe any changes that you think would occur if the blue dye was placed in the tray of room temperature water above the hot H cup and the red dye was placed above the cold C cup (opposite the way we did it).

Guided Practice

Project BLM3, the concept cartoon, for all to see. Ask students to choose a character they disagree with (or partially disagree with) and explain what is wrong with that character's reasoning.

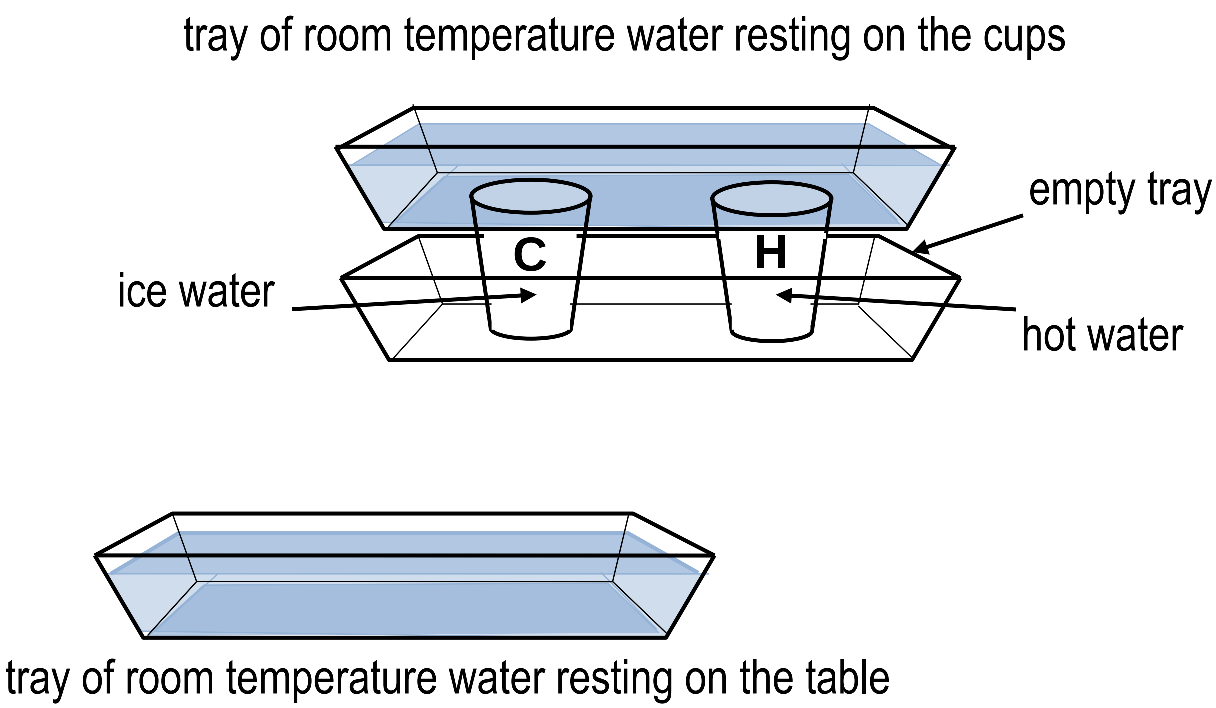
In the scene below, the scuba diver is too tired to swim, and the boat is out of gas. Only the currents in the ocean are moving them. Hot water from the sea floor and ice water from the iceberg are making the currents in this part of the ocean. Which directions are the boat and diver drifting, and why?



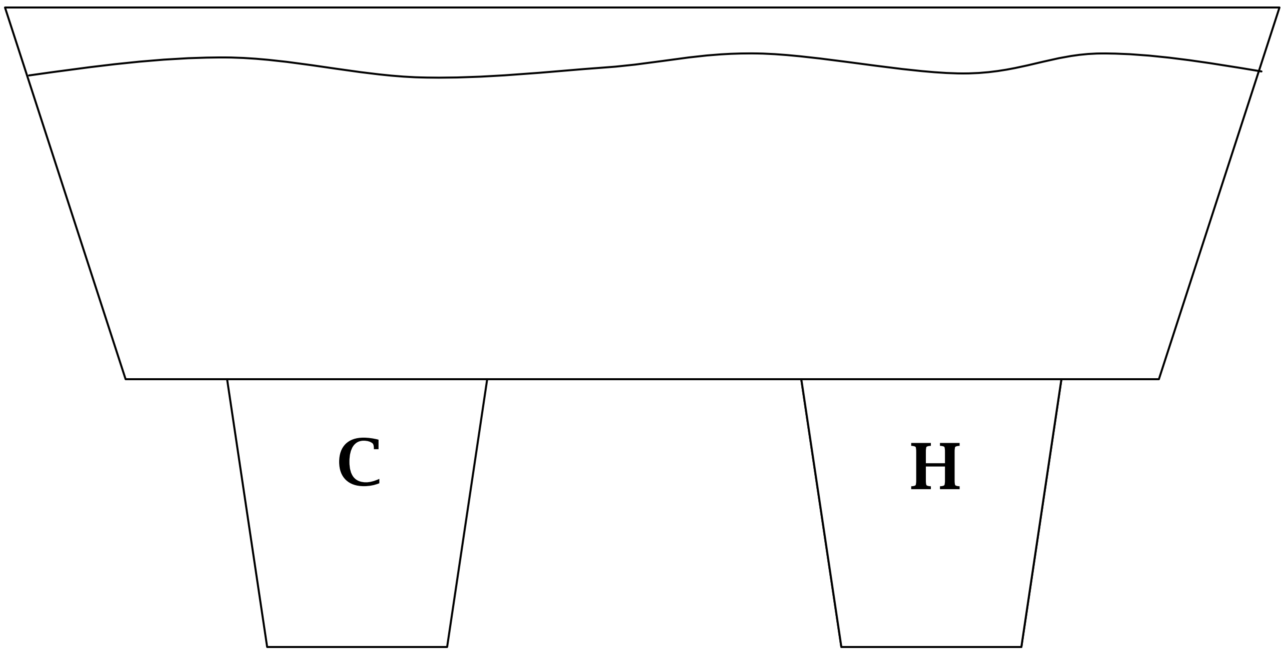
Answer Key

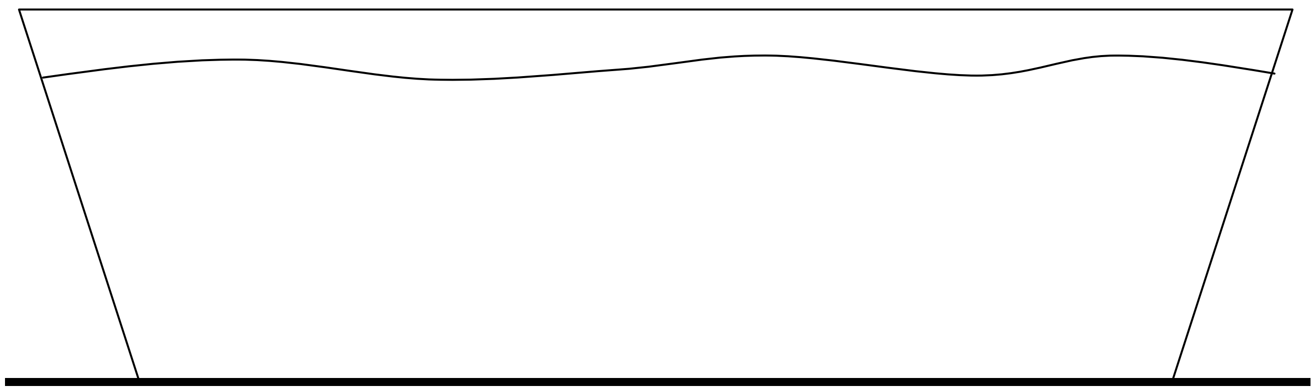
- The boy with no hat says the diver is drifting toward the iceberg. The convection current moves from the thermal vents across the surface of the water toward the iceberg, and then from the iceberg toward the thermal vents across the bottom. The diver would be drifting toward the thermal vents, not away from them.
- The boy in the baseball cap is correct about the direction the diver drifts. The convection current moves across the bottom from the iceberg toward the thermal vents, making the diver drift toward the thermal vents. However, the currents do not move the same way across the bottom and the surface. Contrary to what he says about the current on the surface, it would move toward the iceberg, pushing the boat from B to A.
- The girl correctly says the boat would drift from B to A because convection currents would move from the thermal vents toward the iceberg. However, she says that the diver would drift toward C. Contrary to what she says, the diver would drift toward D because the convection current moves across the bottom from the iceberg toward the thermal vents.

BLM 1


tray of room temperature water resting on the cups
empty tray
C
H
ice water
hot water
tray of room temperature water resting on the table

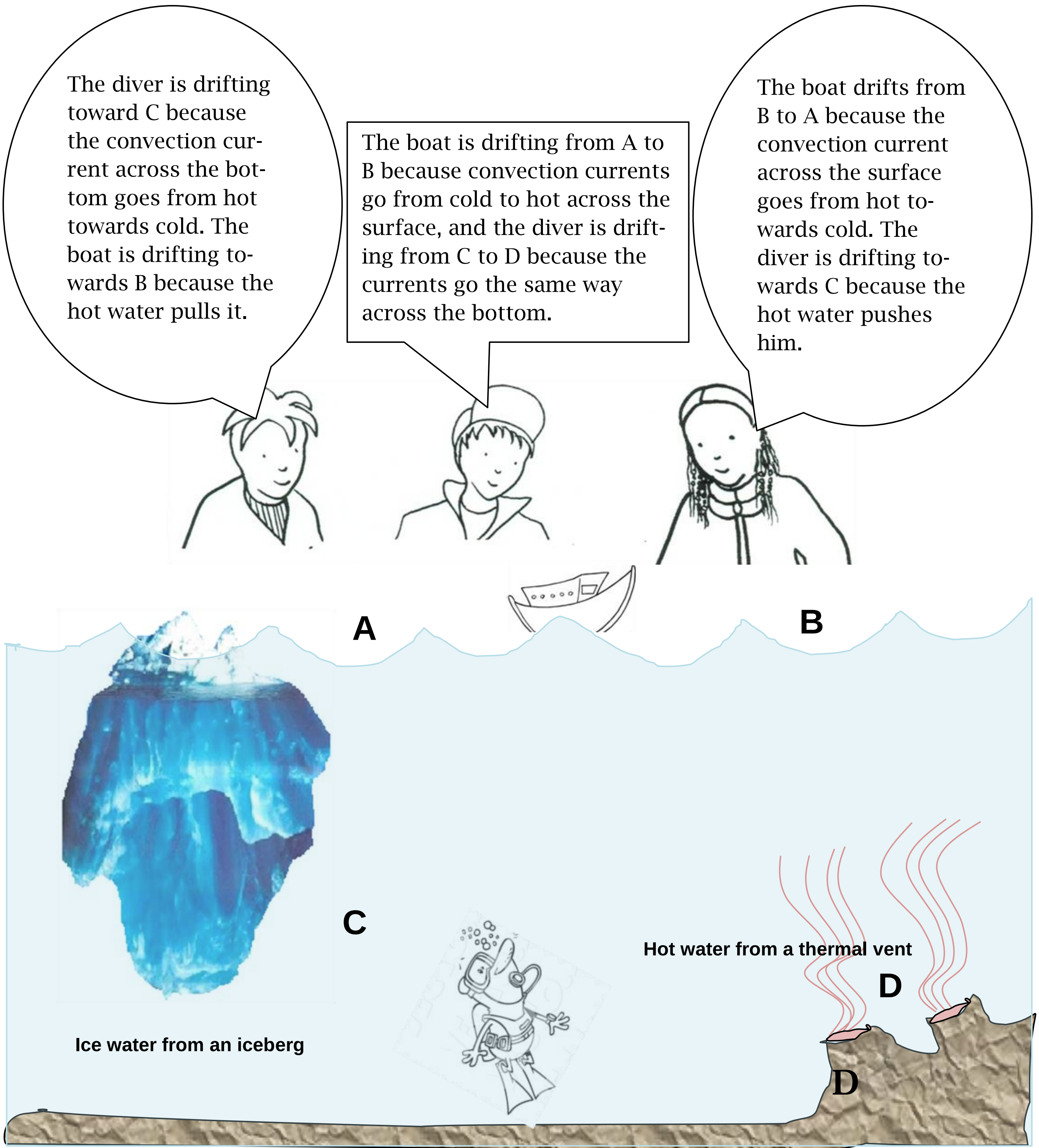
BLM 2





BLM 3 Concept Cartoon

In the scene below, the scuba diver is too tired to swim and the boat is out of gas. They are drifting in the currents. Hot water from the sea floor and ice water from the iceberg are making the currents in this part of the ocean. Which directions are the boat and diver drifting, and why?



Appendix

Common Student Preconceptions About This Topic

Children are familiar with the idea that “heat rises,” but they think of heat as a material that rises, not of a heated gas or fluid becoming buoyant in its surroundings. As a result, they tend to reduce the idea of convection to “heat rises.” Fewer students are familiar with the idea that cooler areas tend to sink. If they are aware of this, they are likely to think of cold as a material that is the opposite of heat. At fifth grade, without a grasp of the particle theory of matter, students are not well equipped to understand how heating and cooling materials decreases and increases density (mass stays the same while volume changes). Even if students know this as a fact, it is difficult to explain the forces that cause floating and sinking to drive convection. It is more appropriate for 5th grade students to understand that different amounts of heat at different places in a fluid or gas generate specific, predictable currents in that material. They might also understand that convection currents distribute heat around the gas or fluid.