NYC Companion Lesson

Investigating Deep Ocean Currents

Overview

This hands-on activity extends students' understanding of what causes ocean currents by providing students with an opportunity to explore deep ocean currents that are driven by density differences. Students observe a model of deep ocean currents and share initial ideas of what could cause water movement. They are then given four different samples of water (hot-fresh, cold-fresh, hot-salty, and cold-salty) and are challenged to create four distinct layers. A discussion of students' results introduces them to the concept of density, which they then use to explain the deep ocean currents model. Afterward, students read an article to gather more information about density and deep ocean currents. The purpose of this lesson is to introduce students to the property of density as a way to explain how deep ocean currents form.

Recommended Placement: *Ocean, Atmosphere, and Climate*, after Lesson 3.3
Suggested Time Frame: 90 minutes (can be spread across multiple class periods)

Note: The homework assignment for Lesson 3.3 (reading the article "Deep Ocean Currents: Driven by Density") should be assigned after this lesson rather than after Lesson 3.3.

NYS P–12 Science Learning Standards

Performance Expectations	• **MS-PS1-7:** Use evidence to illustrate that density is a property that can be used to identify samples of matter. • **MS-ESS2-6:** Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
Disciplinary Core Ideas	• **PS1.A: Structure and Properties of Matter:** ° (NYSED) Each substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-3) (MS-PS1-7) (Note: This Disciplinary Core Idea is also addressed by MS-PS1-2.)

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Disciplinary Core Ideas	• **ESS2.C: The Roles of Water in Earth's Surface Processes:** ° Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. (MS-ESS2-6)
Science and Engineering Practices	• **Practice 2:** Developing and Using Models • **Practice 3:** Planning and Carrying Out Investigations • **Practice 4:** Analyzing and Interpreting Data • **Practice 8:** Obtaining, Evaluating, and Communicating Information
Crosscutting Concepts	• Patterns • Cause and Effect • Systems and System Models • Energy and Matter: Flows, Cycles, and Conservation

Vocabulary

- density
- ocean current
- temperature

Materials & Preparation

Materials

For the Class

- Investigating Deep Ocean Currents copymaster
- 1 clear plastic bin
- 2 small foam cups, 8 oz.
- 2 ½ cups salt
- 10 large foam cups, 24 oz.
- 10 lids for large foam cups
- food coloring: red, blue, yellow, green
- 2 pushpins*
- 6 black rocks**
- water (cold, hot, and room temp.)*
- large pitcher*
- large spoon*
- sheet of white paper*
- tape*
- marker*
- measuring cup, 2-cup*
- measuring spoon, tablespoon*
- 1 large index card*

Materials (continued)

For Each Group of Four Students

- 1 tray*
- 3 clear plastic straws
- 1 small ball of modeling clay
- 4 small foam cups, 8 oz.
- 4 lids for small foam cups
- 4 droppers
- small waste container*
- sets of crayons or colored pencils (1 each red, yellow, blue, and green)*

For Each Student

- Investigating Deep Ocean Currents student sheets*

*teacher provided
**from *Ocean, Atmosphere, and Climate* kit

Preparation

Safety Note: Hot Water

The hot water can burn if it comes in contact with skin. Students should be cautious when handling hot water and when using the droppers with hot water.

1. **Print Investigating Deep Ocean Currents copymaster.** Locate the Investigating Deep Ocean Currents copymaster on the New York City Resources webpage: www.amplify.com/amplify-science-new-york-city-resources. Make one copy of all pages for each student.
2. **Create and post vocabulary card on the classroom wall.** With a marker, write "density" in large print on a large index card. Post this card on the classroom wall.
3. **Read the "Deep Ocean Currents: Driven by Density" article for background information.** The article can be found in the Student Edition, the Amplify Library, or in Digital Resources for *Ocean, Atmosphere, and Climate* Lesson 3.3. The homework assignment (reading "Deep Ocean Currents: Driven by Density") should be assigned after this companion lesson, rather than after Lesson 3.3.
4. **Prepare deep ocean currents demonstration.** See the Teacher Reference section of this lesson.
    a. **Prepare bin setup.** Refer to the first image for guidance. Place the plastic bin on a table where it will be visible to all students. Place two small foam cups in the plastic bin, one at each side and toward the back of the bin, and then place three rocks in each cup to keep them from tipping or floating. Add room temperature water to the bin until it is about ¾ full, but be sure the water is still below the top of the empty cups. Make sure the cups do not float. Stick a pushpin in each cup just below

the surface of the water. Leave the pushpins in the cups. Tape a sheet of white paper to the back of the bin so the colored water will be easily observed during the demonstration.

b. **Prepare purple-cold-salty water.** Fill one large foam cup with 1 1/2 cups of very cold tap water. In the water dissolve 6 tablespoons of salt. Add 3 drops of red food coloring and 3 drops of blue food coloring to make a purple color. Set aside until the demonstration. Prepare more purple-cold-salty water between each class period.

c. **Prepare orange-hot-freshwater.** Fill another large foam cup with 1 1/2 cups of hot freshwater. Add 3 drops of red food coloring and 3 drops of yellow food coloring to make an orange color. Set aside until the demonstration. Prepare more orange-hot-freshwater between each class period.

5. **Prepare layering liquids activity.**

   a. **Create key.** Write the following on the board with the label, "Color Key:"

   "Red = Hot-Salty"

   "Blue = Cold-Salty"

   "Yellow = Hot-Fresh

   "Green = Cold-Fresh"

   b. **Label two large foam cups with each water-color combination.** There should be eight cups in all—two red, two blue, two yellow, and two green.

   c. **Prepare water-color mixtures.** Add about 20 drops of the appropriate food color to each marked foam cup. Add 2 cups of very hot tap water to each Yellow cup. Add 4 cups of very hot tap water to the pitcher and pour in 1 cup of salt. Stir; then distribute to the two Red cups. Add 2 cups of very cold tap water to each Green cup. Add 4 cups of very cold tap water to the pitcher and pour in 1 cup of salt. Stir; then distribute to the two Blue cups. Set cups aside for the layering liquids activity. Note: This will be enough for one class. You will need to prepare additional mixtures between classes or use insulated containers to prepare larger volumes in advance.

   d. **Prepare trays for each group of four students.** Place the following on each tray:

   - 1 small ball of clay (about half the size of a golf ball)
   - 3 straws
   - 4 small foam cups with lids
   - 4 droppers
   - waste container

Preparation (continued)

6. **Practice demonstrating the layering liquids procedure.** Refer to the image in the Teacher Reference section of this lesson.
   a. **Prepare setup.** Take a ball of clay and flatten it slightly to about ½" thickness. Place one straw in the clay at a 45° angle. The clay is a holder for the straw, and the straw needs to be at this angle so the liquid can travel down the side of the straw. Each group needs one straw; two are extra.
   b. **Add first water-color mixture.** Draw one colored liquid into the dropper, place the tip of the dropper just above the opening of the straw, and carefully squeeze the bulb to expel the liquid into the straw, one drop at a time. Add enough drops until the straw is holding about one finger's width of liquid.
   c. **Add next water-color mixture.** Add drops of a different colored mixture in the same way. See whether they form layers or mix together. Students will be attempting to add two additional layers.
   d. **Reset the materials for another test.** To begin another test, discard the water in a waste container. If clay gets stuck in the straw, you can squeeze it out and add it back to the ball of clay. The ball of clay may need to be reformed for the next test. Students will have two extra straws available if the first gets damaged.
7. **Locate and review rubrics.** Review the Rubrics for Assessing Students' Understanding of the Effects of Density on Deep Ocean Currents in the Assessment section of this lesson. These rubrics can help you plan ways to support students as they construct explanations and draw conclusions during the lesson. After the lesson, use the rubrics to formatively assess students' developing facility with crosscutting concepts and their understanding of disciplinary core ideas.
8. **Immediately before the lesson, have on hand the following materials:**
   - student sheets
   - deep ocean current demonstration setup
   - prepared cups of orange and purple water
   - trays of student materials
   - prepared large foam cups with red, blue, yellow and green water mixtures
   - sets of colored pencils

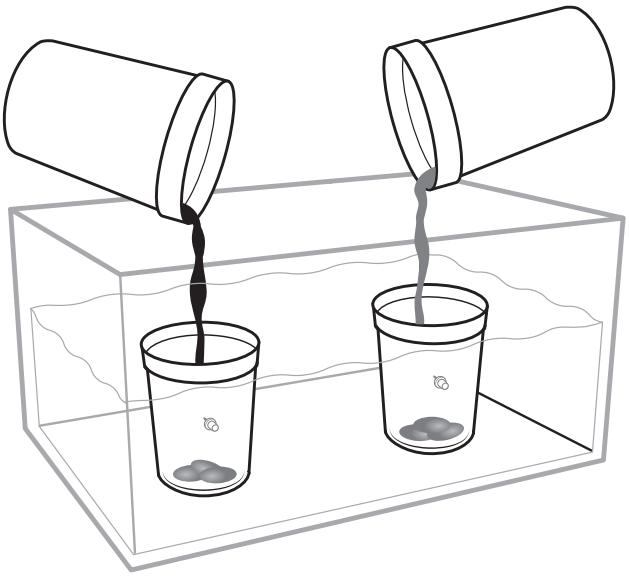
Science Background

Density is the amount of matter in a certain amount of space. A material's density is its mass per unit volume, which depends on the mass of the individual particles (molecules, atoms, or ions) that make up a material, their size, and how far apart they are. When comparing the same volume of salt water to freshwater, the salt water will have more mass. The chlorine and sodium ions have more mass than water molecules. The chlorine and sodium ions also take up some of the space between the water molecules. For both reasons, salt water has more matter in the same amount of space as freshwater.

The density of a material also varies with temperature and pressure. The molecules of materials that are higher in temperature move faster and take up more space. As temperature increases, density decreases (with a few exceptions). Increasing the pressure on an object causes the molecules to get closer together, which decreases the volume of the object and thus increases its density. The force of gravity on Earth causes materials that have different densities to either sink or float when combined. Materials with higher densities sink to the bottom while materials with lower densities float to the top.

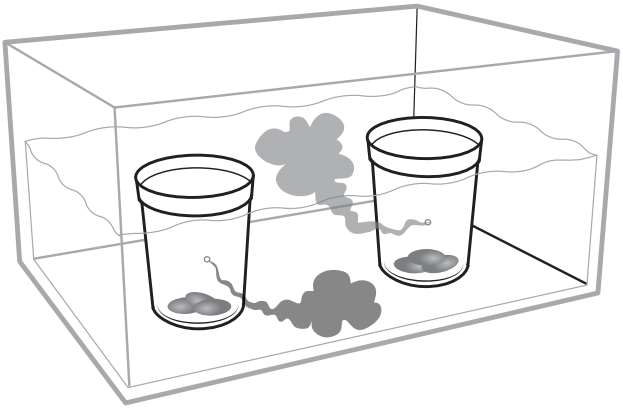
Density drives deep ocean currents; this process is called thermohaline circulation. Differences in density are controlled by temperature and salinity. Colder water and water with a higher salt content are more dense. This dense water sinks and, as it sinks, warm surface water moves horizontally to replace it.

Teacher Reference

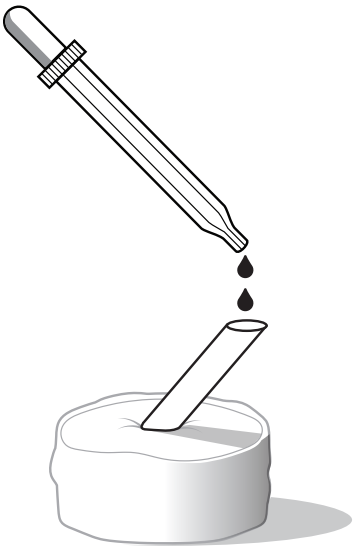


Deep Ocean Currents Demonstration Set Up and Procedure

To set up the deep ocean currents demonstration, pour purple and orange water from the large foam cups into the small foam cups with pushpins.



When the pushpins are removed, the purple water (cold and salty) should sink below the surrounding water and the orange water (hot and fresh) should float on top.



Layering Liquids Set Up and Procedure

This image shows the procedure for layering liquids inside a straw.

Instructional Guide

Explore and Activate Prior Knowledge

1. **Introduce deep ocean currents.** Explain that prevailing winds cause the movement of water on the ocean's surface, but there are also currents below the surface.
2. **Conduct deep ocean currents demonstration.** Distribute the Investigating Deep Ocean Currents student sheets and direct students to Part 1: Deep Ocean Currents Model.
   - Inform students that this is a model of how water under the surface of the ocean moves.
   - Fill one cup in the demonstration bin with the prepared purple water and the other cup with the prepared orange water. Do not tell students how the mixtures differ, just explain that they are different colors so they will be able to see and track the water.
   - Remove the pushpins and prompt students to observe the movement of the water. Direct students to record their observations in Part 1.
   - As the water flows from the cups, point to both currents and explain that something causes some water to sink and travel across the deep ocean while other water stays closer to the surface.
   - Pour additional water into the cups so the water keeps flowing.
3. **Students discuss initial ideas.** Ask students what they think could cause some ocean currents to be deeper in the ocean than others. Prompt students to first discuss and record ideas with a partner, then share ideas with the class. Accept all answers and inform students that they will investigate this in the next activity.

Construct New Ideas

4. **Discuss characteristics of ocean water.** Ask students to describe the characteristics of water in the ocean. Highlight responses related to salt and different temperatures. Explain that in the upcoming investigation, they will work with four different types of water: hot-fresh, cold-fresh, hot-salty, and cold-salty. Explain that freshwater is water with little or no salt. The freshwater that they will be working with today has no salt. They will investigate whether these characteristics can help them explain why some water sinks to the bottom while other water rises to the top.

5. **Introduce layering liquids activity.** Inform students that they will use four different water-color mixtures to try to create distinct layers so none of the colors mix. Point out the Color Key and review the different colors. Point out the materials and challenge them to make as many layers as they can. Suggest that they first try to make two layers, then three, or even four. Point out the Part 2: Layering Liquids student sheets. Explain that students will first plan one test—they will decide on the order in which they add the liquids to the straw, explain their thinking, and color-code the prediction diagram. They will then test and record the results. When they plan the next test, they should consider the results of the previous test.
6. **Demonstrate procedure.** Show students how to set up the clay and straw, add the first water-color mixture, add an additional water-color mixture, and finally, how to use the waste container to reset the materials for another test.
7. **Students make first plan.** Give groups a few minutes to make their first plan, write their reasoning, and draw their predictions in Part 2. Encourage students to discuss their plans with the whole group.
8. **Distribute materials.** From the larger containers mixed earlier, fill the small foam cups on each tray about 1/3 full. Alternatively, keep the water mixtures at a central station, and have students fill their own cups when they are ready. For safety, it is recommended that you remove the lids from the large cups before pouring instead of pouring through a hole in the lid. Remind students that two containers are hot, and they should be careful when handling them. Tell students to keep the lids on their cups whenever they are not using them so the hot water stays hot and the cold water stays cold. Distribute colored pencils.
9. **Students complete activity.** Suggest that students practice the procedure before completing their tests. After testing and recording results, remind students to write and explain their reasoning for the next test. Encourage students to use the results from each test to help them plan for the next test.
10. **Lead a class discussion about results.** Invite students to share how they were able to make different layers (which water was at the bottom and which was at the top). Ask students why they think they were able to layer the water that way. Highlight responses related to salty and cold water being heavier or more dense than fresh and hot water.
11. **Introduce the concept of density.**

    Density is the amount of matter in a certain amount of space. When liquids that have different densities are combined, the one that is more dense will sink to the bottom, and the one that is less dense will float on top. You may have also seen this with other liquid combinations such as salad dressing, unstirred peanut butter, yogurt, and unfiltered fruit juices.

    Point out that the vocabulary word is posted on the classroom wall. Students can also find the definition in the glossary at the back of their Student Editions.

12. **Discuss the densities of the different layers.** Referring to the activity, ask students the following questions:
    - Which liquids were more dense? [Liquids at the bottom. Blue-Cold-Salty.]
    - Which liquids were less dense? [Liquids at the top. Liquids that floated. Yellow- Hot-Fresh.]
    - Why do you think the salt water would be more dense than the freshwater? [Salt water has salt plus water, so there is more stuff in it than freshwater.]
13. **Discuss salt water vs. freshwater.**

    Salt water is more dense than freshwater, as you saw in the layering liquids activity. The particles that make up salt have more mass than the water molecules, plus they take up some of the space between the water molecules, so salt water has more matter in the same volume as freshwater.
14. **Discuss hot and cold water.** Explain that temperature also affects density.

    Molecules are always moving. When the temperature is higher, the molecules move faster, which causes them to spread out a little. When they are farther apart, they fill a larger volume. That makes it less dense.
15. **Explain that density is a property of substances.**

    We can use density to identify different samples of water. Samples of water at specific temperatures have a specific density. Cold water has a higher density than hot water. Water with different amounts of salt in it also have specific densities. Water with a high level of salt is more dense than water with less salt.

Apply New Ideas

16. **Students complete Part 3: Identifying Deep Ocean Currents.** Direct students to Part 3 and have them discuss the questions with a partner. Have students write their responses.
17. **Conduct a class discussion.** Ask students to share their responses to the questions in Part 3. Highlight student responses that correctly explain that liquids with a higher density sink below liquids with a lower density. Students should also explain that salty water has a higher density than freshwater, and cold water has a higher density than hot water.

Rubrics for Assessing Students' Understanding of the Effects of Density on Deep Ocean Currents

The rubrics below may be used to review students' explanations and formatively assess students' developing understanding of crosscutting concepts and disciplinary core ideas.

Rubric 1: Assessing Students' Understanding of the Crosscutting Concept of Cause and Effect

Note that this rubric applies to Part 3: Identifying Deep Ocean Currents of the Investigating Deep Ocean Currents student sheets. Rubric 1 considers how well students are able to apply the crosscutting concept of Cause and Effect to a specific phenomenon. This rubric may be used formatively to support students with the crosscutting concept of Cause and Effect. Students will have more opportunities to apply this crosscutting concept throughout the rest of the *Ocean, Atmosphere, and Climate* unit.

Rubric 1: Assessing Students' Understanding of the Crosscutting Concept of Cause and Effect

Criteria	Description and possible feedback	Level
Consistent with accepted science ideas and data generated. Does the explanation use cause-and-effect relationships to explain phenomena?	Students don't use a cause-and-effect relationship to explain why the purple and orange water moved in the ways they did. Example: The purple water went to the bottom and the orange water went to the top. Possible feedback: *Why did the purple water go to the bottom? Why did the orange water go to the top? What caused that to happen?*	0

(Table continues on the next page.)

Rubric 1: Assessing Students' Understanding of the Crosscutting Concept of Cause and Effect (continued)

Criteria	Description and possible feedback	Level
(continued from previous page)	Students use a cause-and-effect relationship to explain why the purple water moved the way it did OR why the orange water moved the way it did. Example: The purple water sank because it was more dense than the surrounding water, and that caused it to sink. The orange water floated. Possible feedback: *You explained why the purple water sank, why did the orange water float?*	1
	Students use a cause-and-effect relationship to explain why the purple water moved the way it did AND why the orange water moved the way it did. Example: The purple water sank because it was more dense than the surrounding water, and that caused it to sink. The orange water was less dense than the surrounding water and that caused the orange water to float.	2

Rubric 2: Assessing Students' Understanding of Science Ideas Encountered in the Unit

Note that this rubric applies to Part 3: Identifying Deep Ocean Currents of the Investigating Deep Ocean Currents student sheets. Rubric 2 considers whether students have constructed and applied ideas in a way that is consistent with accepted science ideas. This rubric is designed to be formative and inform instruction around the "Deep Ocean Currents: Driven by Density" article. Space is provided to note whether students are demonstrating understanding or if their ideas would benefit from more support. If students are having difficulty with a particular idea or with multiple ideas, you might make time to have students connect the ideas in the "Deep Ocean Currents: Driven by Density" article to the class demonstration of deep ocean currents (purple and orange water). Ask students which part of the model represents a deep ocean current. Ask how the model is similar to or different from deep ocean currents on Earth.

Rubric 2: Assessing Students' Understanding of Science Ideas Encountered in the Unit

Criteria	Description	Is there evidence of student understanding?
Consistent with accepted science ideas. Are students' conclusions consistent with accepted science ideas?	Students demonstrate understanding of the idea that more dense materials sink below less dense materials. Example: The purple water must have been more dense than the surrounding water and this caused it to sink. The orange water must have been less dense than the surrounding water and this caused it to float.	
	Students demonstrate understanding of the idea that density is a property that can be used to identify a material. Example: I think it is the 2°C with salt because it sank down under the water below.	

(Table continues on the next page.)

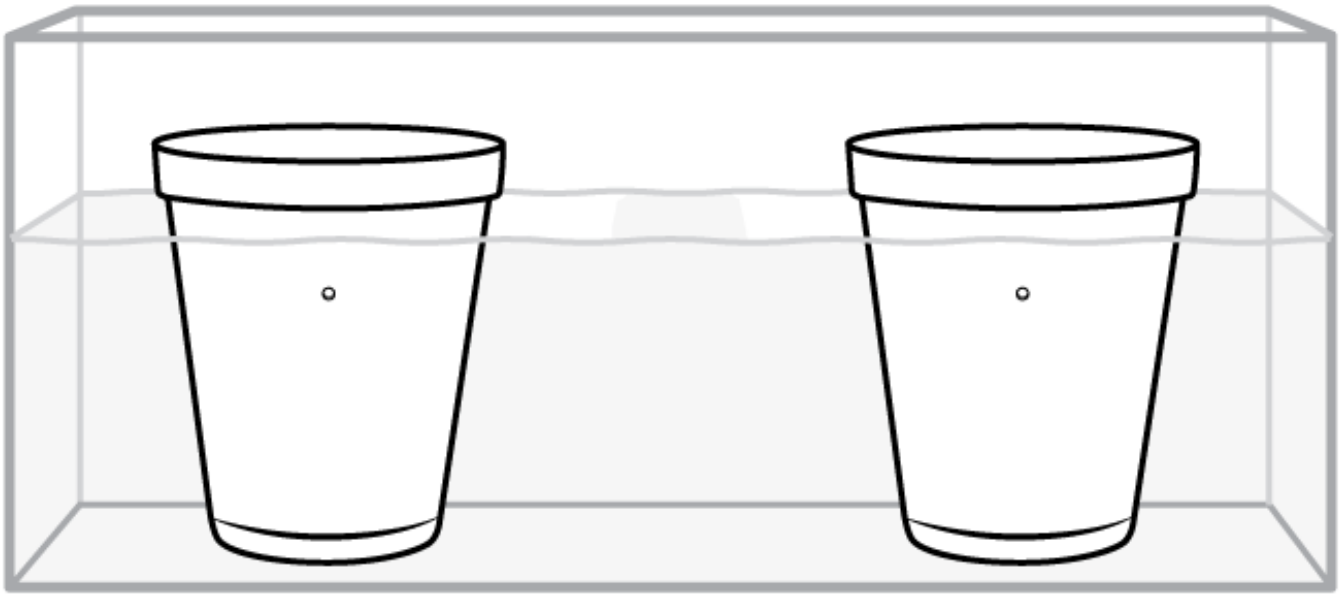
Rubric 2: Assessing Students' Understanding of Science Ideas Encountered in the Unit		
Criteria	**Description**	**Is there evidence of student understanding?**
(continued from previous page)	Students demonstrate understanding of the idea that cooler, saltier water is more dense than warmer, less salty water. Example: Since the water close to the surface is sinking, it could be 2°C with a high level of salt but it could not be 20°C with no salt. The reason is because colder water with a higher salt level would be denser than the water below the surface, which causes it to sink.	

Investigating Deep Ocean Currents

Part 1: Deep Ocean Currents Model

In the diagram below, draw and label your observations of the deep ocean currents model.

Observations will vary.



What are your ideas for why the two types of water moved differently?

Answers will vary.

Possible Student Responses

Investigating Deep Ocean Currents (continued)

Part 2: Layering Liquids

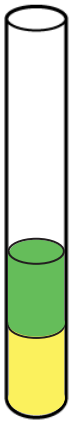
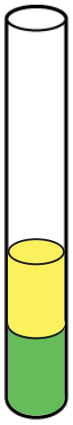
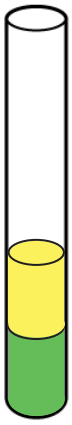
Goal: Use the four liquids to make as many distinct layers as possible.

Plan each test and explain your reasoning for the plan in the table below. Color the prediction diagram to show what you think the layers will look like. Complete the test and record your results. Use what you learned from the previous test when you plan the next test.

Answers will vary. Example responses are shown in the table.

Color Key:

Red = Hot-Salty Blue = Cold-Salty Yellow = Hot-Fresh Green = Cold-Fresh

Test 1: Which liquids will you add and in what order will you add them? I will add Yellow-Hot-Fresh and then Green-Cold-Fresh. Reasoning: I think that hot water is heavier than cold water.	**Prediction** 	**Result** 
Test 2: Which liquids will you add and in what order will you add them? I will add Green-Cold-Fresh and then Yellow-Hot-Fresh. Reasoning: In the previous test, the two liquids mixed so I must have been wrong. Now I think that cold water is heavier than hot water.	**Prediction** 	**Result** 

Investigating Deep Ocean Currents (continued)

Test 3:

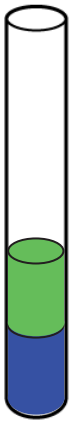
Which liquids will you add and in what order will you add them?

I will add Blue-Cold-Salty and then Green-Cold-Fresh.

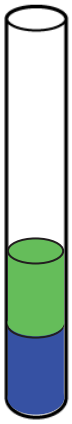
Reasoning:

I think salty water is heavier than freshwater because it has more stuff in it.

Prediction



Result



Test 4:

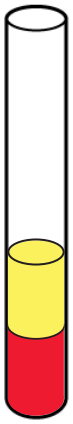
Which liquids will you add and in what order will you add them?

I will add Red-Hot-Salty and then Yellow-Hot-Fresh.

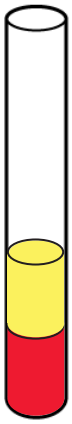
Reasoning:

When I compared cold-salty water to cold freshwater, the saltier water was at the bottom. I think that the same thing will happen with hot-salty water and hot freshwater.

Prediction



Result



Test 5:

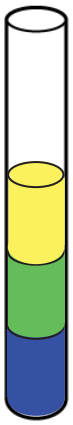
Which liquids will you add and in what order will you add them?

I will add Blue-Cold-Salty, then Green-Cold-Fresh, and finally Yellow-Hot-Fresh.

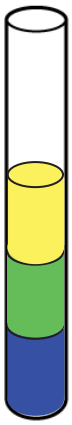
Reasoning:

This is a combination of one test where I saw hot water float on cold water and one test where I saw cold water float on cold-salty water.

Prediction

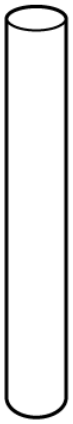
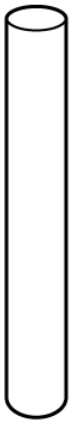


Result



Possible Student Responses

Investigating Deep Ocean Currents (continued)

Test 6: Which liquids will you add and in what order will you add them? Answers will vary. Reasoning:	**Prediction** 	**Result** 
Test 7: Which liquids will you add and in what order will you add them? Answers will vary. Reasoning:	**Prediction** 	**Result** 

Color Key:

Red = Hot-Salty Blue = Cold-Salty Yellow = Hot-Fresh Green = Cold-Fresh

Investigating Deep Ocean Currents (continued)

Part 3: Identifying Deep Ocean Currents

1. Why do you think the purple water and the orange water in the deep ocean currents model moved in the ways they did?

The purple water must have been more dense than the surrounding water and this caused it to sink. The orange water must have been less dense than the surrounding water and this caused it to float on top.

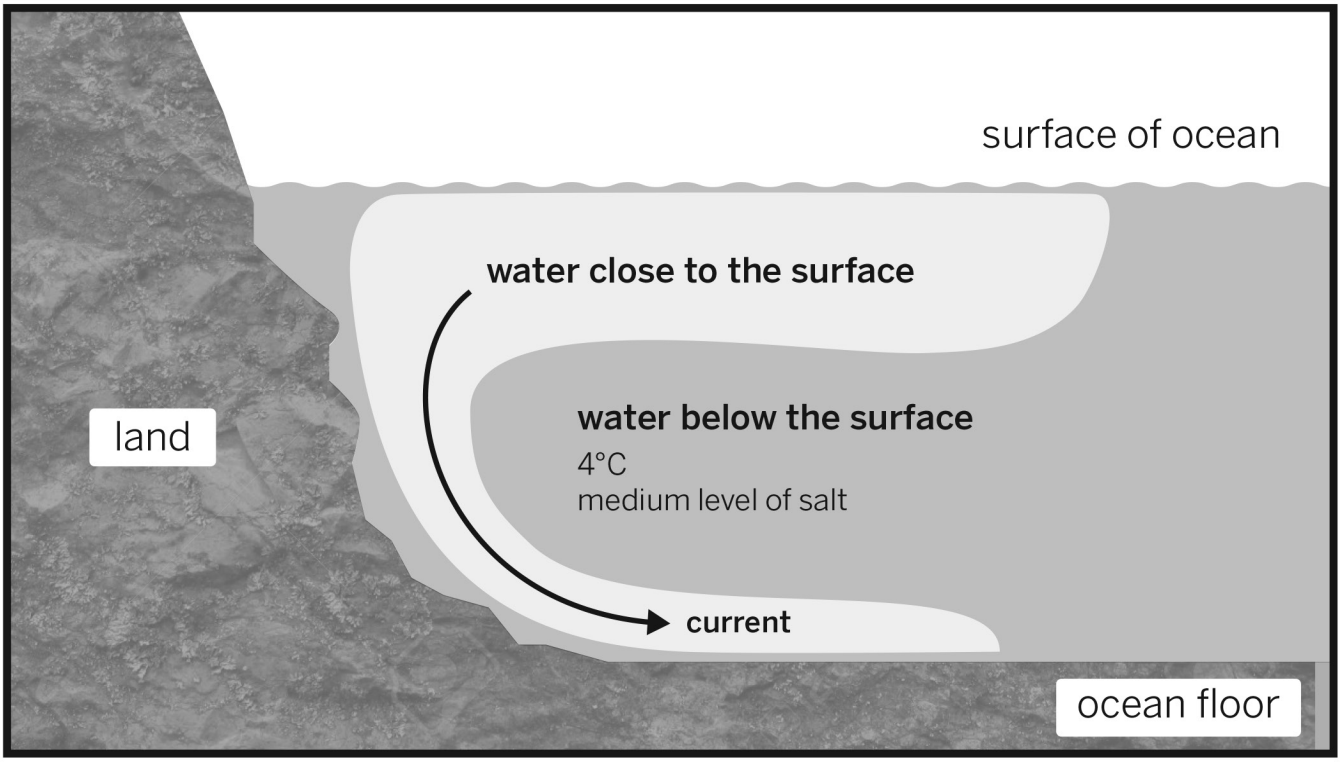
2. Scientists are investigating a certain deep ocean current. The scientists have found that the water close to the surface is sinking through the water below it, forming a current close to the bottom of the ocean. Scientists have identified the water below the surface as having a medium level of salt and a temperature of 4°C. Which of the following could be the identity of the water close to the surface (the water that is sinking)? (check one)

- [x] water 2°C with high level of salt
- [ ] water 20°C with no salt (freshwater)

Explain your choice on the following page.

Possible Student Responses

Investigating Deep Ocean Currents (continued)



Explain your choice.

Since the water close to the surface is sinking, it could be 2°C with a high level of salt, but it could not be 20°C with no salt. The reason is because colder water with a higher level of salt would be denser than the water below the surface, which causes it to sink. Water that is warmer with no salt would be less dense, so it would not sink.