Lesson 3: Mixing Water

Overview

Students design and carry out an investigation to monitor the temperature of water when equal volumes of hot and cold water are mixed.

Teacher Background

It's a beautiful cold winter day in Maine. It's snowing hard and school is canceled. The kids just came in from playing in the snow and it's time for some hot chocolate! Imagine serving a cup of hot chocolate to those "chilled to the bones" children. The hot chocolate is too hot; it requires the addition of cold water to lower the temperature. How much cold water should be mixed with the cocoa to bring the temperature down to one that is suitable? Is there a way to predict the resulting temperature in advance? When the hot chocolate and cold water are mixed, what is going on in terms of heat?

In this lesson students examine the nature of heat and how heat is transferred. In this investigation students mix equal volumes of hot and cold water and discover that the resulting temperature is the midpoint between the starting temperatures of the two samples. While this investigation may seem simple on the surface, the concepts involved are somewhat sophisticated and abstract. Transfer of heat occurs when interacting substances or systems are at different temperatures. When samples of cold and hot water are mixed together, an energy transfer occurs. Transfer occurs until the interacting substances or systems reach the same temperature and transfer only occurs in one direction – from warmer substances to cooler ones. A change in the temperature of a substance is due to the change in the average molecular motion of the molecules. 1

While students may readily grasp the mathematical relationships in this exercise, students may have difficulty explaining what happens in terms of the flow of heat from warmer substances to colder substances. This is especially challenging for students that think of "hot" and "cold" as substances. When the cooler water and the warmer water are mixed together, a transfer of the energy occurs between the particles as they come into contact with each other. Heat transfers from the more energized molecules in the warmer water to the less energized molecules in the colder water until the two have the same average energy (temperature). Since the two samples are the same volume, the temperature at which transfer stops is the midpoint of the two starting temperatures. In actuality, the temperature may be slightly less due to a small amount of heat energy that is transferred to the containers and surrounding environment. While it is not expected that students incorporate directionality (warm to cold) into their thinking about heat transfers at this point, this exercise sets the stage for this concept in the next lesson.

Key Ideas

- Heat can be transferred from one place, object, or system to another.
- Mixing water of two different temperatures results in a sample of water with an intermediate temperature that is predictable given the starting and ending temperatures.

Lesson Goals

Students will:
- explain resulting temperatures in terms of the change in thermal energy.
- describe how heat spreads from one place to another including how cooler materials can become warmer and vice versa.

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Vocabulary

heat: the flow of thermal energy from a warm area to a cooler one.

thermal energy: the collective energies of molecular motion of a substance. (The higher the temperature, the faster the atoms and molecules that make up the substance are moving and thus the more thermal energy the substance has. Thermal energy of a substance takes into account the amount of matter. The greater the amount of matter, the more thermal energy a substance has. This is why an iceberg contains more thermal energy than a cup of boiling water.)

Preparation

- Prepare enough hot (approximately 50°C) and cold (approximately 10°C) water for students to work in pairs. A pitcher of ice water will be about 5°C. This can be brought to about 10°C by adding tap water just before students need to use it. Make sure however that students do not have any ice in the samples of cold water when they are doing their investigation. Likewise, an insulated container (old insulated coffee pot or thermos) with 60°C water gathered just before the lesson begins will drop about 10°C before it is time for students to do their investigation. Another reliable method for preparing cold water is to fill a gallon jug about 1/2 way with water and freeze it overnight. Add enough cold water to fill the jug. The ice chills the water for more than 90 minutes.

- Determine how materials will be managed – especially how students will efficiently and safely obtain hot and cold water samples.
- Prepare a few temperature examples and answers for the mathematical portion of this lesson (see Step 5 in the Reflect and Discuss section).
- Make an overhead or class chart for Student Handout 3.1.

Safety

This investigation requires the use of hot tap water. Check the temperature of the school's tap water to make certain that students would not be accidently burned if water contacts their skin.

Materials

Item	**Quantity**
Cups, foam or insulated paper	3 per student pair plus one set for teacher demo
Graduated cylinders	2 per student pair
Thermometers	2 per student pair
Pipette	1 per student pair
Scientist's Notebook	1 per student
Hot and cold water	Enough for pairs of students to conduct investigation
Cloth towels or sponges to wipe up spills	1 per student pair and a few extras on hand
Dust pan and brush	1 for class
Student Handout 3.1: Mixing Water Class Data	2 copies per student
Overhead of Student Handout 3.1	2
Temperature probes, if available (optional)	

Time Required: 2 sessions

Connection to *Maine Learning Results: Parameters for Essential Instruction (MLR), and Benchmarks for Science Literacy (BSL)*

- Describe several different types of energy forms including heat energy, chemical energy, and mechanical energy. MLR D3(6-8) h
- When warmer things are put with cooler ones, the warmer things get cooler and the cooler things get warmer until they all are the same temperature. BSL 4E/E2a* (3-5)
- Heat moves in predictable ways, flowing from warmer objects to cooler ones until both reach the same temperature. NSES B (5-8).
- Thermal energy is transferred through a material by the collisions of atoms within the material. Over time, the thermal energy tends to spread out through a material and from one material to another if they are in contact. BSL 4E/M3* (6-8)

Teaching The Lesson

Engage

1 Introduce the mixing water investigation.

Explain to students that they will be using their knowledge of thermal energy in an investigation. Remind students that thermal energy is the collective energies of molecular motion of a substance.

Hold up two cups of water, one half-filled with hot water and one half-filled with cold water. Ask students: *If I could see the motion of the individual molecules in each of these samples, what do you think the difference in their motion would be?* (Students should recognize that the sample at the higher temperature would have greater molecular motion.)

Pose the following to the class: *I have been wondering....what would happen if equal volumes of hot water were mixed with an equal volume of cold water?* Ask students to use sketches and/or diagrams to
describe in their scientists' notebooks what they think will happen 5
when equal volumes of hot and cold water are mixed. Circulate around the room as students make this entry in their scientists' notebooks. Ask a few student volunteers to share their ideas.

Ask students to predict the ending temperature of the mixed water sample. Make sure students support their prediction with a reason. Activate students thinking by asking: *Would the ending temperature be higher or lower or the same as the starting hot/cold water samples?* Have a student volunteer take the temperature of each of the water samples. Record the temperature of each sample on the board. Have students record their prediction in their scientists' notebooks.

Alternatively, have students make their predictions interactively. Make a line in the room representing the temperature scale. 50°C to 10° Celsius. Have students stand where they think the final temperature would be after mixing and say why they think this.

2 Plan a "mixing" experiment.

Post the following focus question on the board: When the hot and cold water samples are mixed what do you think the resulting temperature will be in comparison to the beginning temperatures? With this question in mind have students work in pairs to design a simple experiment to test their ideas. Before students begin planning, show them the materials that are available for them to use:

- 3 cups, foam or insulated paper
- 2 graduated cylinders
- 2 thermometers
- pipette
- hot and cold water

Give students (5-10) minutes to record a plan for an experiment in their notebooks. After each pair has their preliminary ideas recorded, bring the class together to briefly discuss those plans. Jot some of these ideas on the board. While it is not critical that each pair follow the exact same plan, make sure student pairs take into consideration the following points:

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- Use equal volumes of hot and cold water in the investigation. The volume students decide to use does not matter as long as students use the same for both the hot and cold. Somewhere between 50 and 100 mL is manageable. Students should specify a volume of water.
- Decide how to record data.
- Measure and record the starting temperatures before mixing.
- Mix the hot and cold water in the 3rd insulated cup.
- Measure the resulting temperature by placing both thermometers in the mixing cup.
- Repeat their experiment (time permitting).

Encourage students to make amendments to their procedures if they've overlooked something brought forth in the discussion. Give them a few minutes to make edits.

Explore

3 Conduct the investigation.

Before students carry out their investigative plans, instruct them in material use and management. Include the following:

- Safe access and transport of hot and cold water.
- Proper use and storage of thermometer.
- Accurate measurement of water volume using the graduated cylinder and pipette.
- Clean up procedures.

While students are conducting investigation, circulate around the room, monitoring students' measuring and temperature reading skills and their ability to record their results accurately and efficiently.

> **Note:** *To help monitor student lab work consider using what is referred to as "Traffic Light Cups." This strategy encourages students to monitor their progress and to use the cups as a visual cue when they require teacher assistance. Each lab group gets a set of green, yellow, and red large plastic stackable party cups. The 3 cups are stacked on top of each other with the green cup on top. If the students need immediate help, they put the red cup on top as a signal. Teacher sees the visual cue and attends to the group. Students use a yellow cup to signal they need some help but they can keep working until they get it. A green cup means they are able to keep working and that they feel they are doing fine without assistance. It is important to monitor and check in with each group no matter what color is displayed when opportunities arise as some groups may feel they are doing fine when in fact they need some guidance. This strategy allows the teacher to attend to groups who feel they are in most need. This monitoring strategy is from* ***Science Formative Assessments*** *by Page Keeley*

Reflect And Discuss

4 Compile and review results.

Create a class data table by asking one student from each pair to write their results on a transparency copy of Student Handout 3.1: Mixing Water. Students can enter class data on their own copy of Student Handout 3.1 or develop their own chart in their scientists' notebooks.

After the class data has been compiled, discuss the following with students:

- *What do you notice about the data?* (Accept reasonable answers.)
- *Is there a pattern between the starting temperatures and the ending temperatures?* (Students should notice that the ending temperature is between the two starting temperatures. More precisely, the ending temperature is exactly halfway between the cold and hot water starting temperatures.)
- Assist students in developing an equation that captures the pattern shown in the data:

$$\frac{\text{Temp}_h\ (\text{hot}) + \text{Temp}_c\ (\text{cold})}{2} = \text{Temp}_f\ (\text{final})$$

- Ask students if they could use this equation to accurately predict the final ending temperature given starting temperatures for different samples of hot and cold water. Give students a few examples to practice using the formula. Be sure to emphasize that for the sake of simplicity, the volumes of hot and cold water used must be the same.

Note: *Teachers should supply numbers easily added and divided by 2 so that the focus of the lesson is not math, but the science concept*.

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5 Discuss findings by asking students to draw motion of mixing molecules.

Ask students to imagine again that they could see the molecules in action as the water mixing was occurring. Ask students to draw a series of pictures (supported with words) that illustrates what they think was going on with respect to the motion of the molecules before, during, and after mixing. After students have had the opportunity to draw their ideas individually, have students discuss their drawings in small groups followed by a large group discussion.

Students should recognize that the "hot" water particles would be moving more rapidly (had higher energy) and the "cold" water particles would be moving more slowly (had lower energy). In other words, students should be able to recognize that the speed of the particle motions (energies) changed in the samples of hot and cold water as a result of mixing. It is not expected that students understand the mechanism behind the change but that the speeds (energies) changed. When the hot and cold water mixed "warm" water resulted.

Note: *Students may wonder why the resulting "warm" water temperature is slightly below the midpoint temperature. Ask students why they think this happened and guide students into recognizing that some of the "hot" water's energy is transferred to the cup and surrounding environment.*

As students are discussing their ideas, consider aiding their understanding by drawing a series of diagrams on the board that show the same number of particles in two samples but in the hot water sample, use short arrows to show the rapid movement of particles in the sample. In the cold water sample, use arrows to show slower movement of particles. Remind students that matter is made up of particles; particles are always moving and because of this, all matter has thermal energy- even matter we think of as "cold."

6 Introduce an additional "mixing" challenge.

Say to students: *In this investigation we used equal volumes of water. Do you think that the same thing would happen if we used unequal volumes? For example, if I added 100 mL of cold water with 10 mL of hot water will I get a temperature that is half way between the two starting temperatures or something else?*

Allow students time to carry out additional investigations using unequal volumes of hot and cold water. Ask students to work under the same guidelines as they did before which included predicting the final temperature and recording their findings on the class data chart.

7 Bring lesson to a close.

Discuss with students their findings as before and bring the lesson to a close by creating a summarizing statement (bulleted list) of what students learned from their investigations.

> **Note:** *It is not expected or even encouraged that students incorporate directionality into their thinking about heat transfers at this point. The next lesson provides students with the opportunity to examine the idea that heat is transferred from warmer to cooler substances.*

Extensions

Student may:

- investigate what would happen if the mixed water sample was allowed to sit for two hours. What is going on in terms of molecules?
- investigate if it makes a difference whether the cold water sample is poured into hot water sample and vice versa.
- try out a virtual mixing experiment at: Concord Consortium. (2005-06). ITSI DIY: Show Activity 126: Temperature of Mixing Water. http://itsidiy.concord.org/activities/126

Connection to Maine Agencies

A Maine Energy Education Program (MEEP) representative and will come to interested schools, free of charge, to guide and support the concepts in lesson. For more information go to the MEEP website: http://www.meepnews.org/classroomactivities.

For schools in Aroostook County, a Maine Public Service (MPS) representative will come to interested schools, free of charge, to guide and support concepts developed in this lesson. A description of programs is available at www.mainepublicservice.com. Click on the education section of the site. To schedule a presentation contact Nancy Chandler at 207.760.2556 or nchandler@mainepublicservice.com.

Online References and Resources

National Science Teachers Association. *Science Objects: Energy: Thermal Energy, Heat, & Temperature*. www.nsta.org

