Lesson 4: Where is Heat Coming From and Where is It Going?

Overview

In this investigation, students expand their understanding of thermal energy transfers by focusing on the directionality of heat transfers. Students collect temperature data from two interacting containers of water and from their results infer that heat is transferred from warmer matter to cooler matter until both substances reach the same temperature.

Teacher Background

In the previous lesson, students focused on the idea that thermal energy changes. This investigation adds another layer to students' understanding by examining the direction of heat transfers- from warmer matter to cooler matter.

The idea that heat transfers from warmer substances to cooler substances is a challenging idea for students for a number of reasons. One reason is, as noted previously, many students believe certain materials are inherently “warm” or “cold” or view “hot” and 1
“cold” as entities of objects. Another reason is that many everyday experiences with “cold and hot” lead students to think that energy moves from cooler areas to warmer areas. For example, most children have been told by their parents to shut the door to keep the cold air out. What they should be saying is close to door **to keep the heated air in!** If we stand in front of a door open to a cold outdoors or open a refrigerator we feel the cold air “escaping.” It's these types of common experiences that lead children to logically conclude, “I feel cold, so cold must be moving.”

Let's consider a few questions involving heat transfers. What is the source of heat for our planet? We all know the source of heat for Earth is the Sun, but how does the warmth of the Sun get to the Earth? Another question about heat transfers to ponder is, what happens to a glass of ice water that is left out in a warm room for a long time? From experience we know that the water will no longer have ice in it and will no longer be “cold.” But how did it warm up? Heat from the surrounding warmer air transferred into the glass and then to the water, warming the ice cube and causing it to melt. Another example of a heat transfer occurs when a person is taking a nice warm bath. Why does the temperature of the bath water cool after a while? The cooling of the bath water occurs in much the same way as in the glass of ice water. Heat is transferred from the warmer water in the tub to the tub and then to the surrounding air in the bathroom because their temperatures are cooler than that of the bath water. That cools off the tub water. These things happen because warm matter does not keep its heat if near colder matter. Heat naturally transfers when there are temperature differences, from warmer areas to colder areas, until the interacting matter reaches the same temperature. Heat transfers occur all the time!

Students may struggle with the idea that heat **moves from** warm matter to cool matter and may frequently revert back to their intuitive notions about heat. Focusing on and discussing everyday experiences that students encounter regularly will go far in helping students conceptually grasp the nature of heat and how it is transferred. A simple yet effective question to continuously ask throughout this and the next few lessons is, "Where is heat coming from and where is it going?" Reflecting on and discussing this simple question not only reinforces the notion that heat moves but will help students see the pattern of heat moving from warmer substance to cooler substances. *Benchmarks for Science Literacy* and the *Maine Learning Results* state "when warmer things are put with cooler ones, the warm ones lose heat and the cool ones gain it until they are the same temperature." While this is a Grade 3-5 expectation, it is worth maintaining a focus on this idea throughout this lesson because a conceptual understanding of this key idea
2 lays the foundation for an understanding of energy transfers and conservation of energy; both middle school expectations. Note that this lesson was deliberately designed to investigate "heat" using something that students often think about as "cold" so that they may begin to recognize that "hot" and "cold" are relative terms.

While this lesson examines heat transfer macroscopically, some students may bring their knowledge of molecular motion and heat to these activities. As objects warm up their kinetic molecular movement increases. Along with this increase in molecular movement is an increase of energy. Since the notion that energy moves from a more energetic state to the less energetic state is a high school grade level expectation a conceptual understanding of this is not expected at this time. Rather, this lesson focuses on macroscopic recognition of transfers of heat from warmer matter to cooler matter.

Key Ideas

- Energy can move from one place, object, or system to another.
- Substances heat or cool as a result of energy transfer.
- Energy always transfers from warmer matter to cooler matter until both reach the same temperature.

Lesson Goals

Students will:

- explain resulting temperatures in terms of energy transfer.
- explain how heat moves from one place to another including how cooler materials can become warmer and vice versa.
- describe conditions necessary for heat transfer; namely that heat is transferred 1) when there is a difference in temperatures between interacting matter, and 2) from warmer matter to cooler matter until both reach the same temperature.

Vocabulary

heat transfer: the transfer of thermal energy between substances due to a difference in their temperatures.

Preparation

- Collect clear 2-L plastic bottles. Remove the top tapered portion of the bottles (screw top and neck) by cutting along the top edge of the bottle's label. Remove the label and discard the top portion of the bottle.
- Prepare enough warm water (with a starting temperature of approximately 35°C – tap water often reaches this temperature) and ice water for students working in pairs.
- Preview and pre-register for the website used in this lesson. Become familiar with how the simulation works and how to navigate the site. http://www.fossweb.com/modulesMS/kit_multimedia/ChemicalInteractions/conduction/conduction.html

  Note: *In order to use the site, teachers need to register in advance. Teachers receive a user name and password via email which can be shared with students to access the animation. Passwords expire July 1 of each year but are renewable.*

- Determine students' graphing abilities and pre-teach necessary skills.

Safety

Make certain that students know how to safely use and handle thermometers. Review thermometer safety with students, making sure students know what to do if breakage occurs. Bottle edges are sharp. Instruct students to use caution when placing plastic bags inside to avoid puncture.

Materials

Item	Quantity
Table lamp with a 100 watt incandescent bulb	1 per class
Cooler (optional, a prop)	1 per class
Thermometers	2 per pair
Temperature probes (optional – if available, could be used in conjunction with student thermometers)	Based on availability
2-L clear plastic bottles with top portion removed	1 per pair
Quart size freezer bags (heavy duty)	1 per pair
Blue food coloring	1 bottle per class
Warm and ice water	Enough for pairs of students to conduct investigation
Cups or beakers (500 mL)	2 per pair
Access to clock with minute hand, timer, or stopwatches	1 per class or 1 per student pair
Scientists' Notebook	1 per student
Student Handout 4.1 (optional): Temperature Changes	1 per student
Graph paper	1 per student
Colored pencils	Each student needs two different colors
Access to internet	Individual, pairs, or whole class depending on availability

Time Required: 2-3 sessions

Session 1: Heat idea discussion, lamp demonstration, introduce model cooler, prep for investigation.
Session 2: Carry out investigation, reflect and discuss results.
Session 3: Carry out virtual heat flow investigations.

Connection to ***National Science Education Standards (NSES) and Benchmarks for Science Literacy Standards (BSL)***

- Energy appears in different forms. Heat energy is the disorderly motion of molecules. BSL 4E(6-8)
- Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature. NSES B(5-8) 8

Teaching The Lesson

Engage

1 Discuss people's ideas about heat.

Ask students: *Where do you think people get their ideas about heat?* Direct students to write down a "heat" or "cold" experience they've had. Give students an example to get them thinking: *When I went out to the garage this morning, I felt the cold hit my face!* Discuss how these experiences shape their ides about heat.

2 Introduce another "heat" experience.

Display in an area visible to all students, a lamp with an incandescent light bulb in it. **Do not turn the light on.** Ask a student volunteer to hold their hand near the light bulb. After a few seconds have the student share with the class how his or her hands feel. (Students should not feel any difference in their hands.)

Turn on the lamp. Have the student hold his or her hands near the incandescent light bulb again.

Safety Note: *Use extreme CAUTION! Do not let any students touch the lamp. Touching a light bulb can cause serious burns.*

After a few seconds, have the student share with the class how his or her hands feel now. (Hands should feel slightly warmer.)

3 Discuss observations.

Discuss with students the following:

- *How did our student volunteer's hands get warm?* (The heat from the bulb warmed the student's hand.)
- *Does heat move?* (Yes, in the experience with the lamp, heat moved from the bulb to the person's hands.)
- *Does heat move in a particular way?* (Students may know that heat moves from something at a higher temperature to something at a lower temperature. The point of this question is to have students begin to think about how heat moves, not to provide a correct answer.)
- *How could you tell if something was gaining heat?* (Students may say that you could feel it or the object could glow, melt, or increase in temperature. Students may suggest using a tool such as a thermometer to see if the object's temperature was increasing.)

- Would you say the lamp is giving off heat? Why? Where does the heat come from? Students will most likely recognize that electricity makes the lamp work and may say that the lamp gives off both heat and light. Some students may explain that the heat comes from the movement of electricity through the lamp.

Explore

4 Present students with the following scenario.

Share the following scenario with students: *Have you ever used a cooler or ice chest to keep your food cold on a hot summer day?* (Many students will be familiar with this situation however some may not have had this experience. Consider bring in a cooler to show students. Ask them what they think it is for and/or demonstrate by putting food inside beforehand and showing them that it is still cool.)

Would you say "heat" is involved in the keeping the food cool? Ask students to talk to a neighboring student about their thoughts. After a few moments, have students share some of their thoughts with the class. (The idea of the "cooler" may initially challenge students' idea of "heat" if they revert to the common, everyday use of word "heat." Students who are beginning to relate "heat" to molecular activity may be able to articulate that all matter has "heat." The movement or transfer of heat is involved in keeping items cold in a cooler and terms such as "hot" and "cold" are relative and somewhat arbitrary.)

As with the light bulb demonstration, ask students to think about how they think heat is moving in the food and cooler example. It may help them to think about the movement of heat in terms of what's gaining heat and what's losing heat. Or in terms of where the heat comes from and where goes.

> **Note:** *Students may think that the "coldness" moves rather than heat and may struggle with the idea that heat moves from objects and materials that are at higher temperature to those that are at a lower temperature until equilibrium is reached. Some students may also think that both heat and cold are transferred at the same time.*

5 Introduce students to a model "cooler" investigation.

Gather the materials for the cooler investigation, and explain to the students that they will be investigating how heat moves using a simple model "cooler." Show students the materials they will be using and explain how they will be using them:

- 2-L bottle (with the top portion removed) filled with a mixture of ice cubes and water.
- quart-sized bag filled with warm water to represent the "food" that is being kept cool in the cooler.

Say to students: *Since we are interested in trying to figure out how heat moves, let's think about things that are important to monitor during this investigation. What measurements and/or observations do you think we should record that will help us understand how heat moves?*

Students may suggest monitoring the temperatures of both the ice water in the "cooler" and the "food" in the bag. Students may suggest noting the temperature in the room. Students should recognize that in order for this to be a fair test, equal volumes of hot and ice water should be used the model. 500 mL (2 cups) of water is a manageable amount to use during this investigation.

> **Note:** *Each student pair will have two thermometers; one that is kept inside the sealed "food" bag and the other that is kept in the cooler of ice water. One thermometer could be left out for the class to measure room temperature.*

Suggest that students add a drop of blue food coloring to the the "food bag." This will help students recognize that the water, the matter, is not changing positions during this investigation and reaffirm that the heat is what moves. Consider adding the food coloring to the class supply of the water representing the food as students are introduced to the location of the warm and ice water and the other investigation supplies. As the food coloring is added, explain to students: *Sometimes people think that heat is a substance – matter – but it is not. Heat is a form of energy. Energy is not matter. Coloring the water will remind us that the heat is moving and that no water is moving in and out of the bag, otherwise the food coloring would show up in the ice water as well. It also will let us know if our food bag springs a leak during our investigation.*

> **Note**: *A leak in the bag would invalidate the investigation because students would be mixing water as in Lesson 3 and this would not help students infer which way heat moves.*

There is no absolute way to prove that heat moves in this activity because energy cannot be seen, but with teacher guidance, students can infer from this activity that heat moves.

6 Make predictions and plan for data collection.

Before students begin, ask them to record the following in their scientists' notebooks:

- **Focus Question:** *Where do you think the heat is coming from and where do you think it is going?*
- **Prediction:** *I think* _________ *because* _________. Make sure that students support their prediction with reasoning that involves "where they think heat is coming from and where they think it is going" in the *"because"* portion of their prediction. For example, students might state *"I think* the temperature of the food will be lower and the temperature of the ice water will be higher *because* the heat is moving from the ice to the food. (This is not correct, but a student may think this.) It may be helpful for students to think about which one of the containers is holding something at a higher temperature and which container is holding something at a lower temperature. Check to see that students have included reasoning in their predictions.

  > **Note**: *If students struggle at making a prediction supported by reasoning involving heat transfers, consider having students work in small groups to craft their predictions or assisting students in crafting a class prediction. Another possibility would be to present several predictions supported by reasoning to students and allowing them to choose the prediction that fits their current thinking.*

- Sketch of "cooler" components.
- Preparation for data collection. Ask students to design a chart to record temperature change over time. Alternately, provide students with Student Handout 4.1: Temperature Changes and ask students to paste this in their notebooks.

7 Conduct the investigation.

Provide students with instructions as to how materials should be managed and used including:

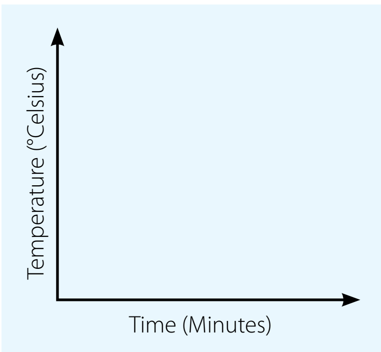
- Access and safe transportation of water.
- Proper use and storage of thermometer.
- Clean up procedures.

While students are conducting their investigation, circulate among groups, monitoring students' work. Students may stop monitoring the temperature once both samples have reached the same temperature. This takes approximately 10-15 minutes.

Reflect And Discuss

8 Graph and review results.

Ask students to create a double line graph (time on x axis, temperature on y axis, plot lines using two different colors) of the data they collected during the investigation. Depending on students familiarity with graphing, consider asking students what kind of graph they would construct and/or why use a double line graph in this case. The following site contains a graphing tutorial to help students think about the types of graphs to use and why: http://nces.ed.gov/nceskids/help/user_guide/graph/whentouse.asp



Support students as needed in constructing this graph. If students prefer to construct their graphs on a separate sheet of graph paper, have students paste their graphs into their scientists' notebooks. If students have access to and familiarity with computer graphing programs, consider using these instead.

Ask students to examine their completed graphs and write about what their graph and the investigation told them about heat transfer. Consider giving students the following prompts to guide their responses:

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- *What does the graph tell us about how heat moves or is transferred?*
- *Where did heat come from and where did it go? Use a picture to help explain your ideas.*
- *How do you know? What evidence do you have that supports your claim?*

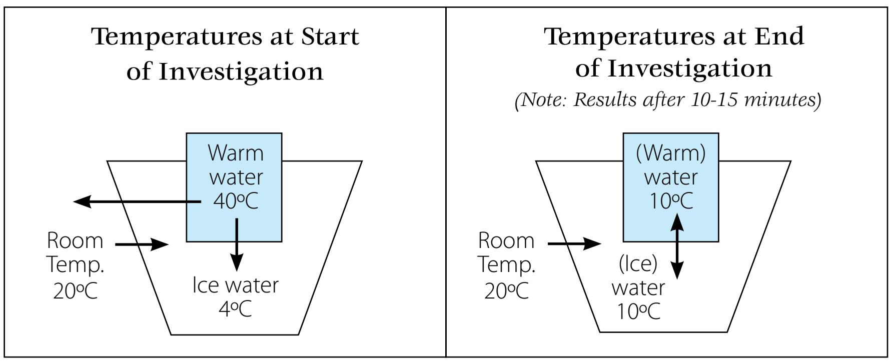
Support students as necessary and consider working through these questions as a large group.

9 Conduct a scientists' meeting.

Ask students to gather in a circle and bring their scientists' notebooks with them. Engage students in a discussion with the following questions:

- *How did heat move during this investigation? Where did it come from and where did it go? What is your evidence that supports what you're claiming?* (Encourage students to share the pictures (drawings) they used to explain their thinking. Heat moved from the warmer water representing the "food" to colder ice water. Students should have noticed that the temperature of the warmer water decreased while the temperature of the ice water increased until both samples of water reached the same temperature.) **Be certain to emphasize that the transfer was from warm to cold. This is the where inference comes in to play. Discussion will be important here since students can't actually see the heat moving from warm to cool.**

- *How can you be sure that it was not the water that moved during this investigation?* (Students should notice that the ice water did not turn blue. This shows us that energy moved, not matter.)
- *How close do objects or substances have to be for heat to be transferred from one to the other? In other words, do substances have to be in direct contact with (touching) one another for heat to be transferred?* (Remind students of the light bulb experience and our Sun.)
- *What happened to the room temperature? How do you think that the room temperature affected the temperature changes in the warm water or ice water samples?* (Guide students in discussing this last point. Students may recognize that heat was transferred from the room to the ice water. It may be helpful to use diagrams to help students understand the directionality of the heat transfers involved. Using a diagram like the one shown below, show students how arrows can be used to indicate the direction of heat transfer between samples. Emphasize that heat moves from warm to cool not the other way around.)



10 Introduce virtual energy flow investigations.

Explain to students that they will be using a website that allows them to examine heat flow virtual containers at different starting temperatures. Show students how to use the website by working through one example together as a class. The opening screen shows two containers, an inner and outer container. The opening screen also shows the temperatures of the water samples in the inner container, the outer container, and room temperature in the upper left hand corner. The user must drag and drop the temperatures to the correct places on the diagram. Once this has been done correctly, the shaded boxes appear over the picture and arrows appear in the top left hand corner. The user must click and drag arrows to show the direction heat flows. Once completed, the user clicks on the check me button. If the arrows have been arranged correctly, another scenario appears. If the arrows are not appropriately placed, the user must correct them before moving to the next scenario. http://www.fossweb.com/modulesMS/kit_multimedia/ChemicalInteractions/conduction/conduction.html

Note: *In order to use the website, teachers need to register in advance. They will receive a user name and password via email which can be shared with students to access the animation. Passwords expire July 1 of each year but are renewable.*

Give students time to complete several scenarios. Consider asking students to record their arrow placement for a certain number of scenarios in their scientists' notebooks using a simple chart, such as the one shown below:

Room Temperature in °C	Direction of Heat Transfer (Arrow)	Outer Tub Temperature in °C	Direction of Heat Transfer (Arrow)	Inner Tub Temperature in °C	Direction of Heat Transfer (Arrow)	Check
30°C	←	60°C	→	0°C	↓	

12 As students work, circulate around the room assisting students as needed. Ask students to write a short summary in their notebooks about what they learned about heat flow the investigations.

Alternatively, this exercise could be done as a class using an LCD projector.

11 Bring lesson to a close.

Ask a few students to share their understanding about the movement of heat from the investigations. Students should have captured the idea that heat moves from warmer places to cooler places in their written summaries.

Extensions

Student may:

- explore electronic cooling devices such as refrigerators and air conditioners.
- examine mood rings, mood beads, and other interesting "toys" that change color due to heat transfers (color changing paper, putty, mugs/glasses, foam, T-shirts) http://www.teachersource.com/Chemistry/Thermochromic/Heat_SensitivePaper.aspx
- investigate different temperature scales (Celsius, Fahrenheit, and Kelvin)
- research the relationship between heat, weather, and climate. Extreme Weather (NASA Lesson Plan: Hurricanes as Heat Engines) http://mynasadata.larc.nasa.gov/preview_lesson.php?&passid=50

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@maine publicservice.com.

Online References and Resources

Chicago Science Group. (2007). *Science Companion: Energy*. Lesson 5: Hot Water, Cold Water: Transferring Heat Energy. USA: Chicago Science Group and Pearson Education, Inc. http://www.sciencecompainion.com