Lesson 6: Testing Heat Transfers through Different Materials

Overview

Students continue investigating heat transfers, focusing on transfer by conduction. By performing a simple experiment, students discover that heat is conducted through different materials at different rates. They put their knowledge of heat transfers to use in everyday situations.

Teacher Background

If you've ever wrapped your hands around a cup of hot chocolate, you've felt heat transfer through conduction. The heat from the hot chocolate transfers through the cup to your hand. Remember that heat is transferred from warmer matter to cooler matter. Let's examine the role the cup plays in the transfer of the heat. When the hot water is poured into the cup the cup is a different temperature than the hot chocolate. The different temperatures set the stage for a heat transfer to occur. Does the material the coffee cup is made from make a difference? Different materials conduct heat differently. Pure metals conduct heat more rapidly than mixed metals due to their closely packed molecular arrangement. Other materials such as wood, plastic, and glass do not conduct heat well. Thermal conductivity is a property – a property that refers to a material's ability to conduct heat. Different materials are given different thermal conductivity values.

Engineers apply knowledge of thermal conductivity in designing a number of items, including cooking utensils, heating systems, buildings, bridges, plastics, mechanical devices, food processing technologies, and so on. Middle school students can begin to appreciate and understand why different materials are selected for particular goods as they come to understand thermal conductivity as a property. In this lesson, students put their developing knowledge to use by considering why certain materials are used for particular items.

Key Ideas

- Different materials conduct thermal energy at different rates. Metals conduct heat rapidly. Plastic and wood do not conduct heat rapidly.
- Some materials conduct heat better than others. Knowledge of thermal conductivity differences is used to develop safe and efficient products and technologies for people.

Lesson Goals

Students will:

- recognize that a thermal conductor is a material that allows heat to readily transfer through it.
- recognize that heat is conducted at different rates through different materials.

Vocabulary

conduction: the transfer of heat through material by direct contact.

conductor: substance that allows heat to flow through it.

thermal conductivity: the rate at which heat passes through a specified material or the property of a material that indicates its ability to conduct heat. Also heat conduction is transfer of thermal energy through matter, from a region of higher temperature to a region of lower temperature and acts to equalize temperature differences.

Preparation

- Set up stations in different areas of the classroom for each sample. Place enough containers, thermometers, and measuring devices for each group at the stations as well.
- Prepare enough hot water for each student group to fill a dishpan. Hot tap water may be sufficient.

Safety

This investigation requires the use of hot tap water. Use caution to make certain that students would not be accidentally burned if water contacts their skin.

Materials

Item	Quantity
Brownie mix package (prop)	1 per class
For each group: • 4-250 mL containers • 5 thermometers • dishpan or baking tray • Enough for each group to have a 200 mL sample of: sand or crushed rock, metal BBs or pennies, glass marbles (small decorative aquarium/floral type), shredded paper or cotton balls	1 set per group
Stopwatches or access to timer that displays minutes and seconds	1 per class or 1 per student group
Hot water	enough to partially fill each group's dishpan or baking tray
Scientist's Notebook	1 per student
Student Handout 6.1 (optional): Heat Transfer through Different Materials	1 per student
Graph paper (optional)	1 per student
Temperature probes (optional)	1 or more based on availability

Time Required: 1 session

Connection to *Maine Learning Results: Parameters for Essential Instruction (MLR), National Science Education Standards (NSES), & Benchmarks for Science Literacy (BSL)*

- Heat moves in predictable ways, flowing from warmer objects to cooler ones until both reach the same temperature. NSES B (5-8)
- Describe how heat is transferred from one object to another by conduction. MLR D3(6-8) j
- 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)
- Design and safely conduct scientific investigations including experiments with controlled variables. MLR B1(6-8) b
- Explain why it is important to identify and control variables and replicate trials in experiments. MLR C1(6-8) b
- Scientific laws, engineering principles, properties of materials, and construction techniques must be taken into account in designing engineering solutions to problems. BSL 3C/M8**

Teaching The Lesson

Engage

1 Engage students in a "quick write."

Bring in a boxed brownie mix. Describe the following scenario: Comment to students that you noticed the directions listed different cooking times for the brownies depending on the type of baking pan used. (Consider reading the cooking directions from the box aloud to students.) Ask students to do a quick write in their scientists' notebooks in response to the following prompt: *Why do you think different cooking times are listed for different baking pans? How is this related to what you have learned about heat transfers?* Use sketches and words to explain your thinking.

Have a few students share their quick write responses. Summarize students' comments and use them to segue into the activity.

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Explore

2 Introduce the investigation by examining different materials.

Ask students: *Have you ever been outside on a playground on a very hot sunny day and touched a metal slide or swing set? Or maybe you've walked on a paved road in your bare feet? Did you have to quickly hop from the pavement to a grassy patch because your feet were getting too hot? Do you think these objects were at different temperatures – even if it is the same temperature outside? How can this be explained in terms of heat transfer?*

Allow students to discuss their ideas. Explain that different materials transfer heat at different rates. When an object absorbs heat, the thermal energy is spread out among the molecules in the substance. The greater the amount of energy, the faster the molecules vibrate.

Give each group of four students a small sample of materials that will be tested: sand or crushed rock, metal BBs or pennies, small glass marbles, shredded paper or cotton balls. Explain that they will be using these materials to investigate whether heat is transferred at different rates through different materials.

Ask students to examine each of the items and to describe what material each item is made out of in their scientists' notebooks. Encourage students to include touch in their description of the materials.

Ask: *How do you think heat will be transferred in these materials?* (Heat is transferred through conduction – direct contact between the various items in the containers. As each sample is warmed up by the hot water bath, heat will move through the samples differently.)

3 Make predictions and review investigation procedures.

Instruct students to make a prediction and record it in their scientists' notebooks:

- *Which material do you think heat will transfer through the fastest and which material do you think heat will transfer through the slowest?* Consider providing students with the following frame (post on the board): I think _____ because_____.

> **Note:** *Clarify that monitoring the change in temperature will determine the rate of transfer. For this investigation the material that has the highest final temperature will be the considered the material that transfers heat most rapidly and the material that has the lowest final temperature will be considered the slowest.*

Ask students to develop a way to record their data in their scientists' notebooks or distribute a copy of Student Handout 6.1: *Heat Transfer Through Different Materials* to each student.

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Explain to students how they will test materials. Each person in the group will be responsible for obtaining a 200 mL sample of one of the materials by going to one of the material stations around the room. Demonstrate how to fill the container part way with the test material, insert the thermometer, and then continue filling the container to the 200 mL mark.

> **Note:** *Instruct students to use caution and to not push too forcefully when filling their containers so they do not break the thermometers.*

Ask students what the starting temperature is for all of the test materials. Point out to students that the starting temperatures of all of the test substances is the same – they are all room temperature. Students may have to verify this for themselves when they go to get their group's sample.

While students are collecting their preparing their test samples, place a dishpan or baking tray on each group's table. Once all students have obtained a test sample and recorded the starting temperature of their sample, direct students to place their samples in the dishpan or baking tray. When all students are seated, fill each group's pan or tray with enough hot water to raise the level just

below the tops of students' samples. Instruct students to be careful not to spill any water into their sample.

Prompt students to measure and record the initial temperatures (established previously) of their samples and the hot water bath.

4 Conduct the investigation.

Have students measure and record the temperature of their samples and the hot water bath every 2 minutes for 10 minutes. Monitor students as they conduct their investigation, reminding them to use care to not splash water into their samples and to not break their thermometers.

Have each student pour their sample into the waste container at the appropriate stations. Ask students to make a bar graph of their findings (sample along the x-axis, temperature along the y-axis).

Reflect And Discuss 

5 Discuss students' findings.

Gather students for a scientists' meeting. Ask students to respond to the following:

- *How did your group's results compare to your prediction? Do different materials transfer heat at different rates?* (If there were differences, discuss with students why they think there were differences. This is a good opportunity to discuss past experiences students have had and which they used as a basis for their predictions.)
- *Why is heat transferred?* (Heat is transferred due to temperature differences among the items.)
- *How did heat transfer in the investigation?* Use words and sketches (or diagrams) to explain the transfers that occurred. (Students should indicate the direction of transfer and indicate that the rate of transfers differed.)

Review students' investigation findings and discuss the heat transfers that occurred during this investigation. Explain to students that some materials are better conductors of heat than others. Ask students where they have heard the word conductor or conduction before. The word conduct is from Latin meaning "brought together." Good conductors transfer heat readily through materials and poor conductors do not transfer heat readily. Ask students to suggest materials that they are familiar with that are good conductors of heat and those that are poor conductors of heat. Explain to students that scientists actually rank or have a formula to figure out different materials' ability to conduct heat and refer to this property as *thermal conductivity*. Different materials have different thermal conductivity values.

Note: *The term "thermal conductivity" is one worth introducing, using, and discussing. However it is not expected for students to memorize this phrase.*

Revisit the brownie baking pan times listed on the mix box. Discuss the need for listing these differences in terms of thermal conductivity. Encourage students to think of other items that they may use in their kitchen. Are there certain objects that people don't want heat to readily travel through and vice versa?

(Examples might include the handles of pots, pans, and spoons) After students have made some suggestions, ask them to think of examples for other areas of their lives.

6 Summarize and bring the lesson to a close.

Revisit the question posed at the beginning of the lesson. Ask students to reflect on their learnings for the day to help them answer the question:

- *Why do you think different cooking times are listed for different baking pans?*
- *How is this related to what you have learned about heat transfers?*

Elaborate on this discussion by asking students to connect what they've learned to spoons, handles of pots and pans, and other items used in the kitchen. What types of materials are these items made out of? What are the pros and cons of various designs? Consider asking students to continue their investigation of these items or other items outside of class.

Extensions

Student may:

- repeat the investigation using an ice water bath or by testing other materials (i.e., rice, oil, water).
- investigate why certain materials feel cooler than others. Consider administering the task "Objects and Temperature" from *Uncovering Student Ideas in Science: 25 Formative Assessment Probes* Volume 1 (see references for full citation). Discuss the following: Why do you think some materials feel colder than others? What is going on in terms on heat transfer?
- experiment with brownie baking. Cook brownies using different types of pans, glass versus metal and compare the cooking times or cook brownies for a certain length of time and rank their "doneness."

- build a simple water heater using PBS's Design Squad's: Feel the Heat project.
- be interested in learning about another matter related to heat; the expansion and contraction of objects as the temperature changes. This "Snack" from the Exploratorium, Cool Hot Rod, demonstrates this concept: http://www.exploratorium.edu/snacks/cool_hot_rod/index.html

Connection to Maine Agencies

A Maine Energy Education Program (MEEP) is a no cost resource for schools and teachers in Maine. MEEP representatives and will come to interested schools, free of charge, to guide and support the concepts in lesson and have programs that supplement concepts in this lesson:

- School Energy Efficiency Investigation: Students use tools to see how their school uses energy and where energy is wasted. Tools include an infrared thermometer, a temperature/humidity datalogger, a light meter and a Kill A Watt meter. Students can then make recommendations on how energy can be conserved in their school. This project can be combined with the Greenhouse Gas Surveys being offered by Maine DEP.

More information can be found on the MEEP website: 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

Lesson adapted from: Teach Engineering: How Much Heat Will it Hold? http://www.teachengineering.org/view_activity.php?url=http://www.teachengineering.org/collection/cub_/activities/cub_energy2/cub_energy2_lesson06_activity2.xml

Texas State Energy Conservation Office and the U.S. Department of Energy. Lesson 9: Testing Materials for Thermal Conductivity. Austin, TX. http://www.infinitepower.org/pdf/09-Lesson-Plan.pdf