The Great Heat Escape

Levels
III-IV
Grades 5-8

Overview:

Students observe a demonstration of the role of thermal conductivity in heat transfer, explore the properties of snow, and design and conduct an experiment to compare the thermal conductivity of four substances. (NOTE: This lesson may require two class periods.)

Objectives:

The student will:
- observe a demonstration of the role of thermal conductivity in heat transfer;
- explain the connection between thermal conductivity and snow cover on sea ice; and
- design and conduct an experiment to compare the thermal conductivity of various substances.

GLEs Addressed:

Science
- [5-8] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.
- [6] SA1.2 The student demonstrates an understanding of the processes of science by collaborating to design and conduct simple repeatable investigations.
- [7-8] SA1.2 The student demonstrates an understanding of the processes of science by collaborating to design and conduct simple repeatable investigations, in order to record, analyze (i.e., range, mean, median, mode), interpret data, and present findings.
- [7] SB1.1 The student demonstrates an understanding of the structure and properties of matter by using physical properties (e.g., density, boiling point, freezing point, conductivity) to differentiate among and/or separate materials (i.e., elements, compounds, and mixtures).
- [8] SB1.1 The student demonstrates an understanding of the structure and properties of matter by using physical and chemical properties (i.e., density, boiling point, freezing point, conductivity, flammability) to differentiate among materials (i.e., elements, compounds, and mixtures).
- [5] SD3.2 The student demonstrates an understanding of cycles influenced by energy from the sun and by Earth's position and motion in our solar system by comparing heat absorption and loss by land and water.
- [8] SD3.2 The student demonstrates an understanding of cycles influenced by energy from the sun and by Earth's position and motion in our solar system by recognizing types of energy transfer (convection, conduction, and radiation) and how they affect weather.
- [6-7] SE2.2 The student demonstrates an understanding that solving problems involves different ways of thinking by comparing the student's work to the work of peers in order to identify multiple paths that can be used to investigate a question or problem.
- [8] SE2.2 The student demonstrates an understanding that solving problems involves different ways of thinking by comparing the student's work to the work of peers in order to identify multiple paths that can be used to investigate and evaluate potential solutions to a question or problem.

Materials:

For Teacher Demonstration:

- Glass beaker
- Styrofoam™ cup
- 2 thermometers
- Hot water
- Snow or ice
- Stopwatch

For Alternative Experiment:

- Cotton balls (1 cup per group)
- Rice (1 cup per group)
- Play dough (2 ounces per group)
- Cups, 3 ounces (four per group)
- Half-pint wide-mouth canning jars (four per group)
- Ice cubes (four per group)
- Aluminum or glass baking dish, 9” x 9” or larger

Activity Procedure:

1. Hold up one glass beaker and one Styrofoam™ cup. Ask students what they think will happen to the temperature of hot water in each cup if the cups are placed in snow or ice. Which will lose heat faster? Record student predictions on the board.
2. Prepare a bucket of ice or snow to use for the demonstration, or if weather permits, take the class outside and use the snow on the ground. Assign one student to be a timekeeper. Assign two other students to be temperature trackers – recording the temperature of the two cups. Explain that when signaled, the timekeeper should begin the stopwatch and announce the time every 30 seconds for 5 minutes. The temperature trackers should note temperature when the timekeeper starts the stopwatch and again after each 30 second interval.
3. Pour 1 cup of hot water into a glass beaker and 1 cup into a Styrofoam™ cup. Place a thermometer inside each cup. [Illustration of setup; showing bucket of ice or snow with glass beaker and Styrofoam™ cup inside, hot water and thermometer inside each cup.] Signal to the timekeeper to start the stopwatch. After five minutes, ask students to stop. If outside, return to the classroom. Write times and temperatures in a chart on the board for all students to see.
4. Ask students to calculate the temperature difference for each cup. Ask them to describe their observations and record them on the board. Remind students that heat can also be called thermal energy and that it transfers by conduction, convection, and radiation. Ask students which type of energy transfer occurred in the cup demonstration (conductivity). (NOTE: Radiation and convection also occur, but only the transfer of heat to the surrounding medium is considered in this demonstration.) Make sure students understand that the water is cooled because heat is being transferred from the hot water through the glass beaker or Styrofoam™ cup to the ice or snow around the cups, not because the ice transfers cold.
5. Discuss why the water in the glass beaker lost heat faster than the Styrofoam™ cup. Explain that the Styrofoam™ cup has a higher thermal conductivity than the glass beaker. Thermal conductivity is a measure of the rate at which heat travels through a substance. A material with a high thermal conductivity, like the glass beaker, transfers heat quickly. A material with a low thermal conductivity, like the Styrofoam™ cup, transfers heat slowly. Explain that things that have a low thermal conductivity are also called insulators, because they insulate or slow down the loss or gain of heat.
6. Ask students why they might want to know the thermal conductivity of a substance. When is thermal conductivity important? (Insulating walls or roof, in jackets or coats, coffee mugs, thermoses, etc.)
7. Explain that thermal conductivity is also important for sea ice growth and melt. In general, snow has a low thermal conductivity compared to most substances (it is lower by a factor of 10 compared to sea

ice). This means snow conducts heat slowly. On the ocean, snow acts as an insulator for sea ice, slowing sea ice growth, as well as melt, by forming a barrier between the sea ice and the atmosphere.

8. Display OVERHEAD: “Thermal Conductivity of Snow.” Explain that the graph shows the thermal conductivity of snow based on density. Remind students that density is a physical property of matter that depends on the atomic mass of a compound and how tightly the atoms or molecules are packed. This means that fluffy snow is the least dense; hard compact snow is the densest.
9. Discuss the graph on the overhead. Ask students to interpret the graph. If necessary, explain that the graph shows the more dense the snow, the higher the thermal conductivity. Fluffy snow has the lowest thermal conductivity, meaning heat transfers through it slowly. Therefore, it is the better insulator. Hard compact snow has the highest thermal conductivity, so it is a less effective insulator.
10. Ask students which material they think has the highest thermal conductivity: air, cotton balls, play dough, or rice. Explain students will design and conduct an experiment to determine which material has the highest thermal conductivity. Divide students into small groups and distribute the STUDENT WORKSHEET: “Is it Hot or Not?”
11. Assist students through the processes of writing a hypothesis and the design of their experiment as needed. Check student experiment procedures for practicality and experimental validity before providing them the necessary materials. Student experiments should have a control group and a single variable. (NOTE: If students are unable to design an appropriate experiment, or if time or materials are unavailable, use the procedure in the TEACHER INFORMATION SHEET: “Alternative Experiment.”) The remainder of this lesson may require a second day.
12. Provide students with time to perform their experiments and complete their worksheets.
13. Ask each group to present their experiment to the class, including their hypothesis, process, data, and conclusion. Discuss how student results differed and why. (Differing experimental procedure resulted in different result.)

Critical Thinking Question: *The 3-minute Rule.* Ask students the following question and wait three minutes before providing an answer: “Based on the results of the experiments, what can be inferred regarding the heat loss of land versus water?” This allows students to think through their replies and provides an opportunity for several students to answer and expand upon the question. Studies show that teachers often answer their own questions within 5 seconds when students do not respond immediately. If necessary, explain that heat loss of land is less than that of water because the thermal conductivity of land is much lower than the thermal conductivity of water, resulting in slower heat transfer. (NOTE: Evaporation and convection also contribute to heat loss in the ocean.)

Teacher’s Note: While the thermal conductivity of air itself is very low, heat may be transported more effectively through convection in the air. This may happen in the control of the experiment, but should not substantially influence results. It is however, important to a more in-depth understanding of density and heat transfer. In low-density materials with high air volumes and large empty spaces, the heat can be transferred quickly through convection, as opposed to more slowly through conduction.

Extension Idea: As a class, read and/or listen to the online story Immiugniq: Winter Sources of Drinking Water, available at http://www.nsbsd.org/anep/public/index.cfm/14.html. Discuss as a class how the ideas presented in the story related to energy transfer and thermal conductivity. If times allows and student interest is strong, ask students to write short stories similar to Immiugniq that explain a scientific or cultural principle through a story.

Answers:

1. Styrofoam cup

2 –14. Answers will vary.

Rubric:

Designing an Experiment. Use this rubric as best fits the class, to assess student's performance and/or allow students to assess their own performance.

Performance Measure	Self	Teacher
1. The design of the experiement tests the hypothesis.		
2. A list of all necessary materials is included.		
3. A detailed step-by-step procedure is included.		
4. The procedures are written so that another person could repeat the experiment.		
5. Data was collected and recorded.		
6. An appropriate graph or chart was created to display the data.		
7. Conclusions were drawn using the data.		

Alternative Experiment

Teacher Information Sheet

Levels III-IV

Materials

- 4 3-ounce cups
- 4 half-pint wide-mouth canning jars
- Cotton balls (1 cup)
- Play dough (2 ounces)
- Rice (1 cup)
- 4 ice cubes
- Hot water, not boiling
- Aluminum or glass baking dish (9x9 or bigger)

Procedure

STEP 1. Place cotton balls in one of the canning jars to the cover the bottom. Fill the bottom of the other two jars with play dough and rice. Leave one cup empty; this is the control, filled with air.

STEP 2. Place a 3 oz. cup inside each of the jars.

STEP 3. Fill the space in-between the cup and the jar with rice, play dough, and/or cotton balls. You may need to remove the cup to fill the sides and then replace the cup. [Illustration]

STEP 4. Place the jars inside the baking dish so that they are evenly spaced. Fill the dish with hot water.

STEP 5. Place an ice cube in each 3 oz. cup. Check cups and make observations every 5 minutes for 30 minutes.

Name:______________________________

Levels III-IV

Is It Hot or Not?

Student Worksheet (page 1 of 4)

Testable Question

Which material has the highest thermal conductivity: air, cotton balls, rice, or play dough?

Observations

1. In the classroom demonstration, which material had the higher thermal conductivity: glass beaker or Styrofoam? ______________________________

2. Based on the classroom demonstration and your own personal experience, which material do you believe has the highest thermal conductivity? Explain your reasoning.

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Background Information

Thermal conductivity is the measure of how much heat is transferred through a substance. The higher the thermal conductivity the faster heat is transferred through the substance. Air has a very low thermal conductivity. In the case of snow, the more dense it is the higher its thermal conductivity.

Hypothesis

3. Use the background information in this worksheet to make a hypothesis to explain which material has the highest thermal conductivity: air, cotton balls, rice, or play dough.

If ____

then ____

because ____

Experiment

Materials:

4. List the materials required for the experiment:

______________________________ ______________________________

______________________________ ______________________________

______________________________ ______________________________

______________________________ ______________________________

Name:___________________________

Is It Hot or Not?

Student Worksheet (page 1 of 4)

Procedure:

5. Write the procedure for the experiment, step by step. If more steps are needed, continue on the back of this sheet, or attach a separate sheet of paper.

STEP 1 ____

____

STEP 2 ____

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STEP 3 ____

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STEP 4 ____

____

STEP 5 ____

____

STEP 6 ____

____

STEP 7 ____

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STEP 8 ____

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STEP 9 ____

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STEP 10 ____

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Name:___________________________

Is It Hot or Not?

Student Worksheet (page 1 of 4)

Data:

6. Use the grid below to chart experimental data.

Analysis:

7. Use the grid below to graph the data.

Name:____________________________

Is It Hot or Not?

Student Worksheet (page 1 of 4)

8. What patterns do you see in the data? ____

9. How would you explain the patterns in the data? ____

Conclusion:

10. Was your hypothesis proved or disproved?____

11. What data proved or disproved your hypothesis? ____

Questions:

12. If your hypothesis was disproved, how would you revise your hypothesis? Explain your reasoning.

13. If you were to repeat the experiment, how would you change the procedure? Why?

14. What new questions do you have?