TEACHER'S GUIDE OBJECTIVES

Students should be able to

- explain the basics of heat transfer.
- list the characteristics of materials that are good thermal insulators.
- design insulating layers that will decrease the rate of thermal energy transfer.
- conduct a controlled experiment to test their insulating layers.
- explain the performance of their insulating layers within the context of other designs in the class.

EQUIPMENT

- Soda bottles, 16 oz and 2 L
- Types of cloth such as flannel, wool, t-shirt material, bath towels, quilt sections, etc.
- Other materials such as newspaper, cotton, aluminum foil, bubble wrap, packing peanuts, and plastic bags
- Tape (duct, electrical, clear, masking)
- Hot glue gun
- Funnel
- PVC pipe, ½ in. diameter and 2 in. long
- Beaker, 500 mL
- Heat source such as Bunsen burner or hot plate
- Water
- Ice
- Lab thermometer, temperature probe, or wireless sensor with data-gathering software such as Vernier with a TI-Nspire or LabQuest or Pasco with Sparkvue on a computer
- Hand heater protector mitts (2)

STUDENT ORIENTATION

The students must design insulating layers to limit the heat transfer between a test container and the atmosphere. The teacher supplies the container for testing the insulating layers and provides design and testing parameters. Once students have designed their insulating layers, they will test them inside the test container.

PREPARATION

1. If this project will be done only in the classroom, gather as many of the materials as possible needed for building an insulated container and enough of each type of material for the number of groups participating.
2. If students will do this project outside of the classroom, provide guidelines regarding materials that they may use. Do not allow materials specifically designed for thermal insulation of liquids. The outer container should be no larger than a 2 L soda bottle and the inner container should be no smaller than a 16 oz soda bottle.
3. Determine how the students will measure the temperature of the fluid in the container (lab thermometer, temperature probe, or wireless temperature sensor). Pasco and Vernier are good sources for these.
4. Construct the containers. (You may want to have the students construct the containers.)

   Note: If you are concerned that the hot glue may not hold, you can drill holes through the lower part of each spout and into the PVC, and secure them with screws. If you choose to do this, you will have to modify the following construction process.

   Cut the external (2 L) bottle into two pieces by cutting where the sides start to curve toward the neck. Insert the PVC pipe into the neck of the external bottle so the top of the PVC is level with the top of the bottle spout. Use hot glue to secure the PVC into the external bottle's neck. Be sure to position the PVC so the bottle cap will still screw on completely. Insert the other end of the PVC pipe into the neck of the 16 oz internal bottle. Secure the PVC into the internal bottle with hot glue. Drill a hole through the cap of the external bottle so the thermometer or temperature probe can be inserted into the bottle. During testing, tape the upper and lower portions of the external bottle together.
5. Divide the students into groups of 2–4.

PROCEDURE

Note: Students should record all notes, designs, data, calculations, analyses, and conclusions in a project log.

Planning the Design

1. Have students research heat flow and the factors that can affect it.
2. Have the students research the insulating value of various materials.
3. Have students examine the construction materials available, measure the container, review the parameters, and discuss ideas for design with their group.
4. Have each student draw their own designs.
5. Allow students to experiment with the materials and modify their designs as needed.

Testing the Design

1. Each group will test their device with warm water. They will heat 450 mL of water to a little more than 50 °C. They will then measure the temperature every 2 minutes for 16 minutes.

2. Each team will test their device with cool water. The will use ice to cool 425 mL of water to a temperature of approximately 5 °C. They will then record temperatures every 2 minutes for 16 minutes.
3. Each team will plot temperature vs. time on graph paper or by using a computer program (data-collecting software, Excel, Sheets, etc.) for each of the two tests. They will then analyze the graphs of the two tests and determine the slope of the best-fit line for each graph.
4. Each team will record the materials used and the slopes of each of the other teams and compare results. The students should draw conclusions regarding the effectiveness of their thermos design compared to those of the other teams. They should include factors that increased or decreased the rate of thermal energy transfer in the devices and what they could do to improve their design further.
5. Allow the teams to modify their designs and retest them.

TEXTBOOK CONNECTIONS

- Pre-Algebra: Ch. 9
- Algebra 1: Ch. 6
- Algebra 2 : Ch. 2
- Physical Science: Ch. 9
- Physics: Ch. 15

ASSESSMENT RUBRIC

	4–Mastery	3–Competent	2–Emerging	1–Poor
Analysis	The relationship between variables is discussed. Trends or patterns are described and analyzed. Predictions are made regarding rate of thermal energy transfer.	The relationship between variables is discussed. Trends or patterns are described. Predictions were made regarding rate of thermal energy transfer.	The relationship between variables is discussed. No patterns or trends mentioned or predictions made.	The relationship between variables is not discussed.
Drawings/Diagrams	Designs show good understanding of insulation principles, have evidence of research, are easy to understand, and are labeled completely.	Designs show good understanding of insulation principles, have evidence of research, are easy to understand, and are partially labeled.	Designs show fair understanding of insulation principles, have little evidence of research, and are partially labeled.	No designs present or design is identical to that of another team member with minor tweaks.
Calculations	All calculations are shown, and the results are accurate and correctly labeled.	Some calculations are shown, and the results are accurate and correctly labeled.	Some calculations are shown, and the results are labeled correctly.	No calculations shown or they are inaccurate.
Conclusion	Evidence is cited to support the conclusion drawn from the activity, and possible reasons are given for errors or success.	Evidence is cited that supports the conclusion drawn from the activity.	What was learned from the experiment was stated.	No conclusions recorded; no evidence of reflection.
Organization/Appearance	Almost all entries are organized, neat, and easy to follow. Numbers, bullet points, and spaces are almost always used to separate different items.	Most entries are organized, neat, and easy to follow. Numbers, bullet points, and spaces are usually used to separate different items.	Some entries are organized, neat, and easy to follow. Many are not. Numbers, bullet points, and spaces are sometimes used to separate different items.	Entries are not organized or neat. Order is difficult to follow. Numbers, bullet points, and spaces are rarely used to separate different items.
Collaboration with Peers	Always listened carefully to others and offered detailed, constructive feedback. Participated fully and shared the workload fairly.	Usually listened to others and usually offered constructive feedback. Participated most of the time and usually shared the workload fairly.	Sometimes listened to others, occasionally offered constructive feedback. Participated but sometimes did not share the workload fairly.	Did not listen to others and often interrupted them. Did not offer constructive feedback. Did not participate and relied on others to carry the workload most of the time.