Some Like It Hot

Dirk and Glen have recently invested in a drive-through coffee shop. They have decided on a name: Caffeine Nation. They agree on the types of beverages that will be offered but disagree about only one thing: whether to serve the beverages in a Styrofoam cup or a paper cup.

Dirk favors Styrofoam. Glen is partial to paper. Dirk says that paper cups would be more difficult to store; Glen has proved that to be untrue. The restaurant supply company quoted the same price for both Styrofoam and paper cups, so there was no economic incentive to choose one over the other. Dirk states that when he drinks coffee, it stays warmer when it is in a Styrofoam cup. Glen remarks that the coffee would be even warmer if it had been in a paper cup. It appears that they have reached an impasse. Dirk and Glen have concluded that there is only one way to settle the dispute. They will conduct an experiment to determine which cup keeps coffee warmer longer, and that would be the cup they will use in Caffeine Nation.

Investigation

In this experiment, you will use the ProScope Digital USB Microscope to closely examine the makeup of Styrofoam and paper. Then, using the Vernier Go! Link and a Temperature Probe, you will determine the rate at which a hot liquid cools in cups made from each material. When you complete your experiment, you will use iMovie to create a one-minute commercial emphasizing the properties of the cup more likely to keep a beverage hot.

Objectives

In this experiment, you will:

- Use a ProScope Digital USB Microscope to record the images of Styrofoam and paper from beverage cups
- Use a Vernier Temperature Probe and Logger Lite software to record temperature over time
- Compare the results of two trials
- Determine the rate of cooling of hot water placed in Styrofoam and paper cups
- Report your test results and recommendations using iMovie software

Materials

- Macintosh computer with Mac OS X
- iMovie software
- Bodelin ProScope Digital USB Microscope
- Bodelin M200 lens
- Vernier Go! Link interface
- Vernier Stainless Steel Temperature Probe
- Logger Lite Software
- 400 mL Pyrex beaker or another type of heat-resistant beaker
- 250 mL graduated cylinder or large glass measuring cup
- Water
- 16 ounce Styrofoam cup
- 16-ounce paper cup
- Microwave oven
- Oven mitt

Pre-lab activity

In your science journal, tell whether you think a Styrofoam cup or a paper cup will keep hot water warm for a longer period of time. Explain your choice, keeping in mind that you may have some personal experience upon which to draw. As you consider your hypothesis, think about whether or not keeping a beverage cold presents the same challenge to a cup as keeping a beverage warm.

Procedure

1 Obtain a 16-ounce Styrofoam cup.

2 Set up the ProScope to examine the cup.

a Connect the ProScope to a USB port on the computer.

b Open the USB Shot application.
You should see an image on your computer screen.

c Focus the ProScope USB Microscope over the cup using the M200 lens, and then snap an image.

d The image can be found in the SNAP folder, which is located in your Applications folder. Rename the image with the name of the material and drag it into a new folder you have created for this experiment.

e Insert the image into a data table like Data Table 2 shown in "Processing the data," and write a description of the Styrofoam material.

3 Obtain a 16-ounce paper cup. Repeat Step 2 to examine this cup.

4 Use a 250 mL graduated cylinder, or another measuring container, to measure out precisely 250 mL of water supplied by your teacher. Pour the water into a 400 mL Pyrex beaker.

5 Place the beaker of water in a microwave oven and heat the water on the highest power setting for exactly three minutes.

6 While the water is heating, connect the Go! Link interface to the computer and connect the Temperature Probe to the Go! Link.

7 Start the Logger Lite software by double-clicking the Logger Lite icon on the desktop of your computer.

8 Choose Data Collection from the Experiment menu.

9 In the Time Based dialog, type "300" for the length of the experiment in seconds.

10 Use an oven mitt to carefully remove the beaker of hot water from the microwave oven. Pour the water into the Styrofoam cup. Use caution when handling the hot water!

11 Immerse the tip of the Temperature Probe in the cup of hot water.

12 Watch the temperature readings on the computer screen. As soon as the temperature starts to decrease, click Collect in the Logger Lite software to begin recording temperature data.

13 The Logger Lite application will collect data for five minutes (300 seconds). When the data collection ends, click the Stats button. Record the minimum and maximum temperature readings in Data Table 1.

14 Choose Store Latest Run from the Experiment menu.

This saves the data and prepares Logger Lite to collect data from a new trial.

15 Pour the hot water down the sink. Fill the cup with room temperature tap water and let it sit until you are ready to conduct another trial.

This brings the cup back to its original temperature.

16 Pour out the room temperature water.

17 Repeat Steps 5-15 until you have completed three trials with the Styrofoam cup and three trials with the paper cup.

Processing the data

1 Record the temperature change for each trial in Data Table 1. Calculate the temperature change by subtracting the ending temperature from the beginning temperature.

2 Calculate the average temperature change by adding the temperature changes for the three trials and dividing by 3. Record the average temperature change for each cup in Data Table 1.

3 Calculate the cooling rate by dividing the average temperature change by the average elapsed time (5 minutes). Record the cooling rate for each cup in Data Table 2.

Data Table 1

Styrofoam Cup Trials	Beginning Temperature (˚C)	Ending Temperature (˚C)	Temperature Change (˚C)	Elapsed Time (minutes)
1				5
2				5
3				5
		Sum		15
		Average		5

Paper Cup Trials	Beginning Temperature (˚C)	Ending Temperature (˚C)	Temperature Change (˚C)	Elapsed Time (minutes)
1				5
2				5
3				5
		Sum		15
		Average		5

Data Table 2

	Styrofoam Cup	Paper Cup
Average Temp. Change (˚C)		
Average Elapsed Time (minutes)		
Average Cooling Rate (˚C/min)		
ProScope Image		
Description of Image		

Analyzing your data

1. Compare the images of the Styrofoam cup and the paper cup. What are the major similarities and differences? How did the ProScope images help you compare the two cups?
2. Which type of cup should Dirk and Glen use in their coffee shop if they want the beverages to stay warm longer?
3. A person buys a 16-ounce cup of coffee from Caffeine Nation. The coffee has a temperature of 80˚C when it is purchased. If the person does not take a drink for 10 minutes, what will be the temperature of the coffee when the first sip is taken from a Styrofoam cup? From a paper cup?
4. Using iMovie, create a one-minute commercial for either the Styrofoam cup or the paper cup. Include your data tables in the commercial.

Teacher Information

Styrofoam is a trademark name for a type of plastic product from Dow Chemical Company known as foamed polystyrene. Polystyrene is a sturdy, versatile plastic that is used in many forms of packaging and as a building material. The surface area of a container such as a coffee cup is roughly 95% air and 5% polystyrene.

The phenomenon of a hot liquid cooling is also known as Newton's law of cooling. It is not a physical law; rather, it is the observed and commonly understood exponential cooling of a container of liquid. Your students may find it interesting to discover the reason why this "law" is attributed to Isaac Newton. Over the relatively short period of time that your students will collect temperature data in this activity, the rate of cooling is very close to linear. If your students were to extend the data collection to 60 minutes or more, they would see a nonlinear (exponential) decrease in temperature over time.

If you are conducting this activity with a large number of students, you may want to assign each group one trial and allow the students to share their data.

Students can use their data table file in their iMovie presentation. You may want to explain the steps involved in exporting their file to iPhoto to have it available in iMovie. To use data tables from a word-processing document or spreadsheet in iMovie, follow these steps:

1. Take a screen shot of the information you want to include. Hold down the Command-Shift-4 keys and drag to highlight the area you want to select.

   A numbered file named Picture is created, such as "Picture 1."

2. Open the Preview application from the Dock or in the Applications folder. (Preview is included on every new Macintosh computer.)

3. Choose Open from the File menu, then locate and open your Picture screen shot file.

4. Choose Export from the File menu, name the file, and save it as a JPG file.

5. Open iPhoto and drag the JPG file into your Photo Library.

   Once the JPG file is in your iPhoto Photo Library, it will appear in iMovie in the Photos area. You can add it from here to your iMovie project.

Materials

In this activity, the students will be measuring the temperature of a cup of hot water as it cools for five minutes. For best results, the students should do two things precisely: (1) measure out the specified volume of tap water, and (2) heat the water for the specified amount of time.

Prior to the activity, set out a container of tap water from which students will pour their samples. A good, easy way to do this is to fill a plastic milk jug with tap water for each team of students. This way, their water samples will be the same temperature before they heat the water in the microwave oven.

If you do not have a microwave oven, use the hottest water possible from a tap. The data will not show as dramatic a temperature decrease, but the students will be able to compare the two types of cups successfully.

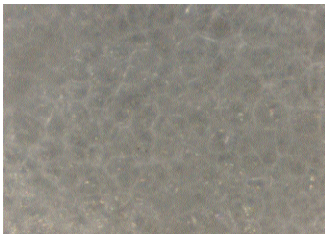
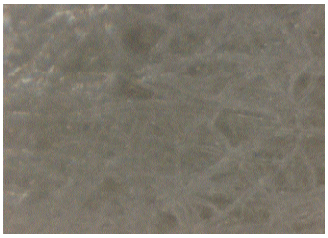
The volume of water and the size of the cups is not important. It is important, however, that the cups be equal in size (and shape) and that the volume of water be the same for all trials.

Sample Data Table 1

Styrofoam Cup Trials	Beginning Temperature (˚C)	Ending Temperature (˚C)	Temperature Change (˚C)	Elapsed Time (minutes)
1	97.2	82.6	14.6	5
2	95.8	81.3	14.5	5
3	93.6	81	12.6	5
		Sum	41.7	15
		Average	13.9	5

Paper Cup Trials	Beginning Temperature (˚C)	Ending Temperature (˚C)	Temperature Change (˚C)	Elapsed Time (minutes)
1	94.8	78.5	16.3	5
2	95.7	78.8	16.9	5
3	93.7	78.5	15.2	5
		Sum	48.4	15
		Average	16.1	5

Sample Data Table 2

	Styrofoam Cup	Paper Cup
Average Temp. Change (˚C)	13.9	16.1
Average Elapsed Time (minutes)	5	5
Average Cooling Rate (˚C/min)	2.78 ˚C/min	3.22 ˚C/min
ProScope Image		
Description of Image	There are lots of small air bubbles trapped inside the Styrofoam that help it trap air and insulate the liquid.	The paper appears more scaly and flat.

Answers to analyzing your data questions

1 Answers will vary. However, students should note that the Styrofoam doesn't seem to be packed as tightly as the paper. Also, the paper may appear more fibrous and made up of long strands while the Styrofoam will look like bits of gravel.

2 Dirk and Glen should use Styrofoam cups, which insulate better (have a lesser rate of cooling).

3 Using the cooling rate from the sample data, the coffee in the Styrofoam cup will have cooled to 52.2˚C and the coffee in the paper cup will have cooled to 47.8˚C.

4 Presentations will vary, but should include the ProScope images and the data from the six trials.

Extensions

1 Students can conduct one trial with the Styrofoam cup and the paper cup in which they collect temperature data for a long period of time (more than 30 minutes).

2 Many materials are used for drinking cups. Students can try this experiment with cups made of ceramic, glass, metal, or other types of plastic.

3 Students can design an experiment to determine which type of cup keeps cold liquids cold longer.

4 Besides insulating properties, students can discuss what other factors Dirk and Glen might consider when choosing the type of cup to use at their coffee shop.

National Science Standards

This experiment provides direct alignment to national standards by allowing students to observe and measure heat energy and temperature. The design of the experiment also emphasizes alignment with measurement, inquiry, and investigative standards by having students use technology to practice and gain insight into these skills.

Content Standard A

Science as Inquiry: B. 5-8

As a result of their activities in grades 5-8, all students should develop an understanding of

1 Abilities necessary to do scientific inquiry.

2 Understandings about scientific inquiry.

Content Standard B

Physical Science: B. 5-8

As a result of their activities in grades 5-8, all students should develop an understanding of

3 Transfer of energy.

Content Standard E

Science and Technology: B. 5-8

As a result of their activities in grades 5-8, all students should develop an understanding of

1 Abilities of technological design.

Special thanks

This lesson was written by Linda Trawick, Science Coordinator and National Board Certified Teacher, Smitha Middle School, Marietta, GA, and edited by Vernier Software & Technology.