What's HOT? What's NOT?

Goldilocks investigates temperature and heat.

By Sandy Buczynski

When Goldilocks finds three bowls of porridge at different temperatures in the three bears' house, she accurately assesses the situation and comes up with one of the most recognizable lines in children's literature, "This porridge is too hot; this porridge is too cold; aahh, this porridge is just right!"

Goldilocks' famous line is a perfect lead-in for an inquiry with upper elementary students that explores the concept of heat energy as measured by temperature. In the investigation, students consider the variables that might account for temperature differences between each bear's porridge. For example, if Papa Bear has the hottest bowl of porridge, does he also have the largest bowl size? I've conducted this inquiry with groups of fifth and sixth graders and also with preservice students with good results. It's fun to observe students as they make surprising discoveries (e.g., a quantity of porridge in a smaller bowl will retain heat energy longer than a large bowl with the same quantity of porridge) and start considering that Papa Bear's bowl could have been the smallest bowl on the table!

I Heard, I Wonder

On the first day, I read *Goldilocks and the Three Bears* with emphasis on the porridge section of the story:

> *Once upon a time, a little girl named Goldilocks went for a walk in the forest. After a while, she came upon a house. Goldilocks was hungry. So she knocked on the door and, when no one answered, she walked right in.*
>
> *At the table in the kitchen, there were three bowls of porridge.*
>
> *She tasted the porridge from Papa bear's bowl.*
>
> *"This porridge is too hot!" she exclaimed.*
>
> *So, she tasted the porridge from Mama bear's bowl.*
>
> *"This porridge is too cold," she said*
>
> *Then, she tasted Baby bear's bowl of porridge.*
>
> *"Ahhh, this porridge is just right," she said happily and she ate it all up.*

Students wrote observations in their science notebook about what they heard concerning the bowls of porridge in a column with the heading "I Heard" (Figure 1).

Next, we discussed students' observations to see if what they "heard" in the story led them to "wonder" anything. Maybe Mama Bear fixed her bowl of porridge first, so it has been on the table the longest, allowing heat energy to dissipate and causing the porridge to grow cold. Or, maybe Papa Bear had a greater quantity of porridge, which retained heat energy longer, explaining why his porridge was "too hot." Or, maybe a bit of cool milk was added to Baby Bear's bowl, lowering the initial heat energy immediately to ensure his porridge was "just right."

Students' reasons for the varying porridge temperatures included:

- Size of the three bowls
- Composition of bowls (glass, ceramic, wood, plastic, metal)
- Coverage of bowl (with lid, without lid)
- Amount of porridge in each bowl
- A cooler/hotter substance added to porridge after preparation
- Length of time each bowl of porridge has been sitting on table
- Shape of bowls (square, round)

Then, we discussed some heat energy concepts (see "Hot Stuff," page 27) and reviewed the idea of a *measurable question*. A *measurable question* is a question about which numeric data can be collected. For example, a measurable question based on the Goldilocks story might be be, "How fast do different amounts of oatmeal lose heat?" Students would measure both the temperature of the oatmeal and periods of time, such as five minutes, 10 minutes, and so on.

Research Design

While students had come up with numerous potential reasons for differences in the oatmeal's temperature in our discussion, for practical purposes we decided to focus on four factors: bowl size, amount of oatmeal in the bowl, whether the bowl was covered or uncovered, and whether an additional substance (milk) added to the oatmeal cooled it faster. Students divided into lab groups based on their interest in the investigation topic.

In this guided inquiry, each group changed only one variable—this is the *manipulated* variable (the condition that is purposely changed or altered). All other conditions of the experiment remained the same. For example, the group investigating whether the "amount of porridge" influences temperature kept constant the size, composition, shape, and depth of bowl; lid use; amount of stirring; amount of hot water added; temperature of initial water; type of porridge used; even the particular thermometer used to measure heat gain/loss. The only variable changed was the porridge portion. Because only

Figure 1.

Student observations and questions.

I heard	I wonder
1. There were three bowls of porridge.	1. Were the bowls different sizes? Did the bowls have lids? Were the bowls different shapes?
2. The porridges were different temperatures.	2. What could cause the porridges to be different temperatures?
3. Goldilocks tasted each bowl to determine its temperature.	3. Could the temperature of the porridge be taken with a thermometer?
4. All the porridge in the last bowl was eaten.	4. Was Goldilocks hungry? (this is NOT a measurable question)

Hot Stuff

Heat is energy. Temperature is not energy but rather the measure of it. The amount of heat energy in a substance depends on the characteristics of the particles (molecules) that make up the substance. These characteristics include speed of particles, mass (the size or number) of particles, and the type of particles. If heat energy is added to a substance, the result is that the temperature will go higher. Higher temperatures mean that the particles that make up a substance are moving (vibrating) with more energy. The converse is also true; if heat energy is removed, the temperature will go lower.

To ensure accurate collection of data during this activity, I have students practice reading a thermometer (see Internet Resources). Taking the time to discuss thermometer readings helps students conceptualize what temperature readings might be considered in the "hot" range (e.g. 40˚C–100˚C) and where a "cool" temperature reading (e.g. 0˚C–20˚C) might fall on a thermometer. Soon students begin to associate a number (in degrees Celsius) on the thermometer with a range of what might be considered hot to Goldilocks!

one variable was changed, any temperature differences observed can be attributed to that one variable.

Next, we discussed the *responding* variable—the measurement that results from changing the manipulated variable (in these investigations, measuring heat by taking the porridge's temperature).

After identifying the variables, each group established a prediction. While formal hypotheses (a testable explanation) are beyond the targeted grade levels, students can begin to learn the logic by completing "If/Then statements with an explanation. IF this is done (manipulated variable), THEN this will happen (direction of responding variable). Aligning the prediction with the variables establishes what will be measured in the experiment. For example, "IF the same amount of porridge is put into different size bowls, THEN porridge in the largest bowl will stay hot longest."

Finally, each group wrote a procedure for their experiment, providing enough detail in the instructions so that another group could follow their directions. Once the groups were comfortable with the variables and had recorded their predictions and plans in their science notebooks, they were ready to proceed with the experiments, which were conducted the next day.

Investigation Day

I assembled the materials for the four experiments, which included various shapes of plastic food-storage bowls with lids, instant oatmeal packets for the porridge, measuring cups, and an electric hot pot to provide the heated water. **Keep heated water within a warm temperature range (40–60°C) that is measurable with a student thermometer. I boil water in the hot pot, pour out half, and replace it with room temperature water. Only the teacher handles the hot pot. Also, be sure students use alcohol—not mercury—thermometers, and do not permit students to eat the porridge.**

CAUTION

Students investigated the following four predictions:

- IF porridge is put into different size bowls, THEN porridge in the largest bowl will stay hot longest.
- IF a bowl of porridge is covered, THEN porridge will stay warm longer than if uncovered.
- IF the amount of porridge in a bowl is increased, THEN the greater the amount of porridge, the longer it will stay hot.
- IF a cold substance (like refrigerated milk) is added to the porridge, THEN the porridge will cool faster than porridge without something added.

Each group picked up its needed materials and followed the procedures they had established for their experiment. Figure 2 (page 28) describes the student investigation plan for the group comparing amounts of porridge, and it includes their data table. Other groups had similar worksheet plans for their predictions.

From Data to Graphs

Each group was required to record their data in a chart. However, some scaffolding is usually necessary to guide the conversion of these data tables into graphs that can be analyzed. To begin, we first considered whether a line graph or bar graph would best represent the data. Generally, continuous data, such as temperature, is represented with a line graph and discrete data (that which falls into categories), such as number of people, colors, or favorite food, is represented with a bar or pie graph.

For this experiment, students were looking at change in temperature over time, so we put time on the X-axis and the responding variable of temperature on the Y-axis. This graph represented the rate of heat loss/gain. If your students are comfortable with graphs, point out that the lines between data points are *interpolations*—explain that we don't have the data for those points, but if we did, we could predict it would be near that line.

A separate graph can be constructed for each manipulated variable or different colored markers used to put all data on one graph. The title of the graph is the relationship of manipulated variable to responding variable and the axes of the graph are always labeled with units of measure. Students can use the information illustrated in the graph to analyze trends and patterns in data.

Figure 2.
Student investigation plan.

Prediction:
IF the amount of porridge is increased, THEN the temperature of the porridge will stay hot longer.

Variables:

Manipulated: Amount of porridge

Responding: Temperature of the porridge

Constant(s):
Size of bowls
Shape of bowls
Number of times stirred
Temperature of water
Room temperature

Materials:
Three packets of instant oatmeal
Three same size, round plastic bowls
Thermometers
Timer
Heated water
Plastic spoon
Measuring cup

Procedure:
1. Line up three identical bowls. In the first bowl pour in one-half packet of instant oatmeal. In the second bowl pour in one whole packet of instant oatmeal, and in the third bowl pour in 1½ packets of instant oatmeal.
2. Add one-half cup of water from the kettle to each bowl.
3. Stir the water and oatmeal together in each bowl 10 times.
4. Put a thermometer in each bowl and take an initial reading.
5. Record the temperature in science notebook.
6. After 5 minutes take another temperature reading and record.
7. Continue until 4 readings are complete (15 minutes).

Data Chart:

Manipulated Variable	Temperature in Degrees Celsius (Responding Variable)			
Time in minutes	0	5	10	15
½ packet of oatmeal	50	41	33	25
1 packet of oatmeal	50	46	39	35
1½ packets of oatmeal	50	48	45	40

What Happened?
In describing what happened in the experiments, I ask students to consider their results from all angles:

- What is the summary or big picture of the results?
- What was the highest and lowest temperature (range)?
- Did the responding variable show an overall increase or decrease (temperature trend)?

Examining the big picture is a good place to reconnect the experiment with the story. Ask,

- *If the temperature of all experimental bowls of porridge went down over the 15 minutes, does that mean that the porridge was getting cooler or warmer?* As students answer getting cooler, students are making connections between decreasing temperature readings and loss of heat energy making the oatmeal cooler.
- *Would Goldilocks consider the porridge at 50°C hot?* If 100°C is the boiling point of water and 0°C is the freezing point of water, students can recognize temperature readings within a relative hot and cold range. The range in this experiment usually runs between 21–50°C, so students will agree that 50°C would be at the hot end.

Conclusions and Beyond
As we concluded the lessons, students examined their predictions to determine if their prediction was supported or not supported, and we talked about some additional questions that arose from the experiments, including the following:

- Would the results be similar if a different type of porridge were used?
- Would the temperature readings be different if the porridges were heated in the microwave oven?
- Would the results be different if they used styrofoam bowls instead—does insulation play a role in heat retention?
- What would happen if we placed the bowls of oatmeal in the sun and in an air-conditioned room to see if outside temperature is a factor?

Finally, we discussed if procedures were compromised in any way (spills, constants not held, thermometer misreading), which may have introduced factors that could have affected the accuracy of the data or affected their conclusions. For example, one group held the bowls in their hands during the experiment. In hindsight, the students realized body heat could have influenced their results.

Figure 3.
Assignment rubric.

Criteria	Beginning Scientist	Developing Scientist	Accomplished Scientist
Investigation Skills	Try to make your "I wonder" question measurable. What information needs to be collected to answer the question?	Accurate data supported your measurable question. How could your results change the story of *Goldilocks and the Three Bears*?	All components of your investigation are accurate. Each bear is matched with his/her bowl of porridge. Three cheers!!
Understanding Temperature	Practice reading a thermometer. If the reading is high, does this mean something is HOT or COLD?	Think about what might cause the porridge to get cooler/warmer. How would changing ONE variable affect the temperature readings?	You connected your manipulated variable to heat retention/loss as measured by temperature. Congratulations!
Collaboration	Most scientists work together—won't you?	You had some great ideas—Also consider your lab partners' ideas!	You worked productively with lab partners! Thank you.

Assessing Students

To assess students' learning, I used a rubric (Figure 3) designed to provide constructive comments/questions on students' progress. If a student's performance is in the "beginning scientist" range, the rubric will provide direction for the student to take in order to move up to the "developing scientist" range by offering ideas on how to improve understanding of scientific investigation.

Learning to design a measurable question, accurately read a thermometer, and making a connection between the temperature reading and amount of heat energy present in the bowl of porridge were the intended learning outcomes from these investigations. In addition, I hoped students would be able to incorporate their investigation into a wider framework and begin to analyze relationships among data. By thinking critically, students learn to reason from evidence.

At the completion of this activity, students were doing just that. Some students were already thinking about how to apply this investigation strategy to other pieces of children's literature. Students were discussing that for *The Three Little Pigs* manipulated variables might be how much fan power would be needed (or at what distance a fan would need to be placed) in order to knock down houses constructed of sugar cubes (bricks), toothpicks (wood), or broom straw!

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Resources

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academy Press.

Internet

The Story of Goldilocks and the Three Bears
www.dltk-kids.com/rhymes/goldilocks.htm
Information About Heat and Energy
www.emints.org/ethemes/resources/S00000503.shtml
Thermometer Use Practice
http://fs.sdsu.edu/pisces/WeatherKit/Lesson05.php

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Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996):

Content Standards

Grades 5–8

Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry

Standard B: Physical Science

- Transfer of energy