4 Mass and Thermal Energy

Unit Essential Question

How do we use and control thermal energy in a system?

Introduction

In this task, students will design and conduct an experiment to see how the size (or more accurately, the mass) of a material affects its rate of temperature change. Students will have fun connecting this important science concept with the familiar book *Goldilocks and the Three Bears*.

Depending on time and the level of student confidence in designing experiments, this activity can be done in two different ways. One option is for the class to work together to design the experiment, and then students, working in small groups, can write out and conduct the experiment. The other option is for each small group to design and conduct the experiment with the materials given to them.

Objectives

Students will be able to

Content

- Explain the relationship between mass and thermal energy.

Science and Engineering Practices

- Design and conduct an experiment.

Equity and Groupwork

- Give reasons for lab decisions.

Language

- Summarize information and use evidence to write an argument.
- Read the displayed ideas from each group and the Culminating Project.
- Use the academic vocabulary in ideas, discussions, and notes.
- Write their ideas in their science notebook and Individual Project Organizer.

Emerging →	Expanding →	Bridging →
Listen for, identify, and restate words and phrases about thermal energy in a system. Ask and answer yes-no questions about the task. Respond using simple phrases.	Describe the task in sequence using words and phrases about thermal energy in a system. Ask questions about the task and use complete sentences. Add information when possible.	Paraphrase and summarize the task in sequence using words and phrases about thermal energy in a system. Ask questions about the task and use complete sentences. Affirm others, and build on their responses.

Assessment

1. Have students independently complete the Task 4 section of the Energy Unit Individual Project Organizer as homework or in class, depending on students' needs and/or class scheduling.
2. Collect Individual Project Organizers and assess them using these criteria:
   - "Planning and Carrying Out an Investigation" row of the Science and Engineering Practices Rubric
   - "Engaging in Arguments from Evidence" row of the Science and Engineering Practices Rubric
3. Return the Individual Project Organizers, and give students time to make revisions. ELLs may need additional time.

Academic Vocabulary

- mass
- variable

Language of Instruction

- account for
- porridge

LANGUAGE SUPPORT STRATEGIES

- Display the academic vocabulary on the board or wall.
- Support students' use of their own words (everyday language) to understand and explain the concepts.
- Highlight the academic vocabulary during debriefs and help make connections with students' own words.
- Encourage students' use of academic vocabulary during discussions and writing by repeating their sentences and phrases with the academic vocabulary in context. Mirror their statements back to them in complete sentences so they hear the academic term and its surrounding syntax.
- Acknowledge when students use the academic vocabulary in context and, when applicable, make connections with students' own words by recasting or rephrasing the use of the terms.

Timing

This task can be completed in 4 class periods (based on 45-minute periods).

- Part I • Design and Conduct an Experiment: This Porridge Is Too Hot! (2 class periods)
- Part II • Debrief the Experiment (1 class period)
- Part III • Connect to the Culminating Project and Assessment (1 class period)

Student Materials

per group

- 2 cups cooked instant oatmeal
- 3 beakers or plastic bowls large enough to hold 1 cup of oatmeal (do not use polystyrene foam or insulated cups)
- 3 thermometers
- Timer
- Graph paper or large piece of poster paper
- Measuring cups for oatmeal (1 cup, $\frac{1}{2}$ cup, $\frac{1}{4}$ cup)

Teacher Materials

- *Goldilocks and the Three Bears*
- Hot plate or slow cooker to keep oatmeal hot
- Cooked oatmeal (enough for 2 cups per group)

Background Knowledge

So far in this unit, students have learned that thermal energy is the total energy of all the particles in an object. They have also learned that thermal energy transfers, in the form of heat, from a hotter substance to a colder substance or from a hotter region to a cooler region. The final concept introduced in this unit is that thermal energy transfer, or heat, is directly related to the mass of an object.

You can use two bowls of water as an example of mass and thermal energy transfer. If you have two bowls that are exactly the same size, one containing 10 ounces of warm water and one containing 20 ounces of warm water, and you put them in the refrigerator so that there is a temperature difference between the water and the refrigerator air, the question becomes, will the two masses (amounts) of water cool down at the same rate? The answer to this question is related to the mass (or amount) of the water and the surface area exposed to the cold refrigerator air. The temperature change is due to energy moving out of the hotter water and into the cooler refrigerator air. If the surface area of the water exposed to the refrigerator is the same, a larger mass (amount) of water will have more thermal energy than a smaller mass (amount) of water at the same temperature; therefore, the larger mass of water needs to release more energy to become the same temperature as the refrigerator. As a result, the larger amount of water will take longer to cool down.

However, if the 20 ounces of warm water (the larger mass) is in a very flat bowl so that the surface area of the water exposed to the cold refrigerator air is larger than the surface area exposed in the 10 ounces of water, then even though there is more water and more thermal energy present it is possible that the larger amount of water will cool down to the refrigerator temperature in the same amount of time as the smaller amount of water.

In conclusion, the speed at which a substance cools is directly proportional to its mass, the size of the surface area exposed to the cooler substance, and the difference in temperature between the two regions. In essence, a larger mass of a substance will cool down slower than a smaller mass if the surface areas of the larger and smaller substances exposed to the cold are the same.

In this task, students will be using oatmeal as the substance to be cooled to show that the change of temperature of a material is dependent on the mass (or amount) of the material. It is important that students keep the surface area of the two masses exposed to the air about the same to get the best results. The surface area is easy to control if students use small bowls to put their oatmeal in, thus only exposing the top surface of the oatmeal to the cooler air.

Part I • Design and Conduct an Experiment: This Porridge Is Too Hot!

1. To motivate the class to start thinking about different reasons for different temperatures of masses, read *Goldilocks and the Three Bears* as a class. Emphasize the following part of the story:

   At the table in the kitchen, there were three bowls of porridge.

   Goldilocks tasted the porridge from Papa Bear's bowl.

   "This porridge is too hot!" she exclaimed.

   So, Goldilocks tasted the porridge from Mama Bear's bowl.

   "This porridge is too cold," she said.

   Then, Goldilocks tasted Baby Bear's bowl of porridge.

   "Aah, this porridge is just right," she said happily, and she ate it all up.

2. With students, brainstorm variables that might account for temperature differences among the three bears' porridges using "I wonder ..." statements. For example:

   - I wonder if the amount of porridge made a difference.
   - I wonder if the size of the bowls made a difference.
   - I wonder if all the bowls were made of different materials.
   - I wonder if the bowls were different shapes.
   - I wonder if Baby Bear's bowl was near an open door and there was a cool breeze coming in.

LANGUAGE SUPPORT STRATEGIES

- Use "I wonder..." statements.
- Display students' ideas of variables.
- Repeat students' ideas using their words.

3. Have students write an experimental question.
   - How does changing the amount of what you are trying to keep hot affect how quickly the temperature changes?

LANGUAGE SUPPORT STRATEGIES

Ensure that ELLs are clear about the language of the instructions, including a review of some terms they know (e.g., *summarize*, *predict*, *graph*, *vary*, and *varying*).

4. Review the materials needed for the experiment.

SAFETY NOTE

Explain how to properly handle hot water and thermometers. Advise students not to eat or spill the oatmeal.
Be prepared to clean up any spills.

5. If the class is working on the design of the experiment together, discuss the following questions:
   - What is your variable? (amount of oatmeal)
   - What are you keeping the same? (amount of hot water, kind of oatmeal, timing of experiment, size of bowls)
   - What are the different values you will have for your variable? (Example amounts: $\frac{1}{4}$ cup oatmeal, $\frac{1}{2}$ cup oatmeal, 1 cup oatmeal)
   - What will you measure? (temperature with a thermometer)
   - How many trials will you conduct? (Each group will conduct one trial, but every group will be doing the same experiment, so the number of groups in the class is the number of trials.)
   - How often will you record your data? (at the start and then every 5 minutes for 15 minutes)
   - What materials will you need? (See list of materials.).

6. After the discussion, tell students to fill in the table in their Student Edition.

7. If students work in groups, have the groups collaborate on the experimental question, materials, procedures, prediction, and how to create a Data Table.

8. Rotate among the groups to check on their procedure (setup). Sign off each group that has experimental procedures that are complete and rational. A sample experimental setup might be as follows: Line up three identical plastic bowls or other containers.
   - In the first bowl put in $\frac{1}{4}$ cup oatmeal. Note the time. Take the temperature. Record the temperature.
   - In the second bowl put in $\frac{1}{2}$ cup oatmeal. Note the time. Take the temperature. Record the temperature.
   - In the third bowl put in 1 cup oatmeal. Note the time. Take the temperature. Record the temperature.
   - Retake the temperatures every 5 minutes for 15 minutes.

NOTE

If there is only one thermometer available per station, then staggering the measurements is important. Make sure students note the time each measurement is taken so they remember when to take the next measurement. You may choose to have students record only two temperatures due to equipment or time limitations.

9. Have groups complete the experiment.

10. Have students collect the data in table form. Here is a sample Data Table.

Sample Data: Temperatures in Degrees Celsius (Dependent Variable)

Time in Minutes	$\frac{1}{4}$ Cup Oatmeal	$\frac{1}{2}$ Cup Oatmeal	1 Cup Oatmeal
0 min	75	75	79
5 min	62	65	76
10 min	50	57	63
15 min	44	50	58
Temperature Change	–31	–25	–21

11. Have students create a graph of their data.
    - Give students graph paper or a large piece of poster paper to graph the data. Students can make a line graph of the data over time or a bar graph of the total amount of change.
    - The three amounts of oatmeal should go on the *x*-axis to represent the independent variable, because that variable is the same for all groups and does not change if the experiment is repeated over and over. The temperature changes (°C) should go on the *y*-axis to represent the dependent variable, because these values depend on the different amounts of oatmeal.

Part II • Debrief the Experiment

1. Have students meet in their groups to discuss their data and reach a conclusion. (Daddy Bear had the most porridge, Mama Bear had the least porridge, and Baby Bear had the middle amount of porridge.)
2. Have students analyze their data and write a conclusion.

	Possible Sentence Starters	Your Response
Claim What is your answer to the question?	The bigger the _____, the less the _____. As the size (mass) of _____ increases/decreases, _____.	The bigger the amount of oatmeal, the less the temperature changes. As the size (mass) of the oatmeal decreases, the more the temperature changes over time.
Evidence What data did your group collect to support your claim?	My group saw that _____. Our data is _____. The temperature for the _____ went down by _____, and the temperature for _____ went down by _____.	My group saw that the $\frac{1}{4}$ cup oatmeal decreased in temperature by 31°C, and the 1 cup of oatmeal decreased in temperature by 21°C.
Reasoning How does your evidence support your claim?	The data makes sense because _____. The data shows that temperature change is dependent on _____. The reason the evidence makes sense is because _____.	The data makes sense because the temperature change depends on the size (mass) of the object. Smaller amounts change more/faster than larger amounts.

3. Then debrief the experiment as a whole class. Share out student graphs and conclusions. Start with the questions in the Student Edition.

   - **Describe your results. How did your results compare to your prediction?**

     Students' answers will vary.

   - **In Task 1, you learned that the amount of thermal energy depends on the number of particles and the amount of kinetic energy. Use this information to answer the following questions.**
   - **Which bowl had more particles?**

     The bowl with the most oatmeal had more particles.

   - **Which bowl had more thermal energy?**

     The bowl with the most oatmeal had more thermal energy. All three bowls started at the same temperature, but because there was more oatmeal, or more particles, in one of the bowls, then there was more thermal energy in that bowl.

   - **In *Goldilocks and the Three Bears*, which bear do you think had the most porridge, the least porridge, and the middle amount of porridge? Explain your reasoning.**

     Papa Bear had the most amount of porridge because his porridge was too hot. It was the hottest, which means it must have had the greatest mass and thus took the longest to cool down.

     Mama Bear had the least amount of porridge because her porridge was too cold. It was the coldest, which means it must have had the smallest mass and cooled down the fastest.

     Baby Bear had the middle amount of porridge because his porridge was just right. It was not too hot or too cold, which means the mass must have been somewhere between the mass of Mama and Papa Bears' bowls.

LANGUAGE SUPPORT STRATEGIES

- Display students' graphs.
- Discuss and write students' conclusions based on their graphs on the board.
- Use academic vocabulary to discuss ideas.

4. There is a chance that the student data may not reveal much change in temperature in the different masses. If the student data contradicts the concept (i.e., as the mass of a substance increases, the amount of energy required to change its temperature also increases), then the class can discuss the reasons for the lack of evidence.

5. Return students to their groups to apply their knowledge of mass to the design of their final device.

Part III • Connect to the Culminating Project and Assessment

1. Have students independently complete the Task 4 section of the Energy Unit Individual Project Organizer as homework or in class, depending on students' needs and/or class scheduling.

LANGUAGE SUPPORT STRATEGIES

Provide sentence frames such as the following for group discussions and for writing:

- Changing the _____ (size, mass, amount) of _____ affects how much the temperature changes because _____. I think this because the data showed _____. Another reason this statement is evident is _____. Finally, _____.

2. Collect Individual Project Organizers and assess them using these criteria:
   - "Planning and Carrying Out an Investigation" row of the Science and Engineering Practices Rubric
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3. Return the Individual Project Organizers, and give students time to make revisions. ELLs may need additional time.