**Unit Essential Question:** *How do people use technology to survive in regions with different climates?*

**Introduction**

So far in this unit, students have been thinking about the context for their design problem—the causes of different climates around the world. Their task for the culminating project is to design a product that makes it possible to live in one of these climates with extreme temperatures. In order to design such a product, they need a thorough understanding of temperature. In this task, students build on their experiential knowledge of temperature changes to try and figure out what is happening at the molecular level and what factors affect temperature changes. To do so, they plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in temperature of samples. This will lay the foundation for them to envision the type of product they will design for their culminating project and the factors they should consider.

**Alignment Table**

|  |  |  |  |
| --- | --- | --- | --- |
| **Performance Expectations** | **Science and Engineering Practices** | **Disciplinary Core Ideas** | **Crosscutting Concepts** |
| **MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.** [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.] | **Planning and Carrying Out Investigations**   * Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. | **PS3.A: Definitions of Energy**   * Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.   **PS3.B: Conservation of Energy and Energy Transfer**   * The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. | **Scale, Proportion, and Quantity**   * Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. |
| **Supplementary Crosscutting Concepts**   * Patterns   + Patterns can be used to identify cause and effect relationships. | | | |
| **Equity and Groupwork**   * Discuss and compare observations and hypotheses with partners. * Participate in group roles to plan and carry out an investigation. | | | |
| **Language**   * Use sequence language to write a procedure. * Read and annotate an article. * Differentiate between related scientific terms and use appropriately in written and verbal contexts. | | | |

**Learning Goals**

This learning task asks students to plan and carry out an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in temperature of the sample. More specifically, the purpose is to:

* Engage prior experiences of thermal energy transfer.
* Explore the above relationships by planning and carrying out their own investigations.
* Explain the above relationships using evidence from their investigations and new scientific terminology.
* Elaborate on what they have learned to explain what is happening at the molecular level in a thermal energy transfer demonstration.
* Apply what they have learned about temperature to begin the initial design of their product.

**Content Background for Teachers**

In this task, students will be investigating concepts related to thermal energy transfer. When learning about thermal energy, one of the most difficult concepts is differentiating between temperature, thermal energy, and heat, and using these terms correctly. For more information on the differences between these terms, please reference the article in the *Explain* section of the Student Guide.

As students investigate thermal energy, they will find that the change in temperature of a sample is highly dependent on the types, states, and amounts of matter present. This also means that these factors affect the amount of energy transfer needed to change the temperature of an object. For example, an object with a lot of mass will take a lot more energy transfer to increase in temperature than an object with a small mass. The type of matter is also very important. For example, if a material is highly conductive, the kinetic energy of particles is more easily transferred and temperature will change more quickly.

**Academic Vocabulary**

* Temperature
* Thermal Energy
* Heat
* Energy Transfer
* Matter
* Particles
* Kinetic Energy
* Mass
* Dependent Variable
* Independent Variable
* Controlled Variables
* Procedure

**Time Needed (Based on 45-Minute Periods)**

5 Days

* Engage: 0.5 period
* Explore: 2 periods
* Explain: 1 period
* Elaborate: 0.5 period
* Evaluate and Reflection: 1 period

**Materials**

* Unit 2, Task 4 Student Version

Engage

* Projector and Speakers

Explore (Options of Materials to Provide Per Group)

* Heat Source
  + Bin or Tub of Hot water (electric kettle recommended to heat water consistently and quickly)
  + Heating Pad
* Any materials that can melt: Butter, Gummy Bear, Chocolate, Crayons, Candle Wax, etc.
* Aluminum Foil
* Wax Paper
* Cardboard
* Tape
* Plastic Knife
* Scissors

Elaborate (Per Class)

* 2 large beakers of same size
* Hot water
* Cold water
* 2 different colors of food coloring
* Projector and Speakers

Evaluate

* Project Organizer Handout

**Instructions**

**Engage**

1. Introduce Task 4: So far in the unit, you have been thinking about why the regions you chose have such extreme climate conditions. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
   * Before you pass out the student guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.
2. Transition to Task 4: Your job for the culminating project is to design a product that makes it possible to live in one of these regions, even with such extreme temperatures. Before we design this product, we first need to understand how temperature actually works!
   * Now pass out their Task 4 student guide.
3. Introduce the following scenario to students: You are boiling a pot of water while cooking pasta. You place a cool metal spoon into the pot to stir the mixture. You have to leave the stove for a minute and when you come back, you grab the metal spoon…ouch! It’s now boiling hot!

* Optional - Show the first 20 seconds of the following video to help set this context: <https://www.youtube.com/watch?v=wV7gzcKegdU>. DO NOT SHOW THE WHOLE VIDEO. They will return to the rest of this video in the *Elaborate*.

1. This activity asks students to call upon any prior experiences they have and make a hypothesis to the following question in pairs: Why is the handle of the spoon hot even though the handle is not submerged in the boiling water?
2. Share out ideas as a class.

* Students will likely be able to convey the general idea of thermal energy transfer without the scientific terminology. For example, many students will discuss how the boiling water heats up the bottom of the spoon, so the whole spoon gets hot. This experiential understanding sets the stage for students to consider how exactly heat is transferred later in this task.
* We encourage using equity sticks to foster more equitable participation in class-wide discussions like these (See “How To Use This Curriculum” for more details).

**Explore**

1. Students know based on experiences like the one above that the temperature of objects can change. But the questions remain: How is temperature able to change? And what factors affect changes in an object’s temperature? In this activity, students plan and conduct their own investigations to try to answer these questions.

* This activity gives students practice at the SEP of **Planning and Carrying Out Investigations** as students engage in all the relevant tasks associated with planning an investigation (i.e., writing an experimental question, identifying variables, writing a procedure, and collecting data).
* Due to the content of these investigations, students will also emphasize the CCC of **Scale, Proportion, and Quantity** as students gather data to identify proportional relationships among different types of quantities, such as mass and temperature.

1. Review the material options you will provide to students (See Materials List above) and assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Facilitator, Materials Manager, Harmonizer, and Recorder.
   * Ask the Facilitator to read the directions and to make sure everyone understands the task.
   * Ask the Materials Manager to gather the materials needed to complete the task.
   * Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone’s voice is heard.
   * Ask the Recorder to make sure the group is recording all parts of their experiment in their Student Guides
2. Keep in mind that this activity will likely require a lot of teacher facilitation. When students plan their own investigations, they can often take paths away from the content you would like them to focus on. Here are some facilitation strategies to help students stay on track:
   * Review the DCIs in the alignment table above so you are clear about what you want students to get out of their investigations.
   * Student investigations should focus on the relationships between mass and temperature change or the type of matter and temperature change.
     1. Walk around and check in with students throughout the planning process. Ask student groups probing questions as they plan their experiments to ensure they are addressing one of the above objectives.
     2. We also recommend establishing checkpoint safter the planning process. For example, first have each group share their experimental design with another group. Then, they must clear their experimental design with you before they can conduct their experiment. This allows you to see if they are on the right track before they go through the entire experimental procedure.
3. Here is a sample of a potential experiment a student group might plan.

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| Experimental Design   1. Write your experimental question: Based on the materials available, what would you like to test?   *How does the mass of an object affect its temperature when heated?*   1. Identify the Dependent Variable: What are you trying to measure or observe at the end of the experiment?   *The change in temperature of the object*   1. Identify the Independent Variable: What will you need to manipulate (change) in order to measure this?   *Mass of the object*   1. Identify the Controlled Variables: What should you keep the same so that you only measure what you want to?   *Type of object, amount of time heated, heat source, vessel to hold object, intervals for measuring temperature*  Materials:   * Bin * Hot water (50-60°C, anything hotter and burns may occur quickly) * Foil * Plastic Knife * Butter   Procedure:   1. Using a plastic knife, cut a piece of butter into two uneven pieces: one large piece and one small piece. 2. Create a small foil boat that will safely hold the piece of butter. 3. Place the large piece of butter into the foil boat and carefully set the foil boat into the tub so it floats on top of hot water. 4. Watch carefully for 2 minutes. Record observations and draw a labeled diagram of what they observe in the notebook data table. 5. Repeat this process with the small piece of butter.   Data Collection Table   |  |  |  |  | | --- | --- | --- | --- | | **Object** | **Observations** | **Diagram** | **Observed Change in Temperature**  **(Hotter or Colder)** | | **Large Piece of Butter** |  |  |  | | **Small Piece of Butter** |  |  |  | |

1. Once students have conducted their experiments, have each group share out their experiment and findings so other groups can use it in their conclusions during the *Explain*. If possible, use a document camera so students can show their experimental set-ups and their data collection as they explain their experiments.

* We recommend students take notes on other experiments that were different from theirs so they can use this information in the *Explain*.
* We also recommend creating a public record of the class data. Record findings as they are shared, so they can be displayed to the class as students do the *Explain*. The public display makes it easier to look for patterns in the data across everyone’s findings. This emphasizes the supplementary CCC of **Patterns** as they look across data to identify cause and effect relationships.

1. Optional: If you feel students still need more exposure to these concepts, select a few groups’ experiments that were well-designed for the objectives. Demonstrate these experiments as a whole class and have students discuss the relationships they see.

**Explain**

1. Students now have the data to draw conclusions about the different relationships they observed. However, it is very difficult to discuss these investigations without the proper terminology, especially since these terms are so closely related, they are often accidentally used interchangeably.
2. To learn about these differences between temperature, thermal energy, and heat, students first individually read and annotate the article provided in their Student Guides.

* We recommend using whichever annotation strategy students are familiar with in your classroom, but an option is also provided in the “How to Use This Curriculum” document, if needed.
* After reading, have students share with a partner to practice describing these terms in their own words.

1. Armed with these new terms, students are ready to draw conclusions about their investigations. We recommend this be done in groups because it is often difficult for students to analyze student-designed investigations without support.

* These conclusions emphasize the CCCs of **Scale, Proportion, and Quantity** and **Patterns.** Students are using patterns across class data to identify and describe proportional relationships, using appropriate scientific terminology.

1. For student groups who are struggling to identify relationships, pose some facilitating questions to jumpstart their thinking.

* For example, if we consider the sample experiment in the *Explore* section, you might ask: “What happened to both pieces of butter when you placed the foil boats in the hot water? Why do you think the temperature of these objects changed? How did the results differ amongst the pieces of butter? What do you think caused these differences?”
* Other general questions could be: “Your experiment measured one factor affecting temperature change…what were other experiments that measured other factors? Based on the experiments, how and why does temperature change? What information from the article can you use to support this idea?”

1. We recommend debriefing these questions in a class discussion for a quick formative assessment to see where students are in their understanding. This gives you an opportunity to address any gaps in understanding before the *Elaborate*.

**Elaborate**

1. So far in this task, students have seen how thermal energy is transferred between objects and how this causes changes in temperature. But what is actually happening at the particle level? Why does thermal energy transfer between objects and why does the temperature change?

* This activity gives students an opportunity to extend their understanding a step further by thinking about the microscopic mechanism that makes everything they saw in the *Explore* possible. It also provides a meaningful transition to the next task as students begin to think about a product that minimizes or maximizes thermal energy transfer.
* Here students are again emphasizing the supplementary CCC of **Patterns** as they use patterns in what they observe to explain the cause-and-effect relationship both at the macroscopic level and the microscopic level.

1. Do a demonstration of food coloring mixing at two different temperatures. Set up two large beakers: one with very cold water and one with very hot water. At the same time, drop 2-3 drops of food coloring into each of the beakers and ask students to observe.

* You may want to ask students to share out some of their observations as a class before writing down their hypotheses about why this happens individually.
* Students should share hypotheses first with a partner and then a few as a whole group. Emphasize to students that there is no right answer at this point!
  + This might be a good time to also ask students to predict what it would like when you drop food coloring into room temperature water based on what they’ve seen. Then, demonstrate this scenario and students can make observations again.
* Again, we encourage using equity sticks to foster more equitable participation in class-wide discussions like these (See “How To Use This Curriculum” for more details).

1. Show the rest of the video from the *Engage* to give students a visual of what is happening at the molecular level during thermal energy transfer: <https://www.youtube.com/watch?v=wV7gzcKegdU>.

* Then show the following simulation to highlight the transfer of energy through conduction between solids with different energy. This allows students to actually see the energy being transferred, with one particle losing energy and the corresponding particle gaining energy during the collision: <http://lab.concord.org/embeddable.html#interactives/external-projects/CREATE/solid-heat-transfer.json>.
* Give students an opportunity to discuss what they learned from the video and simulation in partners.

1. Students now have the information to explain the food coloring demonstration on their own.

* Students should be able to explain that the food coloring mixes more quickly in the hot beaker because the molecules are moving faster at the higher temperature. The molecules in the cold beaker are moving much slower, so the food coloring mixes more slowly.
* Question 3A gives students the opportunity to explicitly connect this idea to their *Explore* investigations. For example, students might say that this gradual transfer of particle motion explains why objects with more mass need more thermal energy transfer to increase temperature.
* This section of the task provides a great opportunity for formative assessment. Collect student work to assess their ability to explain thermal energy transfer within a new context. See “How to Use This Curriculum” for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.

1. Return to the whole-class concept map from the Lift-Off Task.
   * In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See “How To Use This Curriculum” for more details).
     + Some facilitating questions to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
     + Draw circles around each question and boxes around each concept.
     + Write connector words to describe connections between the concept boxes.
     + For this task, students may begin to connect some of their previous question circles to concept boxes about the following: the definition of temperature, what factors affect temperature change, and thermal energy transfer.
   * Have students analyze the additions to the class concept map for as many examples of this task’s crosscutting concept as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
     + **Scale, Proportion, and Quantity**: These could be phrases such as, “is proportional to”, “compared to”, “has a ratio of”, “is bigger/smaller than”, “is longer/shorter than”, etc.

* Once again, the purpose of this concept map is to facilitate generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

**Evaluate: Connecting to the Culminating Project**

1. Students independently complete the Task 4 section of the Unit 2 Project Organizer in class. Revisions can be done for homework, depending upon student’s needs and/or class scheduling.
2. Students have been asked to design a product that makes it more comfortable for people to live in a region with an extreme climate. Their prompt is as follows: Think about the climate in the region you selected.

* Will your product need to help people stay warm or cool down?
* Would this require increasing the kinetic energy of the particles or decreasing the kinetic energy of the particles? Explain.
* Based on your explorations, how might you be able to make this possible? What factors should your product consider?

**Reflection**

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:

* At the beginning of this task, you were asked make a hypothesis to the following question: Why is the handle of the spoon hot even though the handle is not submerged in the boiling water? Look back at your hypothesis. After everything you have learned through this task, what would you change or add to your response? Record this below:
* In this task, we focused on the crosscutting concept of **Scale, Proportion, and Quantity**: Proportional relationships among different quantities tell us about the magnitude of processes. Where did you see examples of **Scale, Proportion, and Quantity** in this task?
* Now that you have learned more about temperature for the design of your product, what questions do you still have?

1. There are no right answers, but encourage students to look back at their student guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

**Assessment**

1. Collect students’ Task 4 Student Versions and assess the *Explore* using the 3-Dimensional Task 4 Rubric below. To maintain the authenticity of the Culminating Project, the SEP of MS-PS3-4 will be assessed through this task rather than within the Culminating Project.
2. You may collect students’ Project Organizer and assess using:

* *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
* This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.

1. You may also give students time to make revisions with one of the two options:

* Students may make changes to their Project Organizer according to your comments OR
* Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.

**Task 4 Rubric**: Student plans an investigation to determine the relationship between change in temperature and mass OR change in temperature and type of matter.

* Use to assess student responses in the *Explore*.
* Dimensions Assessed: SEP – Planning and Carrying Out Investigations; DCI – PS3.A: Definitions of Energy or PS3.B: Conservation of Energy and Energy Transfer

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| --- | --- | --- | --- |
| **Emerging (1)** | **Developing (2)** | **Proficient (3)** | **Advanced (4)** |
| Student plans an **irrelevant** investigation **that does not** determine the relationship between temperature and mass OR temperature and type of matter. | Student plans a **relevant** investigation **with major errors** to determine the relationship between temperature and mass OR temperature and type of matter. | Student plans a **relevant** investigation **with minor errors** to determine the relationship between temperature and mass OR temperature and type of matter. | Student plans a **relevant** and **thorough** investigation to determine the relationship between temperature and mass OR temperature and type of matter. |
| **Look Fors:**   * Student plans an irrelevant experiment that does not investigate the relationship between change in temperature and mass (i.e., IV –mass of an object) or the relationship between change in temperature and type of matter (i.e., IV – type of material). For example, student describes an experiment to see whether hot objects float and cold objects sink in a water bath. | **Look Fors:**   * Student plans a relevant experiment to investigate the relationship between change in temperature and mass (i.e., IV –mass of an object) or the relationship between change in temperature and type of matter (i.e., IV – type of material). * Some parts of the experimental plan are accurate, but there are major errors or many missing components (See *Advanced Look-Fors* for list of requirements). | **Look Fors:**   * Student plans a relevant experiment to investigate the relationship between change in temperature and mass (i.e., IV –mass of an object) or the relationship between change in temperature and type of matter (i.e., IV – type of material). * Most parts of the experimental plan are accurate, but with some minor errors or missing components (See *Advanced Look-Fors* for list of requirements). | **Look Fors:**   * Student plans a relevant experiment to investigate the relationship between change in temperature and mass (i.e., IV –mass of an object) or the relationship between change in temperature and type of matter (i.e., IV – type of material). * All parts of the experimental plan are accurate and complete, including: experimental question, dependent variable, independent variable, controlled variables, material list, experimental set-up, procedure, and data collection table. |