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

**Introduction**

In the last task, students planned and conducted investigations to figure out what is happening at the molecular level during thermal energy transfer and what factors affect temperature change. By the end of the last task, they had begun to envision types of product for their culminating project and the factors they should consider. In this task, they move on to the actual design process! Throughout this task, students engage with a series of guided steps to help them brainstorm, design, build, test, and revise a prototype for a product that makes it possible to live in a region with extreme temperatures. By the end, students will have a solid idea of the product they want to present in their culminating project, including an understanding of the science behind how it works and the engineering process it took to get them to their final product.

**Alignment Table**

|  |  |  |  |
| --- | --- | --- | --- |
| **Performance Expectations** | **Science and Engineering Practices** | **Disciplinary Core Ideas** | **Crosscutting Concepts** |
| **MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.\*** [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.] | **Designing Solutions**   * Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process, or system. | **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**  Energy is spontaneously transferred out of hotter regions or objects and into colder ones. | **Energy and Matter**   * The transfer of energy can be tracked as energy flows through a designed or natural system. |
| **MS-ETS1-3**. **Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.** | **Analyzing and Interpreting Data**   * Analyze and interpret data to determine similarities and differences in findings. | **ETS1.B: Developing Possible Solutions**   * There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. * Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.   **ETS1.C: Optimizing the Design Solution**   * Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. | **No CCC listed** |
| **Supplementary Science and Engineering Practices**   * Asking Questions and Defining Problems   + Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. * Developing and Using Models   + Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. * Planning and Carrying Out Investigations   + Collect data about the performance of a proposed object, tool, process or system under a range of conditions. | | | |
| **Equity and Groupwork**   * Come to consensus on a design idea by considering and combining ideas from all group members. * Participate in group roles to design, build, and test a product through a guided design process. * Participate in group roles to make a poster. * Share data with other groups and learn from others’ data. * Use ideas and data from other groups to inform a redesign of a product. | | | |
| **Language**   * Cite experimental data to support ideas. * Gather and read external research to inspire ideas. * Use sequence language to describe a procedure. * Represent scientific terminology in visual models. | | | |

**Learning Goals**

This learning task asks students to design, construct, test, and revise a device that either minimizes or maximizes thermal energy transfer. More specifically, the purpose is to:

* Engage prior knowledge of heat-regulation devices to brainstorm potential ideas for a product.
* Explore the design process to design, build, and test a prototype of their product.
* Explain products and compare test data to other groups so that all groups can learn from each other’s tests.
* Analyze and interpret data from various tests to improve the design of their final product.
* Draw a labeled diagram of their final product, explaining the science of how it works and the design process used.

**Content Background for Teachers**

In the last task, students learned about thermal energy transfer, temperature, and heat as they relate to the kinetic energy in particles. For more information on these specific terms, please reference the article in the Task 4 *Explain* section of the Student Guide. Students also investigated that the amount of thermal energy transfer needed to change the temperature of a sample is highly dependent on the types, states, and amounts of matter present. By the end of the task, students were able to explain that thermal energy is transferred when particles collide and the kinetic energy of high-energy particles transfer to low-energy particles.

In this task, students build off these ideas to design a product that minimizes or maximizes thermal energy transfer. This could be a range of different products relating to clothing, housing, heating devices, cooling devices, etc. In the design of this product, students will use the idea that thermal energy moves from regions of higher temperature to regions of lower temperature, and not the other way around. Thermal energy is stored in

molecules as vibrations or movement. The more that particles in solids are vibrating, the more thermal energy that solid has. During the transfer of thermal energy between contacting substances, the kinetic energy of one substance decreases, while it increases in the other.

After deciding on a type of product, students will use their investigations from Task 4 and any additional research they gather to build and test a product. In their research, you may want to guide them toward sources about materials that are insulators and materials that are conductors.

For some materials, for example, transferring thermal energy is easy: one high-energy molecule makes a neighboring molecule start to vibrate. That new molecule then makes its neighbors vibrate. Pretty soon, all the molecules are vibrating. Eventually, the whole object may increase in temperature. This type of material is a conductor. Metals are particularly good conductors because there are virtually no spaces between molecules in metals, meaning that particle collisions occur very rapidly, and energy is transferred quickly. Liquids can be good conductors because the molecules also tend to be close together, but not as close as with metals. Some solids (such as wood or plastic), though they have molecules which are close together, also contain empty spaces which reduce the number of possible molecule collisions, thus reducing the substances effectiveness as a conductor.

Insulators are materials that reduce thermal energy transfer because they reduce the amount of possible molecular collisions. The best insulator is a vacuum, or completely empty space devoid of molecules. If there are no molecules, there can be no molecular collisions. A good insulator that is available to students is air. Air does not transfer heat very well because the molecules are so far apart from each other that they do not often bump into other air molecules to transfer the thermal energy. In essence, air is a good insulator because the molecules are too far apart for it to be a good conductor. This is why double-paned glass is used for windows in well-insulated homes. Below are some other good examples of insulators:

* A bunch of air-filled plastic bubbles arranged in a honeycomb pattern
* Foam, a frothy plastic material containing gas within non-connected tiny cells
* Dry wood, which has a great deal of empty space inside it
* Fiberglass, a mat of fine glass strands in a suitable containing wrap.
* Styrofoam

Some fiberglass insulation comes wrapped in an aluminized (reflective) material to also inhibit thermal radiation. Often, reflective surfaces are used as insulators because thermal radiation bounces off the surface rather than being absorbed. For example, in a thermos, the shiny-mirrored surface reflects the heat back toward the source, keeping the fluid hot. Cold substances in the thermos stay cool because the heat from the outside is reflected away from the contents. Though students may research and use these types of technologies in their design, the main elements of their design will need to focus on minimizing or maximizing thermal energy transfer.

**Academic Vocabulary**

* Design
* Product
* Prototype
* Minimize
* Maximize
* Criteria
* Constraints

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

6 Days

* Engage: 0.5 period
* Explore: 2 periods
* Explain: 1 period
* Elaborate: 1.5 periods
* Evaluate and Reflection: 1 period

**Materials**

* Unit 2, Task 5 Student Version

Engage

* Post-its (at least 3 per student)
* Poster Paper (per group)

Explore (Per Group)

* Computers or tablets for research
* Options of materials to build and test prototypes
  + Heat Sources
    - Heating Pads
    - Hot Water in Containers
  + Thermometers
  + Timers
  + Tape
  + Aluminum Foil
  + Newspaper
  + Cardboard
  + Plastic Bags
  + Different kinds of Cloth
  + Bubble Wrap
  + Foam
  + Any additional materials you or students may want to bring from home

Explain

* Computers or tablets to re-watch conduction video if necessary
* Posters
* Markers

Elaborate

* Optional: materials to test new designs of products

Evaluate

* Project Organizer Handout

**Instructions**

**Engage**

1. Introduce Task 5: Your job for your culminating project is to design a product to make it possible to live in a region with extreme temperatures. In the last task, you investigated what temperature is and different factors that affect temperature changes in objects. 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 their 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 5: Today, you’ll be able to use what you learned in your investigations to actually design, build, and test your product!
   * Now pass out the Task 5 student guide.
3. We recommend first giving students individual think-time to picture the region they selected for their culminating project and use the following questions to begin their thought process: What kinds of products might make the temperature conditions more comfortable for the people living there? Which of these products uses the science concepts you investigated in Task 4?
4. In this *Engage*, students will be creating a design board. This involves each student adding post-its of their own ideas to a poster and then clustering these post-its to come to consensus on a design idea for their product.
   * Distribute 3-5 post-its to each student and give them time without speaking to brainstorm and record their own ideas. Because we want product designs to align to the DCIs by relating to thermal energy transfer, ask students to draw a star next to ideas that use concepts they learned in Task 4.
   * Students place their post-its on their group poster.
   * As a group, students review the ideas on the poster, put them into clusters of similar ideas, and revise and combine ideas as necessary.
   * In the end, they will decide on the best idea to move forward with in the next sections of this task. However, save these posters in case students need to return to some of their other ideas for their culminating project.
5. Coming to consensus is challenging for students. We recommend assigning roles to each group. You may use whatever roles you prefer. We recommend the use of the Facilitator, Materials Manager, Harmonizer, and Reporter.
   * 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 Reporter to make sure any revisions are reported on the poster.

**Explore**

1. Now that groups have an idea of the product they want to design, they are ready to begin the design process, which involves: re-defining the problem in terms of criteria and constraints, gathering inspiration from existing data and external research, drawing a prototype, building a prototype, and testing a prototype.

* This activity gives students practice at the SEP of **Designing Solutions** as students apply scientific ideas to design, construct, and test a product that maximizes or minimizes thermal energy transfer.
* In the guided steps of the design process, students are also practicing the supplementary SEPs of **Asking Questions and Defining Problems**, **Developing and Using Models**, and **Planning and Carrying Out Investigations** as they re-define criteria and constraints, draw a model of their prototype, and plan and conduct an investigation to test their prototype.

1. Introduce the task to students by reading the text on their Student Guide aloud: Now that you have an idea for a potential product to minimize or maximize thermal energy transfer, you can design, build, and test it to create the best possible final product. As a group, use the questions below to guide you through this design process.

* If students are not familiar with the terms minimize, maximize, or prototype, use this time to explicitly define them for students, using examples.
* Also present them with the material options they have to design their prototype to help them focus their research. They may also bring in materials from home, but remind students they can’t bring in devices that have already been built for insulation or conduction (ie. a thermos).

1. You will notice that most of the activities in this task are done as a group. This is because students are designing their product for the culminating project and collaboration is essential for a well-designed product. Assign roles to each group, but mix up the role assignments from the *Engage*. 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 design process in their Student Guides.
2. Students first return to the Lift-Off section of their Project Organizer to clarify the criteria and constraints of the problem in their region. This allows them to clearly recall the problem they are solving before they dive into their design.
3. Next students gather more inspiration for their product design.

* Students should cite specific data from Task 4 that they are using to inform their design.
* They will also likely want to do some additional outside research for their product design. Provide students with computers, tablets, or your own curated resources. It may be helpful to point them toward resources about materials that function as insulators and conductors.

1. Now that students have done some research, they can begin to design their prototype. Encourage students to consider structure, material, size, mechanism, etc. in their design. Students draw a diagram of their prototype, using labels to explain how the product will work.
   * This diagram asks students to emphasize the CCC of **Energy and Matter** as they must show how energy flows through their designed system as thermal energy transfer is either maximized or minimized.
   * We recommend establishing a checkpoint after this step. For example, student groups must clear their design with you first before they can test the prototype. This allows you to see if their design actually uses scientific concepts to minimize or maximize thermal energy transfer.
   * Students may come up with a variety of different designs:
     1. For extreme cold: houses with double-paned windows, concrete walls inside of houses with large windows to absorb and retain heat from the sun, building insulation in walls, insulated gloves, hot water bottles, quilts or clothing with pattern of insulation pockets, thick curtains, thermos, radiator foil, solar ovens, etc.
     2. For extreme heat: houses with double-paned windows, wind towers, white washed houses, cooling domes, water trenches beneath huts for evaporative cooling, small windows, dugouts, reflective clothing, loose-fitting clothing, water-wicking clothing, ice chest, etc.
2. Lastly, students build and test their prototype. Because students are not being explicitly assessed on the planning of these investigations, the guiding prompts are looser in structure. However, you may use the same questions in the Task 4 *Explore* if you wish to follow a more rigid structure for planning their experiments.
   * This data will be used to evaluate how successful their product will be and what improvements they should make.

**Explain**

1. Students now have data to serve as evidence for how well their design works. In this *Explain*, students use scientific concepts from Task 4 to analyze why they got these results and distill all this information into a poster they can share with the rest of the class.

* This encourages a sharing of data that can lead all groups to improve their designs.

1. Provide students with materials to make a poster. You may also want to provide a tablet and/or computer so students can revisit the *Conduction* video and simulation from Task 4, if necessary: <https://www.youtube.com/watch?v=wV7gzcKegdU> and <http://lab.concord.org/embeddable.html#interactives/external-projects/CREATE/solid-heat-transfer.json>. Again, assign group roles, but mix up the role assignments.
2. On the poster, students should include a diagram showing how their product works, the data from the test of their prototype, and an explanation for why they think they got those results.

* This last explanation emphasizes the CCC of **Energy and Matter** as students track the energy transfer in their designed system.

1. These posters can be presented as whole class presentations or in a gallery walk. Regardless of the presentation format, encourage students to take notes on not only the features of the designs they liked but also the data that justifies that these designs work well. Emphasize that this data will be essential to include in their individual culminating project so they will want to have good notes.

* We recommend leaving up the posters for the rest of this task, so students can walk up to them and refer to the data as they make revisions to their product in the *Elaborate*.

**Elaborate**

1. Equipped with their own data as well as other groups’ data, students can return to their original design and consider how they might modify it so it better meets the criteria and constraints of the problem.

* This activity emphasizes the SEP of **Analyzing and Interpreting Data** as students analyze the similarities and differences in test data to identify best characteristics of the designs they have seen.

1. As a group, students analyze data from different designs and re-design their product to combine best characteristics from these designs.

* Optional: If time and materials allow, give students an opportunity to test their new design to see how it works.

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: products that minimize or maximize thermal energy transfer, the engineering and design process.
   * 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:
     + **Energy and Matter**: These could be phrases such as, “energy is transferred/flows,” “is conserved,” “is important for,” “is needed,” 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 5 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: You now have a revised prototype of that product!

* Draw a labeled diagram of your final product.
  + Show how thermal energy transfer is either minimized or maximized.
* Explain how it works.
* Describe how you combined best characteristics from different designs to create a product that best meets your criteria and constraints.
  + Cite the data that supported your decisions

1. This prompt again emphasizes the CCC of **Energy and Matter** as students draw a diagram that shows how energy flows through their designed system as thermal energy transfer is either maximized or minimized.

**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 brainstormed a variety of different ideas. After seeing all the tests of the different prototypes, are there any other ideas from your poster that you would still want to try?
* In this task, we focused on the crosscutting concept of **Energy and Matter**: The transfer of energy drives the motion or cycling of matter, and it can be tracked as it flows through a system. Where did you see examples of **Energy and Matter** in this task?
* Now that you have tested a design for 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. 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.