NGSS LESSON PLAN 2 (POETS) MS-PS3-3: APPLY SCIENCTIFIC PRINCILES TO DESIGN, CONSTRUCT, AND TEST A DEVICE

Power Optimization in Electro-Thermic Systems

Grade: 6-8	**Topic: MS THERMAL ENERGY FLOW**	**Lesson # 2 (90 minutes) in a series of 3 lessons.**

- **Brief Lesson Description**: To elaborate on Lesson 1: PLAN AN INVESTIGATION using the Thermoelectric Generator Kits to determine the relationships among the energy transferred and the change in the average kinetic energy of the particles as measured by the temperature and voltage of the sample, the students will discuss what they learned from this activity. The student will then brainstorm ideas to design a real-world application for this Thermoelectric Generator.
- In doing this project, they need to examine factors such as societal and individual needs, cost effectiveness, available materials and natural resources, current scientific knowledge, and current advancements in science and technology.
- Once students have identified the type of device and application they will conceptually construct, they can begin to define the criteria and constraints of the design problem that will help to maximize the transfer of thermal energy to create electricity. Using informational texts to support this process is important because they will draw evidence from these texts in order to support their analysis, reflection, and research.

Performance Expectation(s)/Standards:
(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.]
(MS-ETS1-1) Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
(MS-ETS1-2) Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Lesson Specific Learning Expectations:

Apply scientific principles to design a device that maximizes thermal energy transfer through a designed system to produce electricity.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific ideas or principles to design 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. **ETS1.A: Defining and Delimiting an Engineering Problem** • The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (secondary)	Energy and Matter: Flows, Cycles, and Conservation • Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. • Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). • The transfer of energy can be tracked as energy flows through a designed or natural system. Systems and System Models • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

During this lesson, student learning will also include these Science and Engineering Practices
Engaging in Argument from Evidence

- Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s).
- Respectfully provide and receive critiques about one's explanations, procedures, models and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.
- Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
- Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system, based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints.
- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Specific Learning Outcomes/Including Evidence Statements:

1. Using scientific knowledge to generate design solutions
   a. Given a problem to solve that requires minimizing or maximizing thermal energy transfer, students design a solution to the problem. In the designs, students:
      i. Identify that thermal energy is transferred from hotter objects to colder objects.
      ii. Describe* different types of materials used in the design solution and their properties (e.g., thickness, heat conductivity, reflectivity) and how these materials will be used to minimize or maximize thermal energy transfer.
      iii. Specify how the device will solve the problem.

2. Describing* criteria and constraints, including quantification when appropriate
   a. Students describe* the given criteria and constraints that will be taken into account in the design solution:
      i. Students describe* criteria, including:
         1. The minimum or maximum temperature difference that the device is required to maintain.
         2. The amount of time that the device is required to maintain this difference.
         3. Whether the device is intended to maximize or minimize the transfer of thermal energy.
      ii. Students describe* constraints, which may include:
         1. Materials.
         2. Safety.
         3. Time.
         4. Cost.

Prior Student Knowledge:
MS-PS1-4 Matter and its Interactions
Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
MS-PS3-1 Energy
Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.
MS-PS3-2 Energy
Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

Possible Preconceptions/Misconceptions:

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:

Goal: Design a real-world application for Thermoelectric Generators to create electricity from wasted heat.

Scenario: Your team has been selected by NASA, the National Science Foundation, the National Automobile Industry, and the National Heavy Equipment Vehicle Industry to create a device capable of turning waste heat generated by gasoline motors into electricity. If your design meets all the criteria set by these companies and produces the most electricity from wasted heat, you will win the rights to produce and sell your device to these companies for billions of dollars each year. You are not the only team working on this project, so you must design the best device by the deadline or your project will not be considered. (Give the student a time constraint – how many days will they have to design and present their project).

Remember: Automobiles produce a large amount of heat generated by the burning of gasoline. Most of the energy produced is not used to power the automobile, but is lost as heat. Is there a way to use this wasted heat energy? If so, how can we make a device capable of turning this heat back into usable energy.

- POETS long term goal is to increase the power density of current mobile electrified systems by 10-100 times over current state of the art systems. While ambitious, this would have profound impact on a mobile electrified infrastructure of the U.S. and beyond. On-highway vehicles could save between 100-300 million liters of fuel per year and could nearly double the range of all-electric vehicles. Off-highway vehicles could save on the order of 100 billion liters of fuel since their electrification is starting from a less mature point than current on-highway vehicles. Similarly, aircraft could see 10-30 billion liters of fuel saved as well as up to 10 million tons of CO_2 saved from going into the high altitude atmosphere. These economic and environmental impacts are just the beginning of the art of the possible with the achievement of the POETS vision.

Real World Applications: The automotive industry is particularly interested in making use of the wasted engine heat to generate electricity in next generation vehicles. TE devices have been successfully applied to power famous space missions like the Apollo lunar mission, the Voyager, Viking to Mars, Galileo, Cassini among other spaceships, where TEs were used to generate electricity from the heat released during nuclear decay.

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:

1. Today, we will apply the knowledge of Thermoelectric Generators that showed direct conversion of heat into electrical energy.
2. In your group, brainstorm ideas to design a real-world application for this Thermoelectric Generator.
3. In doing this project, you need to examine factors such as societal and individual needs, cost effectiveness, available materials and natural resources, current scientific knowledge, and current advancements in science and technology.
4. Use the Formative Assessment Lab Report Rubric to help guide the designing process.

EXPLAIN: Concepts Explained

Have students explain their reasoning behind the design that they chose including the materials, safety, time, and cost factors considered.

ELABORATE: Applications and Extensions:

After completing this activity Watch: Woodstove Green Power Generator - Thermoelectric Module - How do I get off the grid?
https://www.youtube.com/watch?v=8PWGXyb67XI

https://www.indiegogo.com/projects/wood-stove-generator#/

Transcript: What is a Thermoelectric Module?
Living off the grid.
Automated Video Production:
In 1821, T. J. Seebeck discovered that different metals, known as a thermocouple, will develop a micro-voltage if the junctions are held at different temperatures. This is known as the "Seebeck effect".

In 1834, Jean Peltier discovered the inverse of the Seebeck effect, known as the "Peltier effect". By applying a voltage to a thermocouple, a temperature differential between two sides is created.
A thermoelectric module, also called a thermoelectric cooler or Peltier cooler, is a semiconductor-based electronic component that functions as a small reliable heat pump with no moving parts. By applying a low voltage to a thermoelectric module, heat will be moved through the module from one side to the other. One module face will be cooled, while the opposite face is simultaneously heated.
A thermoelectric module can also be used for power generation: a thermoelectric module creates a voltage when there is a different temperature on each side. The second law of thermodynamics states that heat will move to a cooler area. Essentially, the module will absorb heat on the "cold side" and eject it out the "hot side", to a heat sink.
Thermoelectric modules have been in use for a number of years. You have probably seen them used for automotive food and beverage coolers, and more commonly, in fans that sit atop wood stoves blowing hot air around the room.
Over the years, inventors have attempted to develop products that use thermoelectric modules for practical purposes. Like this head band that uses the heat of a forehead to generate a small amount of electrical power. Or this coffee cup that uses the heat of the hot beverage in it as the heat source. This one uses the heat of an oil lamp, and this small stove charges batteries. Here's a pot that generates power while cooking, and a LED lamp that uses the heat of a candle. This thermoelectric device, cooled by water, attaches to the side of a wood stove and reportedly produces up to 50 watts.
A few commercial products using thermoelectric modules are appearing now too, like this 30 watt stovetop generator. Even more robust is this 500-watt liquid cooled model. The Power Pot is a commercially produced version of the home made one. Even better is the rocket camp stove that is used to charge up electronic gadgets, like cameras and phones, using a standard USB cable. About to enter production is this thermoelectric module generator equipped wood stove. Many are attempting to harness the power of the TEC and generate green sustainable electrical power for the people.
Various aid attempts have been made to provide the third world with convenient and accessible electric power. But if you are tired of waiting for that elusive NGO to show up and give you the means to charge your phone and other devices, you can easily make a thermoelectric module generator yourself. Every component needed can be easily purchased via the internet.
Computer cooling is required to remove the waste heat produced by high performance computer components. This is to keep computer components within operating temperature limits or output will be diminished until they fail completely. Most commonly, computer component cooling is accomplished by a simple fan, but in extreme cases it is accomplished using devices known as CPU coolers.
CPU coolers use heat sinks, combined with fans or liquid-filled radiators, to carry away the excess heat. The very latest CPU cooling technology uses a heat sink and a thermoelectric module. Electrical power is applied to the thermoelectric module, and using the Peltier effect, the cold side is pressed up against the computer component meant to be cooled.
Take away the applied electrical power, and press one side of the thermoelectric module against the hot surface of a wood stove, and the other side against a heat sink, and the very same device will generate power, not consume it. The only thing that prevents us from using this ready-made thermoelectric device is its lack of high-heat capability. The temperature of a hot wood stove is far greater than the heat generated by a computer component. Wires will burn, solder will melt, and the device will fail.
However, match a properly configured CPU cooler with a high-heat thermoelectric module, and it can be done easily and affordably. Here's what you need:
A CPU cooler with fan. A fan controller. A high heat thermoelectric module. A tube of thermal grease. A length of thin steel cable. Two small cable clamps. A steel tension spring. A length of metal foil ducting. High heat aluminum tape. A thermal switch. A charge controller. A battery bank.
Be sure and match the dimensions of the cooling contact plate of the CPU cooler with the dimensions of the thermoelectric module.
This is how to be off the grid.

EVALUATE:
Formative Monitoring (Questioning / Discussion):

Have students create a poster board, PowerPoint, etc. to explain their reasoning behind the design that they chose to other groups for input and redesign. The students can participate in a gallery walk using sticky notes to give at least one good aspect of the design and at least one way that it can be made better. After redesigns, create a Board of Directors made of one student from each group to determine the best design that will win the rights to produce and sell the device to these companies. The students could also participate in a gallery walk to vote on the best designs, or even vote online, i.e. Survey Monkey or Google Classroom Forms.

Summative Assessment (Quiz / Project / Report):

Create a lab report incorporating the following rubric:

1. Using scientific knowledge to generate design solutions
    a. Given a problem to solve that requires minimizing or maximizing thermal energy transfer, students design a solution to the problem. In the designs, students:
        i. Identify that thermal energy is transferred from hotter objects to colder objects.
        ii. Describe* different types of materials used in the design solution and their properties (e.g., thickness, heat conductivity, reflectivity) and how these materials will be used to minimize or maximize thermal energy transfer.
        iii. Specify how the device will solve the problem.

2. Describing* criteria and constraints, including quantification when appropriate
    a. Students describe* the given criteria and constraints that will be taken into account in the design solution:
        i. Students describe* criteria, including:
            1. The minimum or maximum temperature difference that the device is required to maintain.
            2. The amount of time that the device is required to maintain this difference.
            3. Whether the device is intended to maximize or minimize the transfer of thermal energy.
        ii. Students describe* constraints, which may include:
            1. Materials.
            2. Safety.
            3. Time.
            4. Cost.

Elaborate Further

Reflect: After the presentations, have student reflect/journal which presentation ideas were the most applicable and why, or create an exit ticket, journal entry, etc. to explain their design and give additional ideas that they may have on a new design.
"What would I do differently if I could start over, have additional resources, etc.?"

Enrichment: Field trip opportunities, guest speakers from the university or other areas, engineering/design club – build an actual working model of their design.