Unit: Understanding Science and Engineering Through Solar Power

Lesson 6 Solar Powered Water Pumping – Adding Materials to Test

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DESCRIPTION: Students use a solar module and other materials in conjunction with a water pump to test how quickly one cup of water can be pumped.

GRADE LEVEL(S): 2, 3, 4, 5

SUBJECT AREA(S): Science inquiry, engineering design, scientific method, solar energy, energy, electricity

ACTIVITY LENGTH: 90 minutes

LEARNING GOAL(S): Students will be able to make observations and record data about how different materials affect the speed of a solar powered water pump.

STANDARDS MET:
Common Core:

- W.2.8. Recall information from experiences or gather information from provided sources to answer a question. (K-2-ETS1-1)
- MP.2 Reason abstractly and quantitatively
- MP.5 Use appropriate tools strategically
- 2.MD.10. Draw a picture graph and a bar graph (with single-unit scale) to represent a data set with up to four categories. Solve simple put-together, take-apart, and compare problems using information presented in a bar graph.
- W.3.7 Conduct short research projects that build knowledge about a topic.
- 3.MD.A.2 Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l). Add, subtract, multiply, or divide to solve one-step word problems involving masses or volumes that are given in the same units, e.g., by using drawings (such as a beaker with a measurement scale) to represent the problem.
- 3.MD.3. Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step “how many more” and “how many less”

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problems using information presented in scaled bar graphs. For example, draw a bar graph in which each square in the bar graph might represent 5 pets.
- W.4.7 Conduct short research projects that build knowledge through investigation of different aspects of a topic
- W.4.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.
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Next Generation Science Standards:
- 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
- 4-PS3-4. Apply scientific ideas to design, test and refine a device that converts energy from one form to another.
- 3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

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Student Background:

- Students should be familiar with how to make a circuit using a solar module and water pump as done in the prior lesson, **Understanding Science and Engineering Through Solar Power: Lesson 5 Making Observations and Recording Data for Solar Powered Water Pumping**
- It's helpful if students have already completed the following activities as a part of a larger solar pumping unit:
    - **Understanding Science and Engineering Through Solar Power: Lesson 1 Setting Expectations for Science and Engineering Projects**
    - **Understanding Science and Engineering Through Solar Power: Lesson 2 Probes of Prior Knowledge**
    - **Understanding Science and Engineering Through Solar Power: Lesson 3 Solar Powered Calculator**
    - **Understanding Science and Engineering Through Solar Power: Lesson 4 A Simple Circuit**
    - **Understanding Science and Engineering Through Solar Power: Lesson 5 Making Observations and Recording Data for Solar Powered Water Pumping**

Educator Background:
- **Solar cell** or **modules** are thin wafers of **silicon** that convert sunlight or **light energy** into **electrical energy** using the **photovoltaic effect.**

- A **circuit** is a circular path by which electricity flows from a power source (solar module in this case) to a device that does work (water pump in this case) and then back to the power source. Several power sources can be linked together in a circuit series to produce more energy.
- **Scientific inquiry** is the "diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work." *(National Science Education Standards*, p. 23). Scientific inquiry requires students to form testable questions about the natural world that they have observed. After developing a hypothesis (or educated guess) related to their question, students design and conduct experiments to test whether or not their hypothesis is correct. Conducting an experiment includes gathering data and recording observations. Often time scientists display their data using graphs, which is good practice for students. Students then analyze the data gathered during the experiments and draw conclusions about whether or not their hypothesis was correct.
- **Engineering design** is a process by which students identify or are given a problem to solve. The problem must have given constraints (time, materials, money etc.). Students then design a solution to the problem, create a prototype, and test their design. Data from testing the prototype is collected and the design is evaluated. The prototype is then modified based on the results from the first test and then tested and evaluated again. Finally both designs are evaluated against the criteria of the problem to determine effectiveness. The process can continue iteratively until the design criteria are met.
- These lessons work best outside and in full sun. The best time of day is usually in the early afternoon. If no sun is available, teachers can use shop lights as an alternative light source. Note: overhead classroom lights don't work well for these activities.

Science Kit Materials List:

- (2) Individual Solar Module—1.5 Volt, 500 mA
- Small DC Water Pump

Other Materials List:

Class Materials:

- Copies of class sets of "Solar Student Worksheet Parts 9-13"
    - **"**Part 9: Solar Powered Water Pumping, Adding Materials to Test Introduction"
    - "Part 10: Procedures"
    - "Parts 11 and 12: Data Collection"
    - "Part 13: Data Analysis**"**
- Copies of class sets of "Solar Module Mirror Holder Cutout"
- Electronic copy of Excel spreadsheet: "Lesson 6 Class Data Table"

Materials per Student Group (3-4 students/group):

- One mirror
- One solar module/mirror holder
- Two small clear plastic tubs (small sandwich containers work well) with a cup measurement line marked on both (at one-cup and two-cup measurement points). Fill one plastic tub with water and the other one starts empty.
- Small piece of masking tape

- Stop Watch

Vocabulary:

- Hypothesis
- Circuit
- Silicon
- Photovoltaic Effect
- Data
- Observations
- Conclusions
- Graph
- Solar Module

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Lesson Details:

1. AHEAD OF TIME NOTE: Prep science materials. Either group materials in like piles or separate supplies out so that each group has complete set (whichever works best in your classroom). Also pour water for each group and pour into one of the tubs. Additionally, the teacher will need to copy and construct the "Solar Module/Mirror Holder Cutout**"** according to the directions on the sheet.
2. Begin today's lesson by sharing the content objective. Then explain to students that they will be working in small groups (3-4 students) to conduct a science experiment with solar power. Go over some group norms established in the previous lesson in this unit **Lesson 5: Making Observations and Recording Data for Solar Powered Water Pumping** if you did this lesson with your students. If students have not yet gone through that lesson, create a list of agreed upon norms with your students. Have student verbally agree, raise hands to agree, or sign their names at the bottom of the agreed upon list—this is good classroom management practice.
3. Review with students the procedures outlined in the worksheet, "Part 9: Adding Materials to Test Introduction". Make sure to show students the materials as you describe them referencing the worksheet as needed.
4. Assign students jobs within their groups for each round of data collection. Jobs can include managing the stopwatch, entering data on their worksheet, holding the solar module, etc. With older grades have students self select their jobs and rotate so that each student gets a turn at each job.
5. Once jobs are determined and the worksheet has been reviewed, allow one to two students per group to collect the required experiment supplies.
6. Next, students conduct the experiment according to the worksheets "Part 10: Procedures" and "Parts 11 and 12: Data Collection"
7. Once each group has completed all their trials and completed the worksheet "Parts 11 and 12: Data Collection"**,** reconvene the class to discuss and compile results.
8. Use the "Lesson 6 Class Data Table" Excel spreadsheet to collect and display student's data on a single sheet. It' best to project the spreadsheet on a whiteboard or pull down screen so that all students can view the data.

   a. Ask each group to identify the added material that produced the "fastest time."
   b. Ask groups to report their fastest times. Enter each group's data into the "Lesson 6 Class Data Table" Excel worksheet.
   c. Discuss as a class and come to consensus about what added material (variable) produced the fastest time.
9. Create a graph of student data (or for the older grades allow them to help you create the graph by determining the best type of graph for the data, an appropriate title for the graph, the X and Y units, and/or titles for the X and Y axis.
   a. Highlight just the boxes of the data table.
   b. Choose the green table titled "charts"
   c. Choose the "insert chart" icon
   d. Select the type of graph you want.
   e. Once the graph is displayed choose the purple chart layout tab. This tab will allow the teacher to add any titles missing or display the values of the bars.
   f. The graph can be resized by dragging one of the corners so that it can be seen well.
10. Discuss patterns and observations of the data. Begin to transition student observations into factual statements about the graph.
11. One the worksheet, "Part 13: Data Analysis**"**, have students record:
   a. One factual statement about the graph
   b. Their conclusion about what added material helped pump water the fastest (along with evidence to support that conclusion).
   c. One question that they have regarding solar water pumping
12. Have students share with the class their facts, questions, and ideas for improving the solar water pump.
13. Review content objective.

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Extensions

For older grades (4th-5th), ask students to convert cups into pints, quarts, gallons, and liters. This provides an opportunity for students to grasp conversions (math concept) as well as to better understand how cups, pints, quarts, gallons, and liters compare. Similarly students can convert seconds into minutes and hours as well.

Lastly, for 5th grade define volume and explain the relationship between volume and mass. Explain how volume is related to this experiment.