Unit: Understanding Science and Engineering Through Solar Power

Lesson 7 Designing a Faster Water Pump

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DESCRIPTION: Students use all their prior knowledge to design and construct a water pump that can pump 1 cup of water the fastest.

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

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

ACTIVITY LENGTH: 1 hour, 30 minutes

LEARNING GOAL(S): Students will be able to use available tools to design and test a solar water pump, refine their design, test and finally evaluate their efforts. Through this process students will understand and gain experience with the engineering design process.

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
- 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.
- 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.
- W.4.7 Conduct short research projects that build knowledge through investigation of different aspects of a topic

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- W.4.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.

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 making a circuit using a solar module and water pump as done in the prior lesson (**Understanding Science and Engineering Through Solar Power: Lesson 6 Solar Powered Water Pumping: Adding Materials to Test**).
- 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**
    - **Understanding Science and Engineering Through Solar Power: Lesson 6 Solar Powered Water Pumping: Adding Materials to Test**

Educator Background:

- **Solar cells** 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:

- Class sets of "Solar Student Worksheets Part 14-20"
  - "Part 14: Designing and Testing a Faster Solar Water Pump Introduction"
  - "Part 15-17: Procedures/Designing"
  - "Part 18-19: Second Design"
  - "Part 20: Analyzing Your Designs"
- Copies of class sets of "Solar Module Mirror Holder Cutout"

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

- (2) 1.5 Volt Solar Modules
- (4) Mirrors
- (2) Solar Module/Mirror Holders
- Small DC Water Pump
- 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:

- Engineering design
- Prototype

- Data
- Observations
- Fair Tests
- Analysis
- Conclusions
- Photovoltaic Effect

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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. 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 todays lesson by sharing the content objective. Then explain to students that they will be working to see if they can make a solar water pump work faster than the one from the last experiment.
3. Ask students if they know what engineers do? Get a few answers from students then share that engineers are like scientist that solve problems. Explain that many devices we use everyday are the result of engineering including their computers, classroom, bikes, rollerblades, and cars. Review the engineering process highlighting its focus on goals, working with constraints, and designing and testing multiple prototypes. Define what a prototype is.
4. Go over norms from previous lessons using the water pumps and solar modules.
5. Pass out worksheets "Parts 14-20 Designing and Engineering a Faster Water Pump" sheets.
6. Review with students "Part 14: Introduction**"** and review the class/lesson rules.

a. Show and explain the available materials. Note that their designs are constrained because they can only use these materials to design a faster water pump. Ask students what other constraints are present (e.g., time, cost, etc).

7. On the worksheet "Part 15: Procedures/Designing", have each student draw a design in the "My Own Idea" box. Be sure to remind students of the time and materials constraints as well as the goal of the project (which is to design a faster water pump)
8. Break the class into prearranged teams of three to four students. Tell them to work together, share their design ideas, and then agree to a team design that they'll construct and test. Once each group agrees to a design have them draw their team design in the box titled "First Team Design" on worksheet "Part 16: Procedures/Designing**"**. Only one drawing is necessary for the whole team.
9. Once the teacher has approved each team's drawing/design, teams of students may receive their supplies and begin constructing their prototype.
10. Once all teams have constructed their prototype, review as a class the data collection table on "Part 17: Procedures/Designing**"**. Explain that teams must collect data on their first team prototype as well as answer the questions at the bottom of the worksheet.
11. After students have tested and collected data on their first team prototype, have them work together as a group to come up with a second design (second prototype) following the steps outlined in "Part 18: Second Design**"**. Remind students of the constraints and goal of the project. Again, teams only need to present one drawing.

12. Once the teacher has approved each team's drawing/design, groups of students may receive their supplies and begin constructing their second prototype.
13. Review the data collection table in **"**Part 19: Second Design**"**. Tell students that they must collect data on their second team prototype as well as answer the questions at the bottom of the worksheet.
14. Once all tests have been conducted and the data table filled in, review the questions on "Part 20: Analyzing Your Designs**"** to be sure that each team understands how to complete that worksheet.
15. Allow each team of students an opportunity to share with the class their second design/prototype and their answers to "Part 20: Analyzing Your Designs**"**.
16. Have students display their second design/prototype and conduct a gallery walk around the room. Have students write down one thing that they like about each prototype and one question they have for each prototype. Have students share their questions and likes with the entire class.
17. Review content objective.