Solar Water Heater Lesson Plan

Argonne's Sustainability Workshops for Middle School and High School Teachers were conceived, designed and implemented as part of the Laboratory's educational outreach. The goals of these workshops include knowledge and awareness of alternative energy technologies, their advantages and limitations; the key issues and impacts of technologies related to climate change; to extend the resources of sustainability; and to encourage energy literacy. Participating teachers are asked to synthesize their experiences and knowledge gained into a useable lesson plan. The plans presented in this unit are a compilation of those lessons.

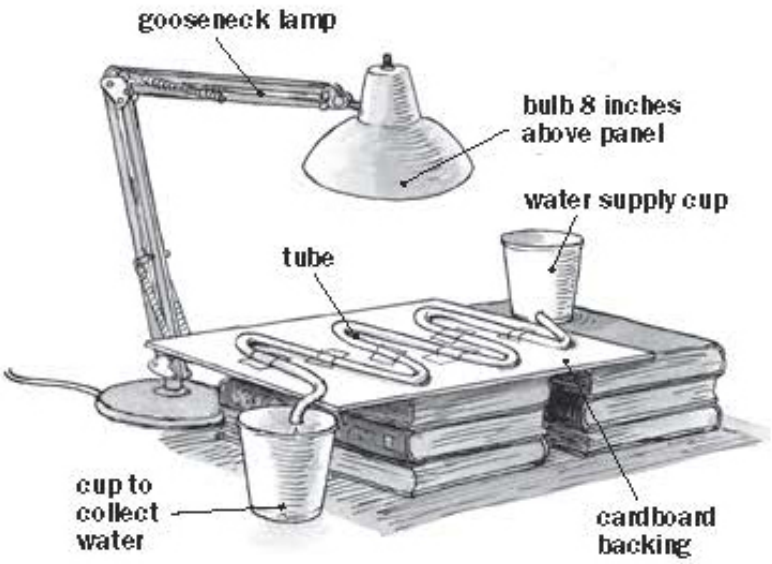
Grade Level
Middle School

Time Needed
3-6 class sessions

Activity Description
Students will design and build a solar water heater and see how large a temperature change they can achieve in their subsequent redesign and testing. First, students will experience the design cycle in the context of a 30-minute challenge to design and build a house of cards. Then they will apply this design cycle strategy to building, testing, redesigning and retesting their solar water heaters.

Goals and Objectives
Students will

- Gain experience in using the design cycle
- Use the design cycle to design a solar water heater
- Design controlled experiments
- Collect and analyze data
- Integrate their own (and shared) data to drive design decisions and improvements to a solar water heater
- Apply their knowledge of light, energy conversions and transfers to the design challenge
- Compare and evaluate the effectiveness of the constructed solar water heaters
- Explain how technology can be used improve the human condition
- Show that solar energy can be easily collected and converted to heat energy



NASA's "Feel the Heat" Water Heater

Background Information

Solar water heaters use the sun's energy to heat water for domestic use. They need a solar collector and a means to store the energy for future use. There are two types of systems: a passive system and the more efficient active system which requires circulating pumps and controls. Both systems require well-insulated storage tanks.

Pasteurization, which kills off most harmful microbes, occurs when water is heated for a short period of time at 65° C. Although pasteurization occurs at 65° C, many people in developing countries don't have access to a thermometer and instead use the boiling point to ensure that the water has been pasteurized.

Materials

- Index cards, 10-20 per team
- Tape, one roll per team
- 30 Minute Design Challenge sheet , one per student
- NASA solar heater design instructions

For water heater, per team:

- Aluminum foil
- Large sheet of cardboard (11 x 17 inches/28 x 43 cm)
- Gooseneck lamp with a 100-watt floodlight light bulb (optional if using sunlight)
- Black marker
- Black paper
- 2 paper cups (medium-sized)
- 3 feet (0.9 m) clear plastic tubing with outside diameter: 1/4 inch/6 mm
- Pitcher of water
- Ruler
- Scissors
- Straws
- Duct tape
- Stopwatch or clock with a second hand
- Indoor-outdoor digital thermometer that can read tenths of a degree
- Design Squad Nation sheet, one per student

Strategies and Methodology

- Whole group discussion
- Small group discussion and activity
- Designing
- Guided inquiry
- Measuring
- Experimental testing
- Data collection and analysis
- Comparing
- Re-designing
- Re-testing
- Diagramming
- Communicating
- Descriptive and scientific writing

Web Search Terms

Need something from the Internet? Use some of these search terms:
Solar water heater, pasteurization, solar energy, MYP design cycle, design cycle, waterborne diseases

PROCEDURE

Introduction of Lesson

(1 class session)

1. Introduce and engage the students in a sample 30 minute design challenge, building a house of cards. After they have finished, have the students do a "gallery walk" to see how other teams met the design challenge.

2. Discuss the steps they documented on their design log. Notice if they missed or assumed steps, and if their description was clear. As a class, decide which houses are the "best," and met or exceeded the design specifications. Think about some of the questions to ask when we design:
   - Who is the design for?
   - What is the purpose of the design?
   - What determines whether the design was a success or failure?
   - How well did we follow the design process?

3. Next, introduce the stages of the MYP Design Cycle in terms of the 30 Minute Challenge, understanding the importance of each step. See Mesa Middle School's website for a description and graphic of the Design Cycle, adapted from the MYP (Middle Years Program) of the International Baccalaureate Organization. (Note: though this was created for a specific program, it is exactly the process we go through in solving any design challenge.)

4. Ask the students to complete the chart they started earlier by using the second column to label which stage

of the Design Cycle they were doing for each step (Investigate, Plan, Create, Evaluate), even if their steps are out of order. With the class, reflect on how important the process is, why each stage comes when it does in the Cycle, and help build their understanding of how they can apply it to all subject areas.

5. Establish the purpose of their actual design challenge, building a solar water heater. Pose the question: why is it necessary to have solar water heaters?

   In a developed country, such as the United States, reasons include: they reduce hot water heating costs and directly reduce the amount of greenhouse gas emissions--carbon dioxide--released into the atmosphere from many other heating methods, so that you are contributing to a healthier environment.

   In third world countries, the benefits of a healthier environment are still true, but there are even more reasons to use a solar water heater. Ask the students what some of these reasons might be.

   For example, most third-world countries are located in regions where there is plenty of sunlight, but little or no electricity. They often don't have access to safe drinking, cooking, or washing water, and may have to walk miles to reach a water source. If the available water is heated enough, most harmful microbes can be killed, making the water safe for human use. Over 1 billion people do not have access to safe water. Preventable waterborne diseases are responsible for approximately 80% of all illnesses and deaths in the developing world. Children are especially susceptible, with nearly two million deaths each year.

Design and Test Solar Water Heaters

(2 - 4 class sessions)

1. Review the design cycle steps and safety rules for the students' design challenge. Introduce the specific solar water heater challenge goals on the student handout, *NASA Design Squad Challenge, Feel the Heat*. You may want to create and share a teacher-made rubric with the students for assessing the students' solar water heater work.

2. Review the energy transfers and conversions that occur in using a solar water heater. *(Solar energy remains inside the tubing, converting to thermal energy and transferring to the water and to kinetic energy as the warmer water moves upwards.)* If you live in a sunny southern latitude, you may want to adjust the challenge to have students attempt to get the water to its boiling point, 100° C. Explain that in many countries, people do not have access to a thermometer, so to be sure the water is hot enough to have killed the microbes, they heat it to boiling.

3. Discuss the design problem with the students. Use the student handout's "Brainstorm and Design" questions to help guide class discussion. Decide on class controls, such as the amount of water in the pitcher, the starting temperature, the time interval used to measure the temperature, and the length of plastic tubing.

4. Have students create a design log in their journals, similar to the one used in the 30 Minute Design Challenge. Ask them to also include a drawing of their first design and a data chart to record their temperatures.

5. Give the student teams enough time to construct and test the basic solar water heater design. Remind them to record their water temperatures.

6. Using the "Test, Evaluate, and Redesign" section of the student handout, encourage each team to improve their solar water heater design to increase the temperature of the water in their next trial. Make sure the students describe the changes they made to increase heat absorption and to collect data on their redesigned solar water heater.

Closure/Sharing/Reflection

Gather the students together again for reporting on their designs. Allow each team to present their design decisions and how they affected the water's final temperature. Assist the class in comparing the teams' results. Provide students with an exit ticket to complete and turn in as they leave. *(Example question: What variables most affected the temperature of water in the classes' solar water heaters?)*

Assessment

Use a teacher-created rubric as a summary assessment for:

- Thoroughness of the students' designs
- Involvement in discussions
- Cooperative teamwork
- Safety behavior
- Quality of experimental data
- Graphs
- Re-design improvements
- Written responses to questions

Be sure to include the students' explanations of how they used data to refine their first design and improve on it. Students with special needs may use diagrams with labels and sentences, or oral explanations to support design modifications rather than longer written summaries. The assessment information can inform teacher instruction for the following school year.

The Exit ticket (*what variables most affected the temperature of water in the classes' solar water heaters?*) as a formative assessment can help the teacher evaluate student understanding at the moment. The best answered exit slips can be read the next day and the teacher can use questioning to recheck students that did not understand.

Extensions

- The design cycle can be linked to the scientific method and controlling variables to create improved designs.
- The teacher can allow students to continue to improve their solar water heater designs.
- The teacher can set up a visit from an engineer (perhaps use Skype) to learn how she/he uses the design cycle to do their work.
- Movies may be used in the classroom to illustrate and discuss the issues and the design cycle process in the real world, such as the Futures Channel, *Collaboration Between Design and Engineering* or *Underground Engineering*.

Teacher Note: Avoiding Potential Classroom Management Challenges

- Assigning group roles will help with classroom management
- Student timekeepers can keep groups moving to complete projects on time
- Teacher should remind teams to complete journal entries
- Student groups not able to agree with designs can use "rock paper scissors" for a decision, or they can test multiple ideas to collect data
- Not enough lamp stations: if a lamp station is not available, the teacher may have one group member "take a number" so the groups know when it's their turn. Groups can work on presentations and journal entries while waiting.˜˜

Resources

- MYP Design Cycle on *Always Learning* and on *TEWM*
- NASA solar heater design challenge sheet
- Solar Cookers International: *Pasteurization*
- Practical Action: *Comprehensive fact brief on solar water heating*
- eHow: *Information on Solar Energy and Solar Water heating in 3rd World* Countries
- eHow: *How to Use Solar Power in 3rd World Countries*
- Solar Energy Background Info and Readings for Students
- The Futures Channel: *Educational Videos and Activities* -- 2-5 minute videos focus on STEM issues and examples

Need more information or help with this lesson?

Contact Argonne National Laboratory by e-mailing SustainabilityEd@anl.gov.

Find out more about Argonne's Sustainability Program at blogs.anl.gov.