Bioreactor Water Heating

Lesson 1: Passive Solar Water Heating

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DESCRIPTION: Students retrofit milk jugs to absorb and retain the most solar energy. This process involves students collecting data that measures the impacts of different variables on the solar energy absorbed by each collection device. Students should be able to see patterns in both the absorption and retention of heat by various types of designs. During this activity, students will build background knowledge to help them apply these concepts on a larger scale in the proceeding lesson plans.

GRADE LEVEL(S): 6th-12th grades

SUBJECT AREA(S): Physical Science, Energy Fundamentals; Sustainable energy, Solar/Renewable energy,

ACTIVITY LENGTH: 1-2 class periods

LEARNING GOAL(S):

1. Students will cover/manipulate milk jugs to achieve the most solar energy absorption.
2. Students will calculate the joules of energy absorbed by the solar heated water.
3. Students will measure and graph the temperature changes of their solar milk jugs.
4. Students will gain an understanding of the amount of energy in sunlight.

NEXT GENERATION SCIENCE STANDARDS:

Students who demonstrate understanding can:

MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

COMMON CORE STATE STANDARDS:

CCSS.ELA-LITERACY.RST.11-12.3
Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

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Materials List

- Thermometer for testing water (electronic probe thermometer recommended)
- 1 milk jug with lid for each group of two
- Black spray paint
- Masking tape
- Aluminum foil
- Miscellaneous colored paper (make sure to include at least black, blue, green, yellow, and white)
- 1 liter measuring pitcher
- Graph paper

Vocabulary

- joule
- radiation
- solar energy
- specific heat capacity
- passive solar energy

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Lesson Detail

Student Background

Pre-teaching:
Make enough copies of the science probe for every student. Read aloud or have the students read the information provided and answer the questions and explain their reasoning at the bottom of the page. It would be great if the teacher had a globe sitting at the front of the room to better illustrate that the Earth is mostly water and that water is the 2nd reason (the sun being #1) for the Earth's temperatures throughout the year.

Watch the videos in the student background information on solar energy and the properties of water. This will make sure the students have a decent background in the properties of water and passive solar heating.

Students participating in this lesson should be familiar with the following:

- Solar energy
- Heat transfer
- http://video.nationalgeographic.com/video/solar-power
- YouTube: SciShow, "Solar Energy", https://youtu.be/4uPVZUTLAvA

- YouTube: ScienceAround, “Air vs. Heat Capacity”, https://youtu.be/hyPLusD-tyM

Educator Background

Educators leading this lesson should be familiar with the following

- Solar energy
- Care and use of electronic thermometers or infrared thermometer
- Specific heat capacity and how to calculate energy in joules
- Watch videos (links above) prior to showing them in class so you can ask higher order questions

Lesson Sequence

This is an inquiry lesson that allows the students to design their own solar water heater. Each group of students decides what modifications they need to make to their water jug to absorb the most solar energy to heat the water. In order to have students identifying and selecting specific variables to influence the effectiveness of their water heater, ensure that they are having a thoughtful discussion that prevents an entirely open-ended construction. Below is one approach:

Constraints:

- All milk jugs are one gallon.
- Each milk jug is filled with one liter of tap water and sealed tightly
- One milk jug is undecorated and is the known sample (control). We use this control to measure the temperature change in the water from the sun/container system. This way, we can tell if our modifications are allowing greater absorption and more heat energy.

Challenge:

- Set up milk jugs with minimal, yet measurable changes made to their design in order for students to make predictions based on background knowledge of light absorption and reflection. This could be:
    - Reflectors vs. no reflectors
    - Black background vs. other backgrounds
    - Reflectors and spray paint vs. just reflectors
- This initial observation of these isolated variables could take place over one class period or be pre-constructed and recorded by the teacher to ensure that students can design their own as quickly as possible.
- Once students have identified through this first activity the most effective variables, allow them to choose their own combination of methods, providing them to record their reasoning for their specific selection.
- Examples of modifications to milk jugs:
    - All jugs must be placed in the same location, and on the same surface.
    - Temperature may be taken as often as needed for data collection. Ideally the time between temperature readings should be approximately the same.
    - Heat energy can be calculated in joules using the student worksheet attached.

- Additionally, students may take more frequent data measurements and use graph paper to graph temperature throughout the day, identifying trends in how quickly or slowly the water gained and lost energy.

- Once students have settled on a jug design, have them use the data sheet to calculate how much energy is gained during the day and lost at night. In plotting this data they should be able to see patterns exhibited differently across different jug designs.

Assessment

Grading Criteria for 6th-9th Grade

Learning Objectives 9th grade	Max Pts	Pts Earned	Instructor Initial
Students cooperatively developed an operational solar water jug	50	___/50	
Water was heated above the “known” water jug temperature.	50	___/50	
Modifications increased absorbed energy	25	___/25	
Behavior – on task	25	___/25	
	Total:		

Lesson Extensions

- This lesson would benefit greatly from taking longer-term data, if possible with multiple recorded points throughout the day. If the equipment will be safe, a Vernier LabQuest with temperature probe could be use to automate the data. (If you have an electronics club or class, you could even partner with them to construct/program simple temperature readers!)
- Students can continue to make modifications to maximize energy absorption. This would involve the addition of more “found” materials that could be added to the design for students to manipulate insulate, absorption, etc.
- Students can spend more time identifying specific variables in their design that they would like to measure, such as color, mass of insulation, and any other measurable variable whose impact can be manipulated and tracked in increments across multiple jugs.
- Students can use identical milk jugs to calculate the temperature changes of varying amounts of water.
- Students can calculate the amount of heat change that should occur for a particular amount of water and then test their calculations.
- Students can modify their milk jugs to maintain the amount of heat overnight by insulating their containers to maximize their heat energy over time.