SOLAR WATER HEATING

Overview:

In this lesson students design, construct and test a simple, passive water heater then record and graph the results of testing their design. Students investigate and discuss the practical applications of this concept in their own communities.

Objectives:

The student will:

- design and construct a simple passive solar heating system;
- record and graph results of testing the system;
- revise their design to make the system more effective; and
- propose ways to utilize solar water heating in their own community.

Targeted Alaska Grade Level Expectations:

[7-8] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.

[7-8] SA1.2 The student demonstrates an understanding of the processes of science by collaborating to design and conduct simple repeatable investigations, in order to record, analyze (i.e., range, mean, median, mode), interpret data, and present findings.

[7] SB2.1 The student demonstrates an understanding of how energy can be transformed, transferred, and conserved by explaining that energy (i.e., heat, light, chemical, electrical, mechanical) can change form.

[8] SB2.1 The student demonstrates an understanding of how energy can be transformed, transferred, and conserved by identifying the initial source and resulting change in forms of energy in common phenomena (e.g., sun to tree to wood to stove to cabin heat).

[7-8] SE2.1 The student demonstrates an understanding that solving problems involves different ways of thinking by indentifying, designing, testing, and revising solutions to a local problem.

Vocabulary:

active solar design – a design strategy using mechanical systems such as batteries, pumps and fans to transport and store solar energy

mean – a number or quantity having a value that is intermediate between other numbers of quantities

median – the middle value in a sequence of numbers (or the average of the two middle numbers when a sequence has an even number of values)

mode – the value that occurs most frequently in a data set

nonrenewable energy source – a mineral energy source that is in limited supply, such as fossil (gas, oil, and coal) and nuclear fuels

passive solar design – a design strategy where the structure itself functions as the solar collector; solar radiation (heat and light) is transferred by natural energy flow (conduction, convection, radiation)

renewable energy source – an energy source that can be replenished in a short period of time (solar, wind, geothermal, tidal)

Whole Picture:

In a traditional Koyukon story it is said the sun was once a beautiful young woman who flew off into the sky. Jules Jette, in 1913, quotes a Koyukon saying, "We do not look at the sun because it would shame a young woman." But the sun is not mentioned much in traditional stories because it is such a dependable natural phenomenon. And nowhere is it said to be a taboo subject.

SOLAR WATER HEATING

This dependable source of energy can be harnessed to produce electricity as well as to heat both air and water. Solar energy heating systems are classified as active or passive. Passive design implies that the structure itself functions as the solar collector. Thermal energy is transferred to air and water by natural energy flow (conduction, convection, radiation). Examples of passive solar design include buildings with south facing windows (to maximize sunlight), greenhouses and solar chimneys. Solar chimneys serve to ventilate buildings via convection. Active solar energy designs use mechanical systems such as batteries, pumps and fans to transport and store solar energy for future use.

Both active and passive solar energy systems can be used to heat water. The main components of an active system are the collectors, the storage tank and the distribution system (often including pumps and circulation pipes). Solar water heating systems often also include an auxiliary heater for times when the solar collector does not get water hot enough to use as a stand alone system. Even in those cases, solar water heaters can still result in significant energy savings by preheating water.

Active solar water heating is a useful and practical application of solar energy for much of Alaska, especially regions where fuel prices are high. Our demand for hot water remains high in the summer months when solar energy abounds. It is estimated that solar energy can provide 40-60% of the annual hot water demand for most locations. However, Alaskan systems do require special considerations including a circulation loop of antifreeze that will flow through the solar collector outdoors. This loop then passes through a heat exchanger where it transfers its heat to water that can be stored in a tank. In milder climates, water can travel directly outdoors and through the solar collectors.

Materials:

- Black aquarium tubing (one piece per group, approximately 36 inches long)
- 9″ x 13″ disposable aluminum cake pan (one per group)
- Scissors (one pair per group)
- Heat lamp (one per group)
- Digital thermometer (one per group)
- Sturdy foam or paper cups (two per group, not plastic!)
- 100-mL graduated cylinder (one per group)
- Caulk (one tube)
- Books, notebooks, and other classroom items to create different level platforms
- Duct tape
- Cool water (at least 100 mL per group)
- STUDENT LAB: "Solar Water Heaters"

Activity Preparation:

1. Review STUDENT LAB: Solar Water Heaters. Gather supplies. Determine what preparation you will do and what students can do. (You may need to cut aquarium tubing, poke holes in disposable cups, gather books, etc.)
2. If you feel it is necessary, construct a solar water heater as described to use as an example.

NOTE: After designing and assembling the solar water heaters, you will need to allow at least two hours for the caulk to dry before testing them. Check the tube of caulk for specifications.

Activity Procedure:

1. Ask students if they have ever heard of or experienced a solar water heater. Most students may initially say no, but encourage them to think a little deeper. Have they ever turned on a hose or another outdoor water source in the summer and then felt warm water? Have they ever left a cup or bucket of water on a window sill on a sunny spring or summer day and noticed that it warmed up? This is solar water heating! Solar radiation (heat and light) from the sun is transferred to the water. Solar water heating is nothing new. People, including Native Alaskans, have been using the sun to heat water for thousands of years.

2. Explain that this lesson will explore how we can harness the sun's solar energy to heat water for use in our homes and schools. The systems mentioned above (hoses in the sun or cups on a window sill) are called passive systems because they have no mechanical parts. Active systems use devices such as pumps and fans to transport water and other substances throughout the system. In today's lab, students will work in groups to design, build and test a passive water heating system.
3. Divide students into groups. Distribute STUDENT LAB: "Solar Water Heaters" and associated supplies.
4. Instruct students to follow the instructions to complete the lab.
5. When all students have finished, pool their data on the white board. Calculate the mean, median and mode of each run and of the total temperature gain. Allow time for each group to share their design, results and revision ideas.
6. Review answers to remaining discussion questions. Lead a discussion about how and where solar water heating could be of use in your community.

Extension Ideas:

1. The shape of a solar collector can affect its efficiency. A parabolic collector is the most powerful type of collector because it concentrates light toward a single point, the focal point. Ask students to design a more efficient parabolic collector using aluminum foil. Repeat the experiment.
2. Calculate the focal point (f) of the parabolic collectors using the following equation: $f = x^2/4a$. Measure the longest diameter (width) of the parabola at its rim. Divide by two to determine the radius (x). Measure the depth of the parabola at its vertex (a). The vertex is the bottom of the "U". The focul point is the distance f from the vertex of the parabola.

Answers to STUDENT LAB: "Solar Water Heaters"

Data: Hypotheses will vary. Graphs will vary but should reflect an increase in water temperature with each run. Be sure that students label each axis and include a title.

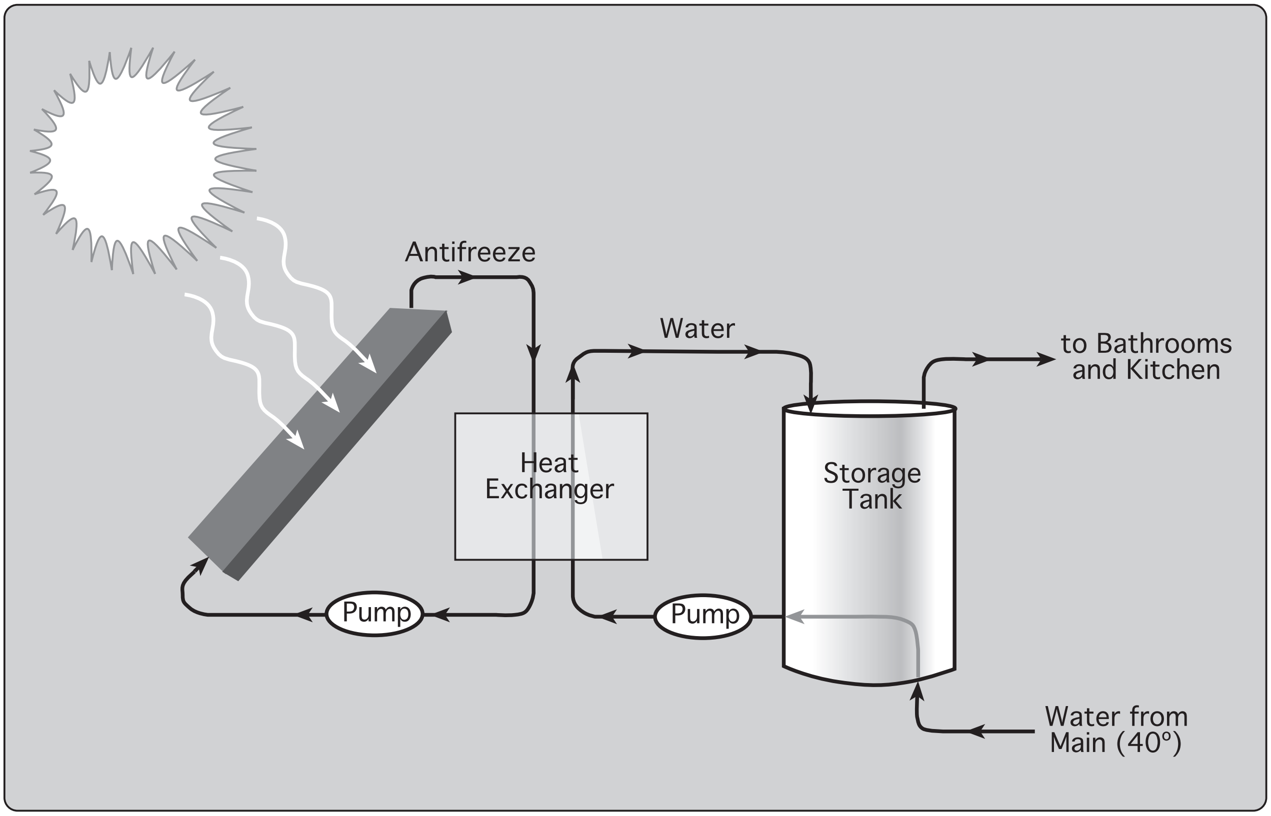
Review:

1. Solar
2. Passive
3. Active
4. 40-60

Conclusion:

5. Students should observe and record an increase of 3-5 degrees Fahrenheit per run.
6. Answers will vary, but students should suggest ways to keep the water in the tubing under the heat lamp as long as possible. Possibilities include decreasing the angle of the collector and increasing the length of the tubing (more loops and curves).
7. Benefits of a solar water heating system in Alaska: saves money on fuel; does not require much maintenance; uses solar energy when it is plentiful (summer months)
   Challenges/drawbacks of solar water heating in Alaska: can only provide 40-60% of hot water needs, so still need a back up water heater; can not provide much hot water in winter months
8. Answers will vary.
9. Answers will vary.

SOLAR WATER HEATERS
NAME: ______________________________



Solar Water Heating

Solar energy is radiant energy carried in the sun's heat and light. It can be used to produce electricity as well as to heat air and water. Solar heating systems can be active or passive. Passive design means that the structure itself is the solar collector. One example is a greenhouse. Active solar designs use mechanical systems such as batteries, pumps, and fans to transport and store heat energy for future use.

Active solar water heaters in cold climates include a solar collector, storage tank and pumps. In cold climates like Alaska, they also require a heat exchanger. A fluid such as antifreeze flows through pipes in a solar collector where it is warmed by the sun. The antifreeze flows through a heat exchanger where it transfers its heat to water. The warm water is stored in an insulated tank until it is used.

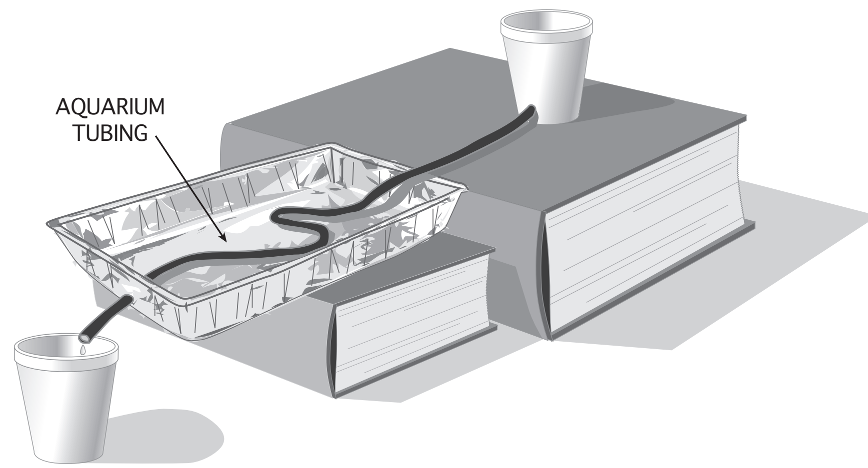
Active solar water heating is a useful and practical way to use solar energy in Alaska, especially in communities where fuel prices are high. People use hot water throughout the year, so solar water heating works especially well in summer when solar energy abounds. It is estimated that solar energy can provide 40-60% of the annual hot water demand for most locations in Alaska.

Directions:

In this lab you will work as a team to design, build and test a solar water heater. You will use a heat lamp to represent the sun. Follow the directions carefully in each section and be creative!

Materials:

- Black aquarium tubing (36 inches)
- Aluminum cake pan (9" x 13")
- Scissors
- Heat lamp
- Sturdy disposable cups (2)
- Caulk
- Books and notebooks (different sizes to create different levels)
- Duct tape
- Digital thermometer
- Cool water
- 100-mL graduated cylinder



Procedure:

1. Build the collector:
   - Gently stretch the piece of black tubing to get it as straight as possible.
   - Use very small pieces of tape to attach the black tubing to the cake pan. The tubing must start at one end of the pan and end at the other. You want the water to stay in the tubing as long as possible, so add loops and curves. Be careful not to kink the tubing and block the water off.

2. Build the storage containers:
   - Carefully poke a hole in one cup, just above the bottom. This is the cool water reservoir. The other cup will be the warm water collector. Label each cup.
   - Insert one end of the black tubing into the hole in the cool water reservoir.
   - Caulk around the hole to seal it.

3. **STOP!** Allow time for caulk to dry (at least two hours or as directed on the tube of caulk).
4. Assemble a platform with at least three levels: the cool water reservoir should be highest, the collector should be in the middle and the warm water collector should be lowest. You want gravity to make the water flow, but you want it to flow as slowly as possible.
5. Set up the heat lamp as directed by your teacher. It should be pointed directly at the black tubing.
6. Measure 100 mL of water in the graduated cylinder. Record the temperature. This is "run 0."
7. Make a prediction about how much heat your water will gain in the solar heater.
8. Carefully pour the water into the cool water container. Adjust the collector and containers as needed to ensure the water will flow into the warm water collector.

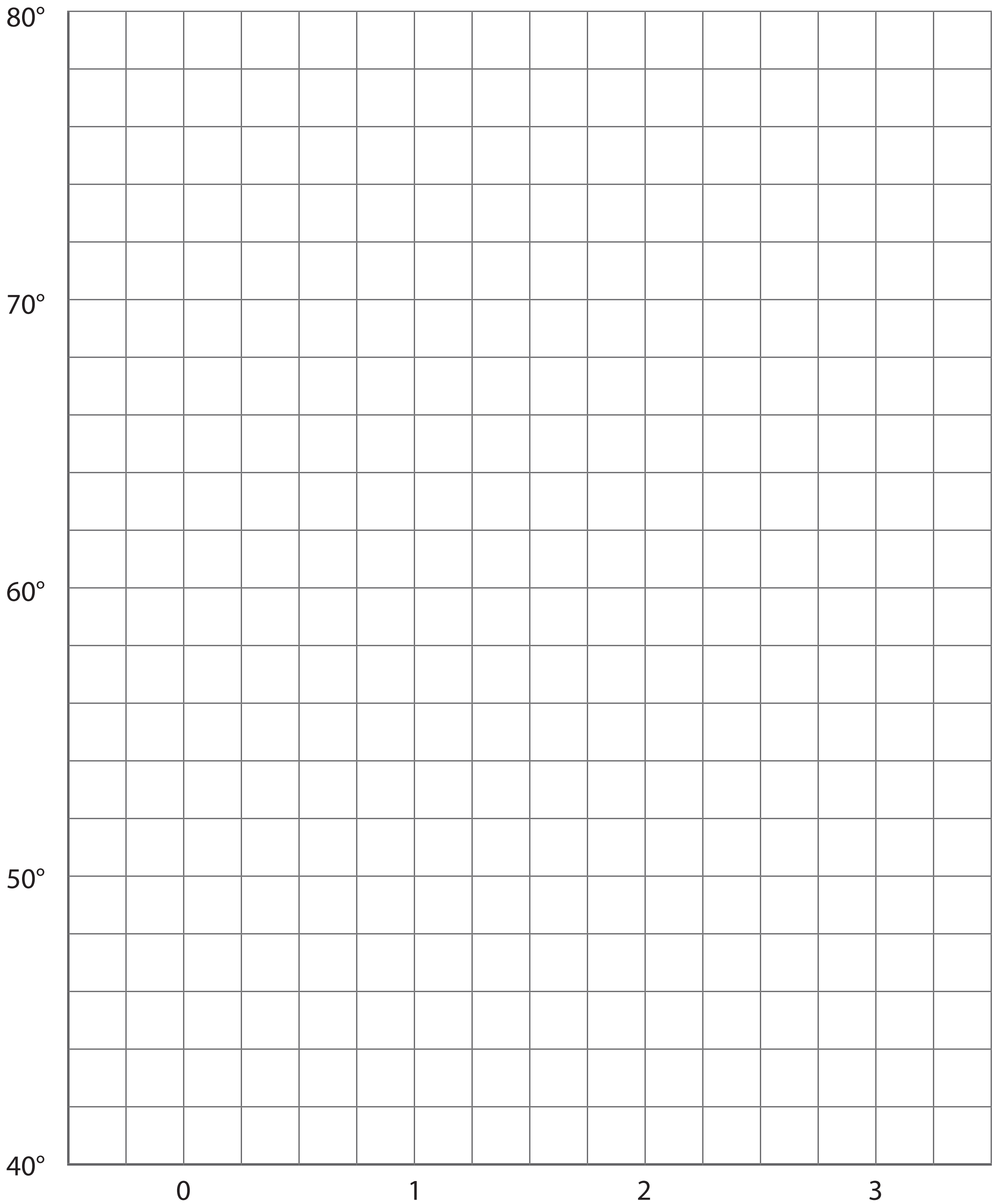
9. As soon as all the water is in the warm water collector, take the final temperature and record. This is "run 1."
10. Run the same water sample through the heater two more times and record each temperature. These are "run 2" and "run 3."
11. Create a bar graph to show your results. Do not forget to include a title for your graph and to label each axis.

Data:

Prediction: ____________________

Run	Water Temperature
0	
1	
2	
3	

Total heat gained in solar heater:____________________


80°
70°
60°
50°
40°
0
1
2
3

SOLAR WATER HEATERS

Review:

1. _________________ energy is radiant energy carried in the sun's heat and light.

2. ____________________ solar design means that the structure itself is the solar collector.

3. _____________________ solar designs use mechanical systems such as batteries, pumps, and fans to transport and store energy for future use.

4. It is estimated that solar energy can provide ________________ % of the annual hot water demand for most locations in Alaska.

Conclusion:

5. Describe the results of each test of your water heater. How close was your prediction?

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6. Using only the materials provided, suggest one way you could make your water heater more efficient. Explain what evidence supports your conclusion. Use complete sentences.

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SOLAR WATER HEATERS

7. List at least one benefit and one drawback of using a solar water heating system in Alaska.

8. Do you think a solar water heater would work at your home or school? Why or why not? Draw one location where you think it could work. Be sure to show the location of the sun and where you would place the solar collector.

SOLAR WATER HEATERS

9. Do you think Native Alaskan people used solar water heating hundreds of years ago? How?