Teacher's Preparatory Guide

Lesson 1: Building Simple Solar Ovens and Testing Thermal Energy

Overview The first lesson in this set of activities for the Heat and Solar Energy unit will be guided, lab-based, and hands-on. The students will be instructed how to build simple solar ovens out of pizza boxes. After a day of building the ovens, the students will spend a second day doing an experiment in which they measure the temperature inside their ovens at set time intervals, as well as the temperature of a water sample at the beginning and end of the experiment.

Purpose At the end of this lesson, students will understand that solar energy radiates from the sun to the Earth and gets trapped within the oven. Students will be able to explain how the thermal energy flows from the hot air to the cold water via conduction and will indicate that this would continue to happen until the water sample reaches the same temperature as the oven air. The students will also answer questions about how heat could be lost in the oven through conduction and convection, as well as how to get more solar radiation into the oven. This experiment will give them an opportunity to learn the relationships between *conduction*, *convection*, and *radiation* through a real-life learning experience. With regard to experimentation, students will also be learning to write hypotheses, utilize thermometers for measuring, and will practice constructing graphs for data analysis.

Level Middle school or high school

Time required Approximately two 50-minute class periods or one 90-minute block period

Did you know?

In one single minute, the Earth receives enough solar radiation to meet energy demands around the planet for an entire year! As scientists, we need to develop more efficient ways to capture and use this energy. This may enable us to conserve other energy sources, minimizing our use of electricity and fossil fuels, allowing us to live on a healthier, greener Earth!

Source: Todd, R. (Ed.). 2001. *Holt Science & Technology: Earth Science Annotated Teacher's Edition*.p 233, Austin, Texas: A Harcourt Classroom Education Company

Materials per Student Group

- 1 medium pizza box
- aluminum foil (approximately 3 feet)
- clear, acrylic Plastic (i.e., Plexiglass)
- aluminum cupcake cups

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- scissors
- duct tape
- white glue or glue guns
- black paper
- colored pencils or markers
- thermometer
- solar oven worksheets
- hole punch
- twine, about 15 inches long
- 2 rulers

Safety Because the students are cutting through cardboard boxes, it is recommended that they use "adult" scissors under the strictest of supervision. It may be helpful to have an adult with a razor blade (or box cutter) who can assist the students with cutting the cardboard boxes. If an adult has a razor blade, be sure that it does not get into the hands of any students. On the oven-building day, it may be helpful to ask for parent volunteers to help in the classroom. If using glue guns, caution students that they are very hot and not to drip glue on lab benches/workstations.

Advance Preparation While the specified materials seem to work best during classroom testing, other materials may work as well. This activity works best with students working in pairs to ensure that all students have the opportunity to build the ovens, as well as participate in the creative thinking involved in the second lesson.

- A local pizza store may be willing to donate pizza boxes for each pair of students. If not, you can always ask students to save used pizza boxes and to bring them into the classroom.
- You will need to create a window for each pizza oven. If you have limited money or want students to take home complete ovens, you may substitute plastic wrap for the acrylic plastic, though it does not seem to work as well and is very difficult to use when building the ovens because it tears easily. Acrylic plates are easy to find at any home improvement store, as well as at some stores that sell picture frames—they are the acrylic pieces inside a frame. Any size plate works as long as it covers the entire hole that is cut in the pizza box, so it really depends on the pizza box size and the size of the hole that is cut out. This lab was tested using two different sizes of acrylic plates (due to availability): 8" × 12" and others were 12" × 18".
- Black butcher paper works well because it is large and easy to cut into any size or shape. Each student will need 1 sheet of black butcher paper that is cut to fit the inside bottom of the pizza box.
- Students will need lots of white glue in order to get their foil to lay flat. One trick to flatten the foil is to use a ruler to smooth it out.
- Make sure that the thermometer you use has a wide temperature range that goes from at least room temperature to 100 degrees Celsius, and that it functions correctly in air.

You may wish to make a pizza box solar oven at various stages of the procedure as an example.

Teacher Background

As energy demands continue to rise and prices for fossil fuels also rise, there is an increased interest for alternative sources of energy. Solar energy is one form of renewable energy with other sources being hydro, wind, geothermal, and biomass. This lesson explores solar thermal energy. This technology is based on energy conversion – a black surface is used to absorb the sun's energy and convert the enrgy to heat water, or air. The sun is a great source of energy especially if we can tap into this source and economically convert it to electrical energy. This is where nanotechnology will play an important role in the development of renewable energy from the sun. Nanotechnology will assist in moving from the conversion of solar energy to thermal energy to the conversion of solar energy to electrical energy via solar cells.

What is nanotechnology? Nanotechnology is an area of science and engineering that occurs at the atomic or molecular level. This interdisciplinary field occurs at the 1-100 nanometer range. One nanometer is 10^{-9} meters or about 3 atoms long. For comparison, a human hair is about 60-80,000 nanometers wide. These materials have unique properties because of their small size. At the nanoscale, properties of materials behave differently and are said to behave under atomic and molecular rules. Researchers are using these unique properties of materials at this small scale to create new and exciting tools and products in all areas of science and engineering.

Currently solar cell technology relies on photovoltaics or devices that directly convert solar energy to electrical energy. This technology, however, is costly to manufacture as it is based on semiconductor or silicon technology and the cells are not very efficient. Enter nanotechnology. Researchers are exploring ways to improve the efficiency of solar cells. Researchers are exploring ways to improve the efficiency of solar cells. Much of the new methods being developed rely on nanoparticles, particularly molecules that can capture light and separate it into positive and negative charges (similar to photosynthesis). Why nanoparticles? Nanoparticles have large surface area to volume ratios and an increase in surface area means the particle has a larger area with which to capture solar energy and in turn produce more electricity. Nanorods, nanofilaments, budckyballs, and quantum dots are just some of the materials being explored to reduce solar costs while increasing efficiency.

Researchers at New Jersey Institute of Technology are exploring solar cells that can be painted on plastic sheets. At Georgia Institute of Technology, researchers are using carbon nanotubes to make towers on photovoltaic cells which allow more of the sun's energy to be absorbed. Commercial development is also occurring. Konarka Tehnology, Inc. is developing solar cells using nanocrystals embedded in plastics. NanoSolar has developed a method which uses nanoparticle ink to print the solar cells on thin strips of foil. The system prints solar cells at 100 feet /minute. To view the process visit http://www.youtube.com/watch?v=4riNlQZHCTQ.

This lesson should be used to encourage students to think about solar energy and its applications to everyday lives. Students should be made aware that they are exploring a simple form of solar energy but that nanoscale science and engineering is developing solar cells that will convert solar energy to electrical energy and in an economically feasible manner.

Teacher Resources You may wish to use these resources either as background or as a resource for students to use in their inquiry-based design.

Site	Topics
NASA www.nasa.gov/	search "solar oven" or "sun used for energy" • the "concentrator" gives ideas on improving solar oven design • Native American's houses warmed by the sun • Photovoltaics get electricity from the sun's energy • NASA aircraft uses the sun's energy to propel itself

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	• Hot dog cookers with instructions are provided
Texas State Energy Conservation Office www.infinitepower.org/	This site includes lesson plans and tests 3 types of solar cookers (instructions provided) to determine what is the most efficient in terms of heat efficiency, availability, and cost effectiveness. It is heavy on calculations and F/C conversions.
Learn NC www.learnnc.org/	search "solar oven" • Lesson plan includes solar oven with cardboard box (instructions are provided) • This uses 1 oven for the class and a student records the temperature every 10 min. • Later, the class cooks a recipe together • Lesson includes a worksheet that shows $ cost savings
TEAK Town http://teak.rit.edu/teacher-information/final-paperwork	Complete kit documentation (available as pdf) has a lesson plan that includes: • The solar energy cycle • Solar ovens • Photovoltaic cells Students can observe what is happening to food and relate it to the greenhouse effect.

Below are some links on solar cells:

http://www.understandingnano.com/solarcells.html

http://en.wikipedia.org/wiki/Solar_cell

http://www.howstuffworks.com/solar-cell.htm

http://www.sciencentral.com/articles/view.php3?language=english&type=24119&article_id=218391978

National Science Content Standards:

Grades 5–8
A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

B: Physical Science—Transfer of Energy section
- Properties and changes of properties in matter
- Transfer of energy

E: Science and Technology—Abilities of Technological Design section
- Abilities of technological design
- Understandings about science and technology

Grades 9-12
A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

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B: Physical Science

- Structure and properties of matter
- Chemical reactions
- Interactions of energy and matter

E: Science and Technology—Abilities of Technological Design section

- Abilities of technological design
- Understandings about science and technology

Principles & Standards for School Mathematics Grades 6-8 and 9-12

- Data Analysis and Probability
    - Formulate questions that be addressed with data and collect, organize, and display relevant data to answer them.
    - Select and use appropriate statistical methods to analyze data.
- Measurement
    - Understand measurable attributes of objects and the units, systems, and processes of measurement.

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Lesson 1, Day 1 Instructional Procedure: Building Simple Solar Ovens

Time	Instructional Activity
5 minutes	Introduce the activity with the "Did you know?" from pg. 2 of this preparatory guide. Explain to students that one way solar energy can be used is by converting it to thermal energy.
	Ask the students: "How does heat energy get from the sun to the Earth when it is traveling in the form of light?" *Radiation*
	Ask: "What other ways can heat be transferred from one thing to another?" *Convection and Conduction*
5 minutes	Have the students complete the top portion of the worksheet, defining *conduction, convection,* and *radiation* in their own words. Have each student write down one example of each type of heat energy transfer.
30 minutes	Next, introduce the solar oven lab. The students will create solar ovens that harness solar energy to create heat. Explain that they will use their knowledge of heat transfer to maximize the amount of radiation they capture, and to minimize the amount of heat loss due to convection and conduction. They will all begin by creating a basic solar oven that they will test to determine whether or not they can capture enough solar radiation to cook food.
5 minutes	Instruct the students on how to build a basic pizza-box solar oven, following the instructions below.
5 minutes	Clean-up the classroom and stack pizza-box solar ovens on a countertop.
	Closure: Ask students to write down the question for tomorrow's experiment, on pg. 2 of their worksheet packet. If there is time, ask the students to write their hypotheses. If there is not time, have them write detailed hypotheses, with explanations, as a homework assignment.

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How to Build a Pizza-Box Solar Oven

1. Use your ruler to draw a line on the top of the box that is two inches from the front side of the box that opens. Draw it along that entire side
2. Now use your ruler to draw a line that is one inch from each of the sides on the top of the box. When you are two inches from the back of the top of the box, stop the line.
3. Being very careful with your scissors, cut along these lines. You should be cutting a rectangle out of the top of the box, but only along three sides. Do not cut the rectangle out along the back side. It should be a flap that opens and closes; it is a window to let in your *solar radiation*.

4. Cover the inside of your pizza box with foil. The foil will reflect the *solar radiation* into the box. You will use white glue (or glue gun) to glue the foil to the box. Do not use excessive amounts of glue. Please be conservative with our classroom supplies. Make sure that you press the foil flat into the box, especially on your window flap. The flatter it is, the better it will act like a mirror.

5. Cut out a rectangular piece of black butcher paper and glue it to the bottom of the pizza box, on top of the aluminum foil. Black will help absorb the heat so that the heat stays in the box and is not lost via *conduction*.

6. Fold your pizza box into a box shape by folding along the creases of the box. Because we do not want heat loss by *convection*, we will use duct tape to tape the edges of the pizza box shut so that air can not escape the box.
7. Tie or tape a piece of string to the back of the box. Then, punch a whole on the middle edge of the flap so that the string can be tied to the flap to keep it open.

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Lesson 1, Day 2 Instructional Procedure: Testing Solar Ovens Experiment

Time	Instructional Activity
5 minutes	Ask a couple of students to share their hypotheses about how hot they think their solar ovens will get. Remind them to put their hypotheses in degrees Celsius and remind them that room temperature is about 25ºC and boiling point is about 100ºC, to ensure that they give reasonable hypotheses.
5 minutes	Review the procedure for testing the solar ovens. Discuss how to set up the solar ovens so that the openings face the sun, and instruct the students on how to angle the window flap such that it directs the sunlight into the pizza-box oven.
5 minutes	Have the students retrieve their solar ovens and set them up outside. Recommend that students bring a notebook to write on while they are outside. Ask the students to record the temperature of the water before closing their ovens. As soon as the solar ovens are set up, ask the students to take the first temperature readings.
25 minutes	Start a timer so that it rings every 5 minutes, indicating to students that they must read and record the temperature. Have the students record the temperature every five minutes, for 25 minutes. In between temperature readings, you can show students how to plot the temperature points on the graph. You may also begin to discuss ways that heat may be lost from the pizza box ovens. If there is time for more than 25 minutes of readings, it is even better to do more.
8 minutes	When the students have finished their final recordings, have them record the final temperature of the water to see if it has changed. Then, have the students clean up their materials and return to the classroom.
2 minutes	Closure: Ask the students to write a conclusion and to answer questions 1–3 on pg. 3 of the worksheet packets for homework. Recommend that students search the Internet for ideas on how to improve their solar ovens before returning to class.

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Pizza Box Solar Oven: Student Worksheet *(with answers)*

Let's put our knowledge of heat energy transfer to the test! Do you have what it takes to design a working solar oven? Can you use your understanding of heat and energy to harness the sun's radiation and cook food without using any other energy sources (no electricity or fuel)?

Define the following and state one example of each:

Conduction *Conduction is a transfer of heat from one object to another through direct contact.*

Example *Burning a finger on a hot pan, or a popsicle making your tongue cold.*

Convection *Convection is a transfer of heat through the movement of a liquid or a gas.*

Example *Heater blowing air around a house or a pool heater moving water around a pool.*

Radiation *Radiation is a transfer of heat through electromagnetic waves (light).*

Example *Sun heats the Earth via sunlight, from a long distance away.*

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Pizza Box Solar Oven: Student Worksheet ***(with answers)***

Question/ Purpose *How hot will my solar oven get after 25 minutes?*

Hypothesis (*Remember:* Room temperature is about 22°C & boiling point is 100°C.)

I think that my solar oven will get to be about 75°C because I think it will be hotter than the air, but colder than boiling water.

Materials

- pizza box solar oven
- thermometer
- timer
- small cup of water *(small enough for the pizza box to close with the cup inside)*

Procedure

1. Set up your pizza-box solar oven in the sun. Turn the box so that the opening is facing the sun. Then tilt the window until you can see the sun's light reflect into your box. Tie the window open at this distance.
2. Place the small cup of water in the oven and record the initial temperature of the water.
3. Cover your window opening with an acrylic sheet. Although this is plastic, you must still be careful not to break it or cut yourself.
4. Push the thermometer through a small hole on the edge of the box until the tip reaches the place where the sun shines through the window, but try not to let it touch the ground. Record the initial temperature inside the box right away.
5. Every 5 minutes, record the temperature inside the pizza-box solar oven. Leave the thermometer in place while you are waiting. You can pull the thermometer out slightly to look at the temperature if necessary, but not for long.
6. When you have finished all of the recordings, open the pizza box and quickly record the final temperature of the water.
7. You will now need to carry the materials back to the classroom. Close your pizza box after removing the water and thermometer. Leave these on another tray or bin outside.

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Data

Temperature Outside: 24 ℃__________ (Remember to always use degrees Celsius.)
Initial Water Temperature: 23 ℃______
Final Water Temperature: 34 ℃______

Time (minutes)	Temperature (˚C)
0 minutes	24˚C
5 minutes	35˚C
10 minutes	47˚C
15 minutes	53˚C
20 minutes	61˚C
25 minutes	67˚C

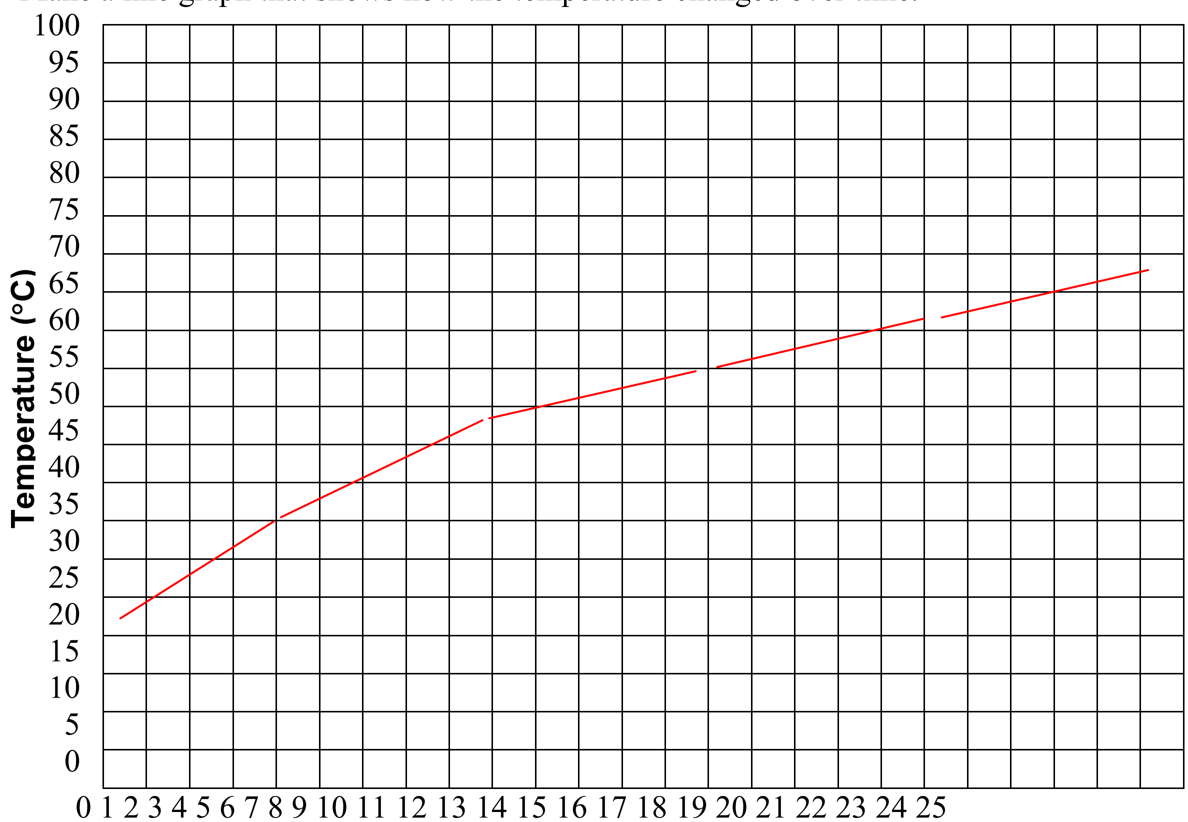
Final Oven Temperature: 67 ℃___________

Analysis

8. What is the final oven temperature in degrees Fahrenheit? 153 ℉_____

Use this equation: ˚F = (9/5 × ˚C) + 32

9. Make a line graph that shows how the temperature changed over time.



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Time (minutes)

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Conclusion *Example conclusion: My hypothesis was close, but not correct. My solar oven only reached a temperature of 67°C instead of a temperature of 75°C.*

Name 3 ways that you think you may have lost heat from your pizza-box solar oven.

1. *The ground absorbed some of the heat away from my solar oven.*

   Was this conduction, convection or radiation? *Conduction*

   How might you be able to fix this problem to make your oven better? *Add more insulation to the bottom of my solar oven, or lift it up on stilts so that it is touching less.*

2. *Air was escaping out of the cracks around the edges of the solar oven.*

   Was this conduction, convection or radiation? *Convection*

   How might you be able to fix this problem to make your oven better? *Tape up all of the corners to prevent hot air from escaping.*

3. *There was not enough light shining into my solar oven the whole time.*

   Was this conduction, convection or radiation? *Radiation*

   How might you be able to fix this problem to make your oven better? *Add more reflective flaps to get more light into the oven.*

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Assessment

Assessments *for* Learning:

The students will begin by constructing definitions and examples of the three key terms listed on the worksheet: *conduction, convection,* and *radiation.* The teacher will check to see how well students are defining the terms and will check that their examples are appropriate for each process of heat transfer. The class will then construct the definitions orally to ensure that every student knows the definitions correctly and that they each hear many examples of each process.

Throughout the lesson, the teacher will continue to check for understanding of the three main terms and will ask questions that require the students to apply their understanding of the terms to the solar oven project. Examples of these questions are provided in the curriculum plan.

Assessments *of* Learning:

Description	What is Assessed	Feedback
The students will complete a packet of worksheets for the solar oven project. The packet requires students to define conduction, convection, and radiation, in addition to writing up the lab portion of the project. For each of the labs, students must write a hypothesis, record data, analyze the data in the form of a graph, and draw conclusions. In addition, students must answer questions about how to improve the solar ovens in terms of conduction, convection, and radiation.	This worksheet packet assesses students' abilities to write hypotheses, to collect and record data, to display the data in the form of a graph, and to draw conclusions based on the data presented. In addition, the solar oven packet assesses students' understandings of the energy transfer concepts of conduction, convection, and radiation because the students must understand these concepts in order to explain how their solar oven modifications are intended to improve the oven design.	Students receive a score, according to their abilities to demonstrate what is being assessed. They also receive written comments to draw the connections between their solar ovens and energy transfer, in order to help them think more critically about it. Comments are also provided that help students improve their scientific method skills.

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