Teacher's Preparatory Guide

Lesson 2: Inquiry-Based Solar Oven Revisions And Solar Oven Cooking

Overview The second lesson in this set of culminating activities for the Heat and Solar Energy unit will be an inquiry-based laboratory activity that is a follow-up to the previous lab. The students will focus on improving their solar ovens through their own design.

The students will be provided with information and materials that will help them come up with ideas for how to create more efficient solar ovens, such as creating wings, insulation, or coloring the outside of the pizza boxes; however, they will be free to make any improvements that they wish. The students will perform the same experiment, measuring the temperature inside the ovens at set time intervals, as they had done before.

The guided lab (lesson 1) will act as the control and the improved ovens will serve as the experimental trial. Rather than heating water in their ovens, which demonstrated that heat is transferred from hot to cold, the students will cook scrambled eggs during this second day of experimentation. If there is not enough time to cook eggs, students could melt cheese atop an English muffin.

The students will give short mini-presentations—in between the temperature measurements—that explain their modifications and improvements to the solar oven design. After the experiment, students will graph their data again and will compare it to the control trial, drawing conclusions about the improvements.

Purpose At the end of this lesson, students will analyze their data to determine if there were any differences in results between the previous simple ovens and the new, improved ovens, evaluating their designs. They will explain in their own words why their modifications improved the functionality of the solar ovens, utilizing the terms *conduction, convection,* and *radiation.*

Level Middle school or high school

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

National Science Content Standards: Grades 5–8

A: Science as Inquiry

- Identify questions that can be answered through scientific investigations
- Design and conduct a scientific investigation
- Use appropriate tools and techniques to gather, analyze, and interpret data
- Develop descriptions, explanations, predictions, and models using evidence
- Think critically and logically to make the relationships between evidence and explanations
- Communicate scientific procedures and explanations
- Use mathematics in scientific inquiry

B: Physical Science—Transfer of Energy section

- Energy is a property of many substances and is associated with heat, light… Energy is transferred in many ways

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- Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature
- The sun is a major source of energy…The sun's energy arrives as light…

E: Science and Technology—Abilities of Technological Design section

- Identify appropriate problems for technological design
- Design a solution or product
- Implement a proposed design
- Evaluate completed technological designs or products
- Communicate the process of technological design.

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 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.

Materials available for student groups

- original pizza-box solar ovens
- extra cardboard
- aluminum foil
- clear, acrylic plastic
- scissors
- duct tape
- white glue
- black paper
- colored pencils or markers
- thermometer
- solar oven worksheets
- food to cook (scrambled eggs in this lab)

Safety

Keep in mind the same safety precautions as in Lesson 1. Strictly supervise students who are using "adult" scissors to cut through the cardboard. Students have a tendency to want to hold the scissors open and use them like a razor blade. They will need constant reminders that this is not safe. If an adult is assisting with a razor blade, ensure that the students do not get their hands on it. Again, it may be helpful to ask for parent volunteers to help in the classroom.

Advance Preparation The preparation for the second lesson is slightly different than the prior lesson because of its inquiry-based nature. There are no specific materials that are necessary for the students to be using. In fact, you could have them bring their own materials for this second lesson, so that they can maximize their creative thinking. Some students may even want to start over and build a new solar oven from scratch. However, for students who may not end up bringing their own materials, it is recommended that you bring some basics for the students, including extra cardboard, extra aluminum foil, and duct tape. With these three materials, students can:

- add extra flaps to capture more solar radiation
- add insulation to the bottom of the box to minimize heat loss via conduction
- entirely seal off cracks to minimize heat loss due to convection

Other than supplying some extra materials so that students have materials available for improving their solar-ovens, the only other preparation is getting eggs scrambled and ready to cook. Eggs were used in this lesson in order to incorporate protein denaturing, as eggs cook, because protein denaturing happens on the nano-scale. Additionally, it is easy to see when eggs are cooked because of the color change that occurs. However, various other foods can be used. For example, students could try to melt cheese on top of English muffins or warm hot dogs in their solar ovens. If you are working within a 45–50 minute period, you should plan on having a

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thin layer of egg or something that needs very little warming. However, if you have a 90-minute block period, or have students throughout an entire day, you may want to consider cooking other foods, such as cookies, which require more time.

Teacher Resources You may wish to use these resources 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 • 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.

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Lesson 2, Day 3 Instructional Procedure:

Individual Solar Oven Design

Time	Instructional Activity
15 minutes	Start the day by presenting the solar oven revision activity as a scenario or problem. Ask the students: "What do you think were some of the problems with our solar ovens when we did our tests?" Get the students to share ideas about where they think they were losing heat from their previous solar ovens. Discuss the weaknesses of the ovens in terms of radiation, convection, and conduction. *Not getting enough light into the box, hot air escaping through the openings in the box,* and *heat being absorbed through the bottom of the box by the cement.* Listen to some student opinions about how they can fix the mentioned problems. Then, present the short PowerPoint presentation so that students can get more ideas about improvements.
30 minutes	Allow the students to obtain their solar ovens and to begin making improvements to their designs. Make sure that the students are writing down their improvements as they go. You may want to walk around asking them which methods of heat transfer are related to the improvements they are making, to ensure that they are thinking about their solar ovens in terms of science.
5 minutes	Clean up the classroom and stack pizza-box solar ovens on a countertop if students are not going to work on them overnight at home. Closure: Tell the students that they should bring home their solar ovens if they would like to work on them some more, but remind them that they must be brought back if they are going to take them home. If there is time, ask the students to write their new hypotheses. If there is not time, have them write detailed hypotheses, with explanations, as a homework assignment.

Encourage Creativity!

Try presenting this second lesson as a scenario or a problem to be solved. You could tell the students to pretend that they are competing to sell their improved solar oven designs to a private company, or to imagine that they are going on a camping trip and want the best possible solar ovens so that they do not have to use fuel to cook. You may even encourage the students to see if they can make their solar ovens good and hot enough to cook their own meals at home.

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Lesson 2, Day 4 Instructional Procedure: Cooking in Modified Solar Ovens

Time	Instructional Activity
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.
10 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. Have each group of students get a piece of foil and make a shallow dish out of it. Then have each student get a shallow layer of scrambled egg to cook in his/her foil dish. It is best to have an adult pour the scrambled egg to ensure than no hands and germs end up in the eggs, as well as to make sure that there is not an excess amount of egg. If there is too much egg, it will not cook within 25–30 minutes. You may wish to measure equal amounts of egg—this will allow the class to compare the effectiveness of solar oven designs from group to group. As soon as the solar ovens are set up, ask the students to take the first temperature readings. Make sure the students know not to measure the temperature of the eggs because science thermometers may have chemicals left on them.
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 5 minutes, for 25 minutes. In between temperature readings, the students can graph their data and answer their lab questions on page 5 of the worksheet packet. 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 get their foods out of the ovens to eat while returning to the classroom.
2 minutes	Closure: Ask the students to complete the remainder of the worksheet packets for homework, or plan to allow the students additional time to complete these in class on a different day.

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Pizza Box Solar Oven: Student Worksheet (with answers)

New Question If I make the following modifications to my pizza-box solar oven, can I get my oven to be hotter than I did before? Also, will my oven be hot enough to cook food?

Modifications Write down at least 3 ways that you will modify your solar oven to prevent heat loss by *conduction or convection*, or how you will increase the *solar radiation* that enters the solar oven.

1. *I will add more insulation to the bottom of my solar oven, or lift it up on stilts so that it is touching fewer objects in order to prevent heat loss by conduction.*

2. *I will tape up all of the corners and edges to prevent hot air from escaping out of my solar oven so that I do not lose heat by convection.*

3. *I will add more reflective flaps to get more light into the oven and will aim my flaps better to get more solar radiation to enter my solar oven.*

Hypothesis *I belive that my solar oven will actually reach 75℃ because I think my modifications will make more solar oven lose less heat than during the trial. I think that this temperature will be hot enough to cook my food.*

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Materials

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

Procedure *Repeat the same procedure as before, except that this time, food will be cooked instead of having a cup of water. The temperature of the food will not be measured because we will be using a science thermometer.*

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 tray with food in the oven.
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 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 box.
7. You will now need to carry the materials back to the classroom. Close your box after removing the tray with food and thermometer. Leave these on another tray or bin outside.

Experiment and Data Collection

Temperature Outside: *24 ˚C* (Remember to always use degrees Celsius.)

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	*75˚C*

Final Oven Temperature: *75 ˚C*

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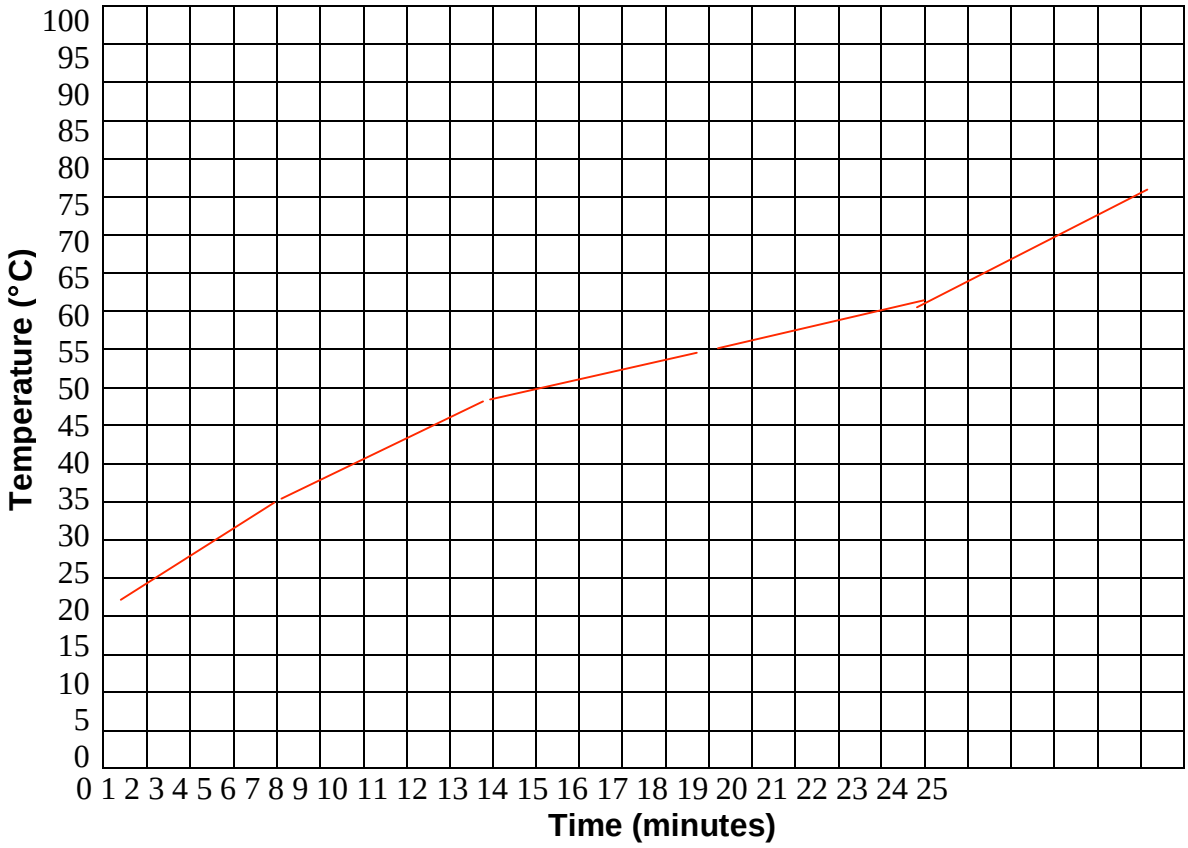
Analysis

8. What is the final oven temperature in degrees Fahrenheit? *167℉*

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

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



Conclusion

1. Specify whether or not your solar oven was hot enough to cook your food and use your data to support your conclusion.

   Example: My solar oven was hot enough to melt my cheese because it reached 75℃.

2. State whether or not your modifications helped to make your oven hotter.

   Example: My modifications helped make my solar oven hotter because it got to 75℃ this time instead of only 67℃.

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3. Do you think you were able to get more solar radiation into your oven? Explain.

   Example: I think that I was able to get more solar radiation into my oven this time because of the flaps I added.

4. Do you think you allowed for less heat loss by conduction or convection? Explain.

   I think that the tape and insulation helped prevent heat loss from my oven and that it why it got hotter than before.

5. Do you think that the weather may have affected your results? How do you think the weather changed them?

   I think the weather could have affected my results because if it was cloudy or cold outside my solar oven might not have gotten as hot as it did. I could also lose more heat due to convection if it was windy.

6. If you were to do another experimental test to see if you could improve your oven again, what might you try to test?

   I would cover the whole outside of my solar oven with black paper to see if it would help me absorb more solar radiation and have a hotter temperature.

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Going Further Advanced students can have an additional challenge. After testing their new design, they could take a recipe and modify it. The challenge would be to predict the cooking time and then test it to see if their predictions are accurate.

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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