Engineering Design Challenge - Solar Cook-Off

Student Objectives
The student:
- will explain the principles of solar thermal and heat transfer
- will explain how and why a solar cooker works
- will use the engineering design process to complete a task
- will work with a team to design and build a solar cooker and use it to cook a recipe of the team's choosing.

Key Words:
conduction
convection
glazing
insulation
radiation
reflector
solar collector
solar thermal
transmission

Time:
2 – 5 class periods for building & testing
2 hours during midday for cooking

Materials (construction)
- various materials to construct solar cookers such as: sheet cardboard, cardboard boxes, corrugated sheet plastic, styrofoam, plexiglass, sheet mylar, insulation board, aluminum duct tape, black construction paper
- box cutter, ruler, tape measure, scissors, protractor
- spray glue, white glue, glue gun, high temperature black spray paint, sponge brush, tray for glue mixing, string, wire

Materials (testing)
- small beakers or baby food jars
- thermometers
- pieces of high temperature cooking bags
- rubber bands
- clock, stop watch, or other timepiece

Materials (cooking)
- ingredients needed for chosen recipe
- cooking vessel appropriate for cooker design and recipe chosen (see *What's Cooking?* for guidelines)
- pot holders, oven roasting bags, plastic wrap
- non-latex rubber gloves

Background Information

If you are unfamiliar with the Solar Energy Cook-Off competition, you may want to preview the EnergyWhiz video (link in Internet Sites section) and read the rules for the Solar Energy Cook-Off prior to class.

The Solar Energy Cook-off is a solar cooker competition where students work in teams of two to six, designing and building a solar cooker. This process challenges students to use creative thinking, science know-how, teamwork and the engineering process. At the competition, students demonstrate the performance of their cookers by creating and cooking an original dish of food. Cookers are judged on their design and construction, and the team's food is judged on its taste, appeal, creativity and suitability to cooking with solar.

Solar Cook-Off competitions may be held in the school or as a local event. Regional Solar Cook-Offs are held as part of EnergyWhiz Expos throughout the State of Florida, and annually at the statewide EnergyWhiz at the Florida Solar Energy Center in Cocoa, Florida. Additionally, solar cooking events are held worldwide for those teams not in the southeastern part of the United States.

Procedure (during class time)

1. Tell the students that they are going to be designing and constructing original solar cookers for the Solar Cook-Off competition. Show the EnergyWhiz video *(link in Internet Sites section below)*.
2. Assign students to groups of 2 – 6 students per group.
3. Show the class photos of student designed cookers, pausing at each photo to let the students share what they like and dislike about each design. *(Photo Gallery link in the Internet Sites section below)*
4. Explain to the students that they are to design, construct, and test (by boiling 75 mL of water) an **original** cooker. In other words, if they decide to use a published cooker pattern, either from a cooker design that they learned about in class or one they discover during research on the internet, they are to modify it to make it their own original creation.
5. Tell the students that the first step in this engineering project is research and planning. Their goal is to decide what kind of cooker they want to build, sketch out the design including desired measurements, and create a list of materials. They should note on their list of materials where they will get any materials that are not available in class.
6. Assist the groups as needed during this day and during the following construction days.

Procedure (testing)

1. After the teams complete their cooker, they should follow the steps in their Science Journal to test their cooker.
2. Remind the students that a critical part of the Engineering Process is testing, modifying and retesting their design.
3. Encourage the teams that do not get the water in their test to boil within a reasonable amount of time (less than a ½ hour on a clear day for parabolic, and less than 1 hour for panel and box cookers) to modify and improve their cookers, and then test again.

Procedure (cooking day)

1. Tell students to get their cooker set up before beginning to prepare their food.
2. Remind students of safety precautions with hot cookers and kitchen implements. Additionally, remind students to wash their hands and to wear rubber gloves while preparing their food.
3. At the appropriate time, students should plate their food remembering to make it look as appealing as possible.
4. If you do not have a judging panel to taste their food, you may wish to have the students share their food with the other teams and collect their feedback.

Procedure (wrap-up discussion)

Note: This discussion is a wrap-up activity that can be held the same day as the solar cooking, or can be done during the following class.

1. Lead a discussion on the variety of cooker designs, testing results and cooking techniques that occurred during this unit. Some of the points to cover could include:
   - What design elements seemed to work the best for the box cookers built by the teams? ....for the panel cookers? .....for the parabolics?
   - What was the best use of recycled materials in the class?
   - If given an unlimited budget, what materials would they like to use in their "ultimate" solar cooker?
   - What design elements would they like to put in their "ultimate" solar cooker?
   - How well did their chosen recipe work being cooked in a solar cooker? What changes would they make next time?
2. Have the teams graph their testing data on the board, by cooker type: box, panel, and parabolic. *(Note: You can either have them do three separate graphs, or have them use three different colors on the same large graph.)* Discuss the data similarities and differences with the class.

Key Words & Definitions

- **conduction** – the movement of heat or cold through materials that are solid
- **convection** – the movement of heat through air or in liquids
- **glazing** – the clear material (i.e. glass or plastic wrap) that lets in light and traps heat
- **insulation** – material used to reduce heat loss or gain
- **radiation** – the way we receive heat from the Sun each day. The energy is emitted in the form of waves/particles, and can move from one object to another without heating the area in between.
- **reflector** – shiny device used to alter the path of light
- **solar collector** – a device that collects and traps solar energy
- **solar thermal** – using the Sun's energy to heat something

Related Research

1. Have the students cook a snack for another class, younger students, or a neighborhood

group.

2. Have your best teams compete in the statewide EnergyWhiz in May.

Related Reading

- ***Cooking With Sunshine: The Complete Guide to Solar Cuisine with 150 Easy Sun-Cooked Recipes*** by Lorraine Anderson & Rick Palkovic (De Capo Press, 2006)
  This book describes how to build your own inexpensive solar cooker, explains how solar cooking works, its benefits over traditional methods, and then includes more than 100 recipes that emphasize healthy ingredients.
- ***Solar Cooking for Home & Camp: How to Make and Use a Solar Cooker*** by Linda Frederick Yaffe (Stackpole Books, 2007)
  This book contains directions for making two different types of solar cookers as well as source lists, how to pasteurize water/milk, and more than 150 recipes.

Internet Sites

http://vimeo.com/9522310
EnergyWhiz video describing the competitions and events of the day.

https://fsec.zenfolio.com/ew
Photo gallery of competition photos from Solar Cook-Off competitions from 2009 to the present.

http://www.fsec.ucf.edu/go/energywhiz
FSEC's EnergyWhiz competition page with links to the Solar Cook-Off rules, and photos and recipes from past years.

http://solarcooking.org/
Solar Cooking International Network, solar cooking archive includes solar cooking articles and worldwide news.

Videos featuring solar cooking:

https://www.youtube.com/watch?v=Hjo-Les1FF0
Solar Chef, a Jamaican solar chef cooks chicken with a parabolic cooker.

https://www.youtube.com/watch?v=WXwPIrrjA-c
Solar Cooked blackened seafood Alfredo with angel hair pasta is cooked.

https://www.youtube.com/watch?v=cIt8NXDA3B8
Solar BBQ, features a reflector on the bottom.

https://www.youtube.com/watch?v=7Ix36JtLBrU
This video shows cooking scalloped potatoes and ham in the winter with snow on the ground; it is also a good way to dispel student's belief that it is the outside temperature that makes the solar cookers work.

https://www.youtube.com/watch?v=kW1ERh8Q0rk
Step by step directions to make Masoor Daal (lentil soup) in a solar cooker.

Solar Cook-off ~ Design Judging Score Sheet

Design decisions: How well does the team understand solar cooking and solar thermal design? Was careful attention paid to parts selection and integration?

Construction: How well did the students construct their design? Are the students able to discuss the materials used?
Is the cooker sturdy enough to cook their food? Is it replicable?

Function: How well does the design function as a cooking apparatus? Are the students able to discuss how well the cooker works and what temperature it achieved?

Creativity: How creative is the design and/or use of materials? Were recycled materials used? Is the design/project presented in a creative way?

Durability: Has the cooker been designed for repeated usage? Can the cooker stand up to moderate wind, humidity and light rain?

0 1 2 3 4 5 6 7 8 9 10
Poor.....Fair.....Good.....Impressive.....Excellent!

Team Name	Design	Construction	Function	Creativity	Durability	Design Total
Comments:						
Comments:						
Comments:						
Comments:						
Comments:						

Solar Cook-off ~ Solar Chef Score Sheet

Suitability: How well does the team's prepared recipe fit the capabilities of their cooker design? Was the team able to prepare it easily? Did the team finish cooking in a timely manner?
Appeal: How appealing is the team's prepared dish in appearance? In taste?
Difficulty: Was the recipe difficult enough to show the versatility of solar cookers (i.e. not a simple heat and serve?)
Nutrition/Creativity: Does the recipe use a variety of ingredients or techniques? Does the recipe show creativity?

0 1 2 3 4 5 6 7 8 9 10
Poor.....Fair.....Good.....Impressive.....Excellent!

Team Name	Suitability	Appeal	Difficulty	Nutrition/ Creativity	Culinary Total
Comments:					
Comments:					
Comments:					
Comments:					
Comments:					

Engineering Design Challenge - Solar Cook-Off

Florida NGSS Standards & Related Subject Common Core

			.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	.11	.12
Grade 6														
Practice of Science	**# 1**	**SC.6.N.1**				**X**								
Earth Systems & Patterns	**# 7**	**SC.6.E.7**	**X**											
Grade 7														
Forms of Energy	**# 10**	**SC.7.P.10**	**X**	**X**										
Energy Transfer & Transformations	**# 11**	**SC.7.P.11**	**X**	**X**		**X**								

Sixth Grade Benchmarks

Science–Big Idea 1: The Practice of Science

- SC.6.N.1.4 - Discuss, compare, and negotiate methods used, results obtained, and explanations among groups of students conducting the same investigation.

Science–Big Idea 7: Earth Systems and Patterns

- SC.6.E.7.1 - Differentiate among radiation, conduction, and convection, the three mechanisms by which heat is transferred through Earth's system.

Seventh Grade Benchmarks

Science–Big Idea 10: Forms of Energy

- SC.7.P.10.1 - Illustrate that the Sun's energy arrives as radiation with a wide range of wavelengths, including infrared, visible, and ultraviolet, and that white light is made up of a spectrum of many different colors.
- SC.7.P.10.2 - Observe and explain that light can be reflected, refracted, and/or absorbed.

Science–Big Idea 11: Energy Transfer and Transformations

- SC.7.P.11.1 - Recognize that adding heat to or removing heat from a system may result in a temperature change and possibly a change of state.
- SC.7.P.11.2 - Investigate and describe the transformation of energy from one form to another.
- SC.7.P.11.4 - Observe and describe that heat flows in predictable ways, moving from warmer objects to cooler ones until they reach the same temperature.

National Next Generation Science Standards - Sixth to Eighth Grade Standards

Science–Energy

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

Science–Engineering

- MS-ETS1-1 - Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 - Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-ETS1-3 - Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Engineering Challenge - Solar Cook-Off

Planning Day

1. What type of cooker did your team decide to construct?

2. Why did you pick this cooker design?

3. Where did get the idea for this cooker?

4. If you are using a printed cooker template (or plan), explain how you are modifying it to make it your own design.

5. Sketch below the cooker your team plans to construct. Include measurements and material to be used for each part.

6. List the materials needed (and size needed of each), for your cooker. For materials not available in your class, note where they will be found, recycled from, or purchased.

Construction days

Complete a daily log below. For each day, list the date, what the team did, any problems encountered, and solutions that were tried. Use more pages as necessary.

Date:
What we did today:

Problems encountered:

Solutions tried:

- -

Date:
What we did today:

Problems encountered:

Solutions tried:

- -

Date:
What we did today:

Problems encountered:

Solutions tried:

- -

Date:
What we did today:

Problems encountered:

Solutions tried:

- -

Date:
What we did today:

Problems encountered:

Solutions tried:

- -

Cooker Testing

Test to see if your cooker is able to get 75 mL of water to boil, and if so, how long it takes for it to reach boiling temperature.

To perform the test, put 75 mL of water in a small beaker or jar. Insert a thermometer in the beaker, and cover the top tightly with a piece of high temperature cooking bag plastic, held in place with a rubber band. Place the water container in your cooker the way you will place your food when cooking. For example, if you have a panel cooker, you should place the thermometer/jar apparatus inside a cooking bag, and for a parabolic, you should place it in a pan.

1. What are the weather conditions (amount of sunlight)?

2. Take periodic temperature readings.

Time									
Temp.									

3. Did the water boil?

4. If so, how long did it take to boil?

5. If the water did not boil, why do you think it did not boil?

6. What can you do to your cooker to improve it, so that it can reach a temperature that will boil water, or reach that temperature in less time?

Recipe Selection

1. What recipe is your team planning to make using your cooker?

2. Where did you get this recipe (for example, family, recipe book, internet, etc)

3. How will you modify the recipe for cooking with solar?