RUWANKA PURASINGHE

Pasteurizing Water to Become a Great Engineer

STEM Lesson Plan for Grades 6-8

Helping all students, especially girls, to be interested in engineering as a possible future can be challenging. Research suggests that role models are important for helping students to see themselves in a jobs where they have been underrepresented. In addition, having challenging and fun engineering experiences help students to want to become engineers.

Many engineering projects though are focused on competitions, but that isn’t the essence of engineering. The cycle of determining a problem, identifying what’s needed to solve the problem, trying and testing possible solutions, and optimizing and iterating to find an adequate solution is what makes an engineering project.

In this lesson plan, students will watch a video where Ruwanka Purasinghe explains how she became a successful engineer. After figuring out what she says are some key factors to being a great engineer, they will try to develop a way to pasteurize water using solar power alone. Finally, they will look back at their work habits to determine how closely they matched skills that the engineer suggested were important.

NGSS Standards
CCC: Structure and Function
ETS1.A: Defining and Delimiting Engineering Problems
ETS1.B: Developing Possible Solutions
ETS1.C: Optimizing the Design Solution

Part I: Watching the Ruwanka Purasinghe Video

Before the students watch the video, the teacher should explain that in this video an engineer will explain what makes her a successful engineer. The teacher should ask students to record what personality traits, desires, and behaviors are important to becoming an engineer.

For younger students, you may need to use sentence starters like

Ruwanka Purasinghe said that she had to overcome the obstacles of _________
Ruwanka Purasinghe said that she wants to _______

The video has on-screen icons that will help students when she is saying key components of her success. For some students, pausing the video at those moments will help them better record what is going on.

In small groups have the students summarize what they saw and then make sure that the entire class has all of the points. While they may have more than these, they should at least note:

- Ruwanka Purasinghe succeeded as an engineer because she was put on the right career track.
- Ruwanka Purasinghe loves engineering because she gets to be creative.
- Ruwanka Purasinghe succeeded as an engineer because of teamwork.

Making a Great Engineer Checklist

Students now should now make a checklist of things for themselves to do if they want to be a good engineer. Then when they do something on the checklist, they should mark it off. For example

Activity	
I helped someone	𝍸 I
I didn't give up when something didn't go the way I planned	𝍸 III

Students will use this checklist several times in the following projects. Don’t assign points or give too much praise, otherwise students will just game the system. We just want them noting when they are doing something a good engineer does, helping them to internalize that they can be an engineer. Alternatively, you can make it the task of one of the members of the group to note when their groupmates are being good engineers.

Part II: Engineering Cycle

Sufficient clean water is essential to survival, but it isn’t available to everyone, especially in a crisis. While water can be contaminated with many things to make it undrinkable, in some situations, the biggest problem is biological contamination from bacteria, viruses, and protozoa. Although many methods exist to fight them, in some circumstances, simple heating can be the best approach.

In this engineering challenge, students will build a solar water pasteurizer. Using the power of the sun, they will develop a system that can heat one liter of water to 75 degrees Celsius for at least six minutes. Students will be given a design to start, but then will work on an improvement of their own devising.

Warning: Solar ovens can heat materials hot enough to burn. Only handle the jar with heat protecting gloves or mitts.

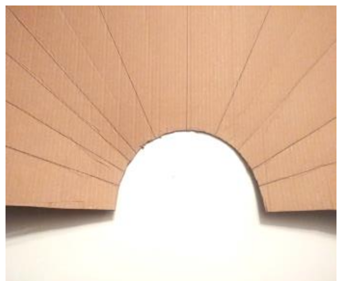
Materials

- Poster board or other cardboard at least 18 in x 36 in
- Scissors
- Straightedge
- Cardboard banker’s box
- Glue
- Aluminum foil or Mylar
- 2 large binder clips
- Wooden or polystyrene (Styrofoam) block approximately 1.5 in x 3.5 in x 3.5 in
- Pint Mason jar painted black
- Clear heat-resistant bag
- 10 d or similar nail and hammer
- Probe thermometer or other thermometer that can be submerged
- Oven mitts

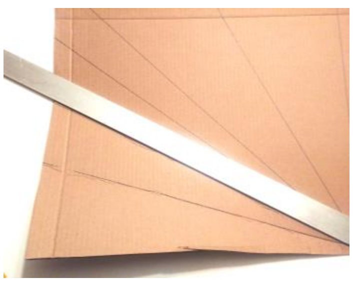
Construction

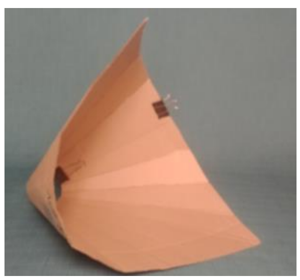
1. Draw 11 or so diagonal lines from the center of the four foot edge radially to the far side of the 18 in x 36 in rectangular piece of cardboard.

2. Draw and cut a semi-circle along the four foot edge of the piece of cardboard. The cardboard is going to be to bent into a funnel. When folded the hole's diameter will be approximately half the size as when it is cut. So, for a hole that has a diameter of six inches when folded, cut a hole that is 12 inches in diameter.



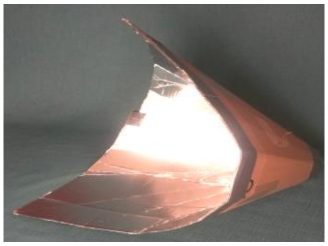
3. Gently fold along the diagonal lines to help give the cardboard a funnel shape. Pull into a funnel to make sure of the fit. Flatten the board back down.





4. Glue aluminum to the surface of the cardboard, shiny-side up. Overlap edges. Try to keep the foil as smooth as possible. Some small bumps are not a problem.

5. Twist the cardboard into a funnel shape. The two short sides will overlap by about an inch or so. Use binder clips to hold in place.

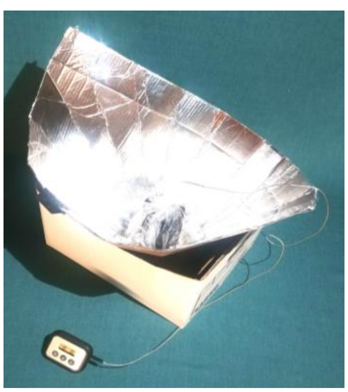


6. Punch a hole in the lid of the Mason jar with a nail. Expand as necessary until a thermometer fits through the hole.

7. Place the wooden block in the bottom of the oven bag. Fill the Mason jar with 500 mL of water. Screw on the cap and insert the thermometer. Put Mason jar in the bag and gather the opening around the probe wire. Tie closed.

8. Place funnel in the banker's box. Put the jar in the center. Put the box in the sun and point the funnel towards the sun. On a warm day in April or May (in the Northern Hemisphere) near solar noon, the funnel should be able to pasteurize a pint of water in under 30 minutes.



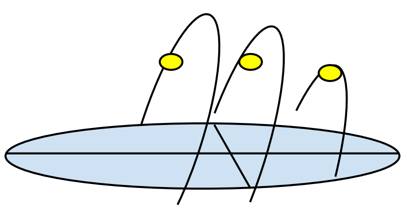
9. Use oven mitts to handle the jar after it is hot.

How Does the Solar Oven Work

The funnel reflects sunlight so that it mostly hits the jar. While a parabolic reflector is able to concentrate sunlight to a small point, constructing one would be much more difficult and parabolic mirrors are less stable. Also, the light doesn't need to be concentrated to a small point, it only needs to be concentrated enough to hit the jar. The amount of solar energy available depends on the time of day, with more energy available when the sun is directly overhead (solar noon). Similarly, the sun is more overhead closer to the summer solstice. Low exterior temperatures can steal heat away from the jar, causing it to heat more slowly. So that students can make good comparisons between designs, they will need to record the date, time, and external temperature of each run.

Nearer the winter solstice and nearer to sunrise or sunset, students will need to aim the funnel closer to the horizon. The edge of the banker's box can be propped up with a book or two, or the side of the box can be cut down.

The sun's position in the sky changes over time the day. Students should watch to make sure the light continues to be reflected onto the jar. For longer cooks, they may need to adjust the orientation to keep the greatest reflection of sunlight on the jar.



The jar is painted black to absorb more of the visible light from the sun. It's worth noting, though, that about half of the incident solar energy is in the infrared part of the spectrum. Water strongly absorbs infrared light, so the painting is only to improve the visible light absorption. Wind blowing across the jar can steal heat away. Even on a relatively calm day, the hot jar can move air around and help to cool its surface. The plastic bag reduces these convective heat losses by interrupting air flow. Plastic waste, however, is a concern for some people. and the surface of the bag itself reflects a few percent of the total sunlight. Students may want to try their experiments without the bag to see if it is really valuable.

Engineering Cycle

For the first trial, have students record the initial temperature of the water. Bring the box outside and have the students place it in direct sunlight. Aim the funnel so that it faces the sun. Record the temperature of the water at 5 minute intervals. Water that stays above 75 degrees C for six minutes has been pasteurized. That is, nearly all the unsafe biological organisms have been killed or inactivated. For much of the world biological contaminants are the biggest problem, but since this process doesn't remove poisonous substances like lead or arsenic, it won't make all water safe to drink. On a warm sunny day at 30 degrees latitude in April or September near noon, pasteurizing 500 mL of water takes about 30 minutes or less.

Allow students to make adjustments to their design until they are able to pasteurize water in a reasonable time. Common mistakes include not attaching the aluminum foil smoothly and not aiming the funnel towards the sun.

Selecting a New Goal

After students can make the solar oven work, they should try to make it better. Maybe they want to

- Pasteurize water faster
- Pasteurize a greater amount of water
- Cook pasta, rice, or potatoes
- Make a hand warmer
- Have easier construction or easier to set up and break down
- Or something else

Have each group select a goal for their work. Each goal has different considerations. For example, pasteurizing water faster or in a greater amount might mean needing to increase the size of the funnel. A bigger funnel may require a studier set up. Cooking food may require research into cooking temperatures and times, especially for cooking food at less than boiling. For example, pasta only needs to reach 180 F to be fully cooked. Many foods take longer to cook at lower temperatures but will cook fine. Other foods can be soaked first at room temperature and then cooked for a shorter time. Hand warmers generally need materials that release their heat slowly. The internet can helpful, but teachers may need to help students evaluate information to make sure that it is accurate.

After each group has settled on a particular goal, help the students to settle on a reasonable measure to see if the goal is successful. For example, instead of pasteurizing 500 mL of water in 30 minutes, can the group heat 750 mL?

Help students to understand that this is the engineering process. Engineering uses a cycle of

- determining a problem
- identifying what's needed to solve the problem
- trying and testing possible solutions
- optimizing
- iterating

For many of these projects, it will take several iterations to achieve their goal. Careful notes will help students sort through problems to find solutions.If time is available, you can have students set additional goals and work towards them as well.

While many teachers would be inclined to assign a single task for the class, letting each group set its own goal has many advantages. Students tend to be more invested in the design and work harder. Groups don't just copy the work of other groups. Voices that are less often heard get a chance to shine.

The groups to work on their projects to get them functioning as they'd like. Once they can get them to work, have them repeat the project to try to minimize the amount of materials used. Optimizing so that the cost of project is lower is key part of engineering.

Some ideas may end up being impossible. Trying to pasteurize 2000 mL of water in 15 minutes isn't going to happen. The struggle can still be worthwhile, and sometimes you may be surprised by what students will come up with. Have students keep track of what they have done so that their classmates can over suggestions if they get stuck.

Part III: Evaluation

While many kinds of assessment work, the students and the teacher should assess how well they improved their solar oven. You could write an assessment that offers possible changes and asks students to predict how that will improve or hurt the heating.

In addition, each group should report out on how well they worked together. Having the students briefly present their work to their classmates tends to give the best opportunity to figure out what happened in their group. They should explain

- What their problem/goal was
- What they tried
- Whether or not it was successful
- How they could tell if it was working
- What they did if they didn't all agree on what to do
- How often did they get to put a mark on their checklists

References

The solar funnel is based on the work of Steven E. Jones, Professor of Physics at Brigham Young University (BYU), with Colter Paulson, Jason Chesley, Jacob Fugal, Derek Hullinger, Jamie Winterton, Jeannette Lawler, and Seth, David, Nathan, and Danelle Jones.

Additional resources can be found at http://solarcooking.org/plans/funnel.htm

A similar design can be found at http://solarcooking.wikia.com/wiki/Fun-Panel along with many ideas at http://solarcooking.wikia.com.