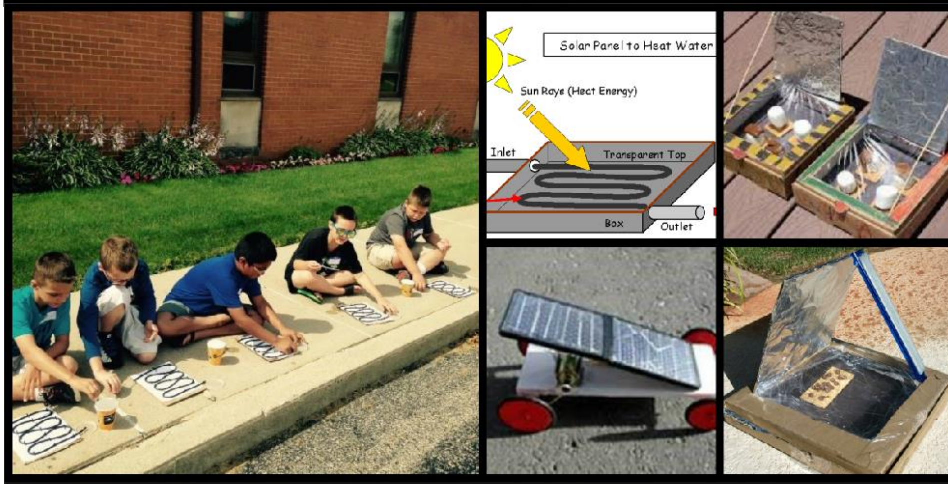
DESIGNING A SOLAR WATER HEATER

Fifth Grade - Earth Science



PURPOSE

IN *DESIGNING A SOLAR WATER HEATER CHALLENGE*, STUDENTS WILL:

- Plan and design a solar water heater as an alternative energy source to solve a real-world problem using the Engineering Design Process (EDP)
- Apply background knowledge of scientific principles about solar radiation
- Exhibit understanding of relevant science content/concepts
- Construct relevant questions
- Determine effectiveness of their design
- Answer the Focus Question.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Performance Expectations

- 5-ESS3-1 Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

Science and Engineering Practices (SEP):

- Asking questions and defining problems in 3–5 builds on K–2 experiences and progresses to specifying qualitative relationships. (SEP-1)
    - Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.
    - Use prior knowledge to describe problems that can be solved.
    - Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.

- Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions. (SEP-2)
    - Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events.
    - Develop and/or use models to describe and/or predict phenomena.
    - Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.

- Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions. (SEP-3)
    - Make predictions about what would happen if a variable changes.
    - Test two different models of the same proposed object, tool, or process to determine which better meets criteria for success.

- Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used. (SEP-4)

    - Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
    - Analyze data to refine a problem statement or the design of a proposed object, tool, or process.
    - Use data to evaluate and refine design solutions.

- Mathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions. (SEP-5)

    - Organize simple data sets to reveal patterns that suggest relationships.
    - Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems.

- Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems. (SEP-6)

    - Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
    - Apply scientific ideas to solve design problems.

Cross Cutting Concepts (CCC)

- Cause and Effect (CCC-2)
    - Students routinely identify and test causal relationships and use these relationships to explain change. They understand events that occur together with regularity might or might not signify a cause and effect relationship.

- Scale, Proportion, and Quantity (CCC-3)
    - Students recognize natural objects and observable phenomena exist from the very small to the immensely large. They use standard units to measure

and describe physical quantities such as weight, time, temperature, and volume.

CA COMMON CORE STANDARDS CONNECTIONS

- **English Language Arts / Literacy Connections:**
  - RI.5.7 Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.
  - W.5.8 Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources.
  - SL.5.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 5 topics* and *texts,* building on others' ideas and expressing their own clearly.

CA ENGLISH LANGUAGE DEVELOPMENT CONNECTIONS

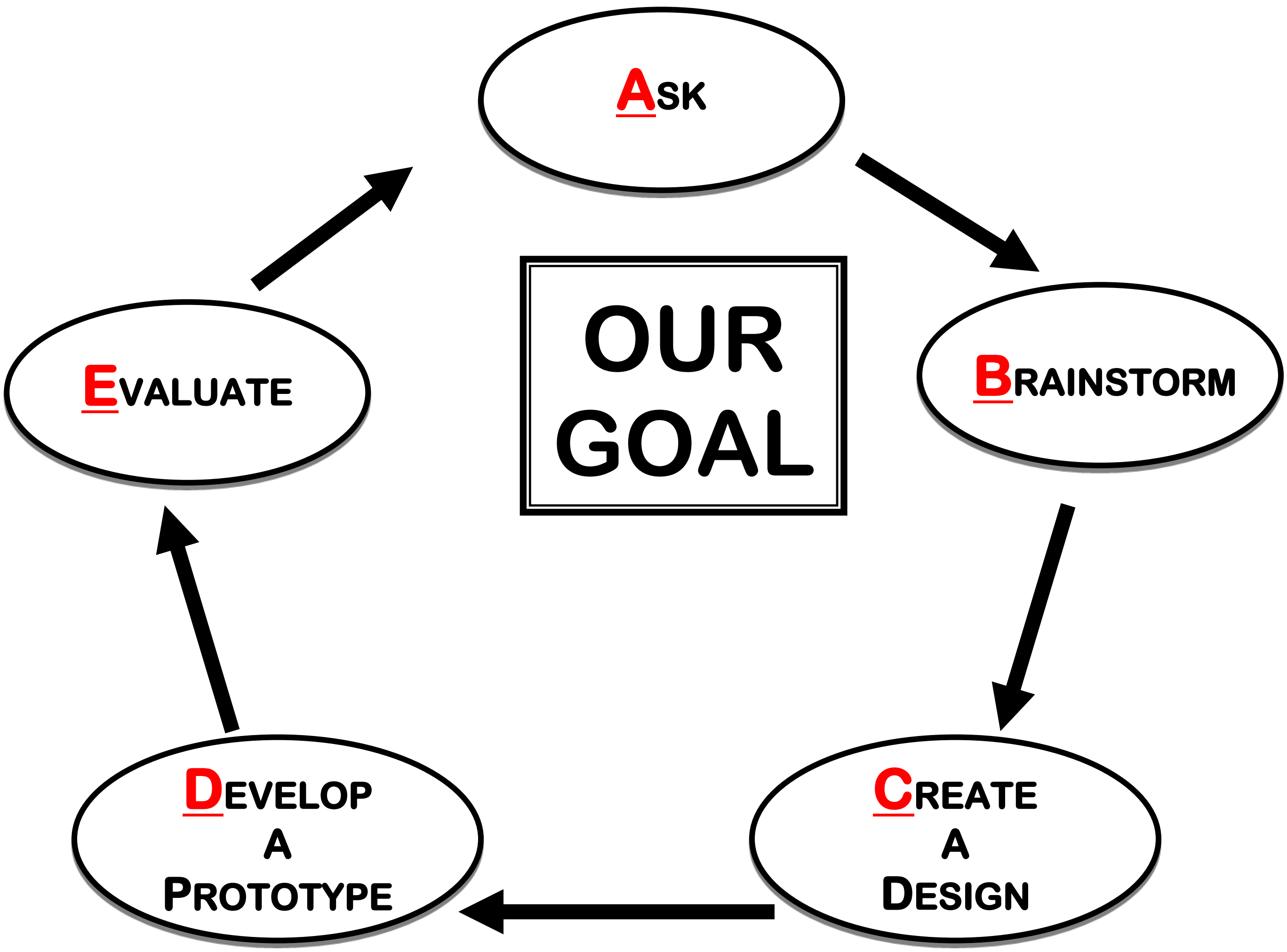
- P1.5.A.1 Exchanging information and ideas with others through oral collaborative discussions on a range of social and academic topics
- P1.5.A.3 Offering and supporting opinions and negotiating with others in communicative exchanges.
- P1.5.B.5 Listening actively to spoken English in a range of social and academic contexts.
- P1.5.C.11 Supporting own opinions and evaluating others' opinions in speaking and writing

BACKGROUND FOR THE TEACHER

You may teach this lesson once students have completed:

FOSS CA – WATER PLANET
Investigation 3: ***Water Vapor (Parts 1-4)***
Investigation 4: ***Heating Earth (Parts 1-3)***

THE ENGINEERING DESIGN PROCESS (EDP)



ENGINEERING DESIGN PROCESS (EDP)

ASK

- What is the **problem** or **need**?
- What is already out there?
- What are the **requirements (criteria)** and **restrictions (constraints)**?

BRAINSTORM

- What are possible **solutions**?
- Choose your two best solutions.

CREATE - A - DESIGN

- **Draw** a diagram with labels.
- Have a critical design review (peer review & input).
- What materials are available?

DEVELOP - A - PROTOTYPE

- Follow your best diagram and **build** a Prototype.
- **Test** the prototype!

EVALUATE

- **Improve** your prototype!
- Conduct more compatibility tests.

MATERIALS

FOR EACH STUDENT

- Engineering Design Notebook
- "Puerto Rico struggles with massive environmental crisis," *Boston Globe* article (see next page)

FOR THE LESSON

- Engineering Design Process chart
- 2 pitchers* of water set out at room temperature

FOR EACH TEAM

- Chart paper & marker for team consensus model
- 1/2 - liter container*
- 1/4 - liter container*
- 1 container lid with slit*
- Different size containers found in other FOSS kits
- 1 thermometer, Celsius*
- 50-mL syringe*
- 1 cardboard sheet*
- trash bags (white and black)
- foil
- black construction paper
- tape
- rubber bands
- timer or stopwatch
- other insulation materials (e.g. plastic, paper, foam, felt)

**Materials found in FOSS CA Water Planet*

***Optional teacher provided materials to further challenge: larger containers, 2-liter bottles, soda cans, aquarium tubing, plastic tubing, plastic wrap, straws, paper towels, and / or black paint.*

Puerto Rico struggles with massive environmental crisis

ASSOCIATED PRESS
OCTOBER 17, 2017

CAGUAS, Puerto Rico — Raw sewage is pouring into the rivers and reservoirs of Puerto Rico in the aftermath of Hurricane Maria. People without running water bathe and wash their clothes in contaminated streams, and some islanders have been drinking water from condemned wells.

Nearly a month after the hurricane made landfall, Puerto Rico is just beginning to come to grips with a massive environmental emergency that has no clear end in sight.

“I think this will be the most challenging environmental response after a hurricane that our country has ever seen,” said Judith Enck, who served as administrator of the US Environmental Protection Agency region that includes Puerto Rico under President Barack Obama.

With hundreds of thousands of people still without running water, and 20 of the island’s 51 sewage treatment plants out of service, there are growing concerns about contamination and disease.

“People in the US can’t comprehend the scale and scope of what’s needed,” said Drew Koslow, an ecologist with the nonprofit Ridge to Reefs who recently spent a week in Puerto Rico.

Puerto Rico has a long history of industrial pollution, and environmental problems have worsened due to neglect during a decade-long economic crisis. A dozen overpacked landfills remain open despite EPA orders to close them because local governments say they don’t have the money.

Twelve days after Maria made landfall, less than 20 percent of the island’s power grid was back online. Officials say running water has been restored to 72 percent of the island’s people. The water authority says it’s safe to drink, though the health department still recommends boiling or disinfecting it.

GETTING READY

1. **Schedule the Investigation**
    - This challenge will take about 3-5, 45-minute sessions
    - Choose an appropriate time and place to test design. Solar water heaters work best outdoors in full, direct sunlight. Check the weather forecast for the next 7 days. This lesson will work best during sunny days in the fall and late spring.

2. **Gather/Obtain Materials**

3. **Prepare Materials**
    - The day before testing, set out at pitchers of water and let them sit at room temperature to equilibrate. On testing day, pour into 1/2-liter containers and distribute to each group.
    - Photocopy article, "Puerto Rico struggles with massive environmental crisis."

4. **Plan Teams**

5. **Focus Question**

    "How does our understanding of solar radiation (sunlight) help us solve real world problems?"

GUIDING THE ACTIVITY

Students will engage in the Engineering Design Process (EDP).

1. Setting the Context

Engineering Design Process

"The citizens of Puerto Rico have just experienced a major natural disaster, Hurricane Maria, that has destroyed much of their infrastructure, access to resources, and landscape. Let's watch a video to identify some of the problems the people of Puerto Rico are faced with in the aftermath of the hurricane. Record any thoughts or ideas in your Engineering Design Notebook."

Show video clip. https://www.youtube.com/watch?v=d1KeP7MFikY

Encourage students to make observations and identify all problems noted in clip. The video can be watched multiple times. After allowing individual thinking time, *ask...*

> *"What observations did you make while watching this video clip?"*
> *"What problems are the citizens of Puerto Rico faced with?"*
> *"Are there any other thoughts or ideas you would like to share?"*

Chart all responses. Student responses may include that they observed destruction of homes, damaged roadways, plant material in streets, and gas station closure/limited access to gasoline.

Continue setting the context. While it is apparent that there are many problems and challenges the people of Puerto Rico face, guide students toward the water problem. Display an excerpt of the following news article from the Boston Globe, reported by the Associated Press. Distribute and provide time for students to read article in its entirety:

> "Officials say running water has been restored to 72 percent of the island's people. The water authority says it's safe to drink, though the health department still recommends boiling or disinfecting it." -*Associated Press, October 17, 2017*

Focus on the fact that 72% of the population has access to water. So while we can't solve all of their problems, we may be able to develop some possible solutions to the water problem.

Emphasize that the water could be safe to drink although the health department still recommends boiling or disinfecting it. Students can turn and talk to a partner about ways they could heat the water.

2. ASK

Present Problem or Need

- Display the Focus Question and have students write it in their Engineering Design Notebooks

  "How does our understanding of solar radiation (sunlight) *help us solve real world problems?"*

- Have students record the focus question in their Engineering Notebook.

  Ask, ***"How can we use what we have learned about solar radiation to help us solve the problem of not having safe drinking water?"***

- Allow time for students to discuss and then present challenge.

  Challenge: Design a basic solar water heater for the people of Puerto Rico who will be living without electricity and gas as they work to rebuild their infrastructure.

  Allow time for students to ask questions before setting criteria and constraints.

3. Present Requirements and Restrictions

- Requirements (Criteria):
  - The solar water heater must increase the temperature of 100 mL of water by 10 degrees Celsius.
  - Solar energy is the only heat source.
  - Students must work collaboratively to develop the solar water heater.
  - Keep careful data collection in order to replicate design for the people of Puerto Rico.
  - Water will be stored in the 1/4-liter container and must be integrated into design.

- Restrictions (Constraints):
  - Solar water heater design can only be constructed using only the materials provided (not all materials have to be used)
  - Time
  - Solar energy can be the only heat source.
  - Cardboard sheet is not to be used in the design, but rather as place to rest the solar heater on when testing outdoors.
  - You must keep the slit to the container lid accessible in order to be able to insert the thermometer for temperature reading and data collection.

4. BRAINSTORM

- Activate prior knowledge from previous investigations that would help in students' design process.
- Provide opportunities for students to discuss. Review available materials.
- Students can test materials outside to see which heat up in the sun.

As you facilitate the process, prompting questions may include:
- What *materials could make good conductors of heat?*
- *What do you already know about solar radiation?*
- *How can you imagine the materials being used to help you create a solar heater?*

5. CREATE - A – DESIGN

Students individually record ideas and create model designs in their Engineering Design Notebook. Students will use this time to create and record a solar water heater design in their notebooks. After allowing for independent design time, students share ideas with their team and work together to create a consensus model.

As you facilitate the process, prompting questions may include:

- *How are the materials being used in your design?*
- *How will others be able to replicate your design?*
- *How are you meeting the criteria?*
- *How are all of the team member's ideas reflected in the consensus model?*

6. DEVELOP - A – PROTOTYPE

Materials can be distributed to teams or set-up at a materials station for students to gather as needed. Allow time for construction of solar heater and schedule a day and time to test. Note, the container lid with slit can be used in the design but the slit must remain uncovered.

As you facilitate the process, prompting questions may include:

- *Can you describe how the materials you selected will help you heat water?*
- *How are you selecting/testing materials?*
- *How will you know that you were successful in creating a solar water heater that heats water?*
- *How are you recording your design process?*
- *How are you collaborating/sharing the team responsibility?*
- *How does your process reflect each team members' ideas?*

Once teams are ready to test their solar water heaters, guide them to your designated testing area. 100 mL of water will need to be placed in their solar water heater and initial water temperature recorded prior to going outside.

Container lids with slits can be placed on top and thermometers inserted into the slit. Once outside, teams will place their solar water heater in full, direct sunlight on top of the cardboard sheet for 15 minutes. After 15 minutes, teams will record the ending temperature of the water within their solar water heater design.

7. EVALUATE

After testing, take to time to collect and record each team's data. This is a great opportunity to take a gallery walk to allow for observation and analysis of each team's prototype and consensus model. When ready, redirect students to a discussion on the Engineering Design Process and challenge.

As you facilitate the process, prompting questions may include:

- *What were successes?*
- *Were the criteria met? If not all, what parts of the criteria were met?*
- *What did you find challenging?*
- *How did you problem-solve or work around that challenge?*

- *How might the material used change the outcome?*
- *Did some materials heat up faster? Which ones? Why?*
- *How did you use solar radiation (sunlight) to help solve a real-world problem?*
- *Can you describe the science behind this challenge?*

- *What commonalities/differences did you notice about each teams' approach to creating a solar heater?*
- *What do you like about a team's design? How did they meet the criteria?*
- *How would you improve a teams' design?*
- *How would you measure the success of working through this design challenge?*
- *How would you measure the success of team collaboration?*

Redesign opportunity:

- *How can we improve our design?*
- *Do we need to adjust or improve any aspect of the model designed in order to use it on a larger scale, i.e. in Puerto Rico?*

Notebooking Opportunity:

- *Students* can answer focus question in Engineering Design Notebook.

Student Name:
Date:
Engineering Team:

Solar Water Heater
Engineering Design Challenge Rubric

	4	3	2	1
Asking Questions and Defining Problems	Student asked questions and used knowledge to brainstorm clear and focused ideas. Student demonstrated a high level of understanding of the problem that needed to be solved noting criteria for a successful solution and identification of constraints.	Student asked questions and used knowledge to brainstorm clear and focused ideas. Student demonstrated an understanding of the problem that needed to be solved noting criteria for a successful solution and identification of constraints.	Student asked some questions and used knowledge to brainstorm ideas that were somewhat focused. Student demonstrated some understanding of the problem that needed to be solved.	Student asked limited questions and were limited in their ability to brainstorm ideas. Student demonstrated limited understanding of the problem that needed to be solved.
Developing and Using Models	Team developed a prototype & tested their model. There was a high level of success in creating a solar water heater that increased the temperature of water by 10 degrees Celsius. Design ideas were improved and retested using appropriate tools.	Team developed a prototype & tested their model. There was a success in creating a solar water heater that increased the temperature of water by 10 degrees Celsius. Design ideas were improved and retested using appropriate tools.	Team developed a prototype & tested their model. There was some success in creating a solar water heater and evidence of a temperature increase. There may have been some attempt to redesign and retest using appropriate tools.	Team was limited in their ability to develop a prototype that could be tested. An attempt was made to create a solar water heater but model is incomplete.
Collaboration	Team shared ideas and worked productively in their group to a high degree. All members listened to, interpreted, and used information provided by others in their design process.	Team shared ideas and worked productively in their group. Members listened to, interpreted, and used information provided by others in their design process.	Team shared some ideas and worked with their group. Members needed direction in order to listen, interpret, and figure out how to use information provided by others in their design process.	Team shared few ideas and only worked in group with teacher guidance. Few ideas were used in their design process as members needed a high level of support in being able to listen and interpret information shared by others.