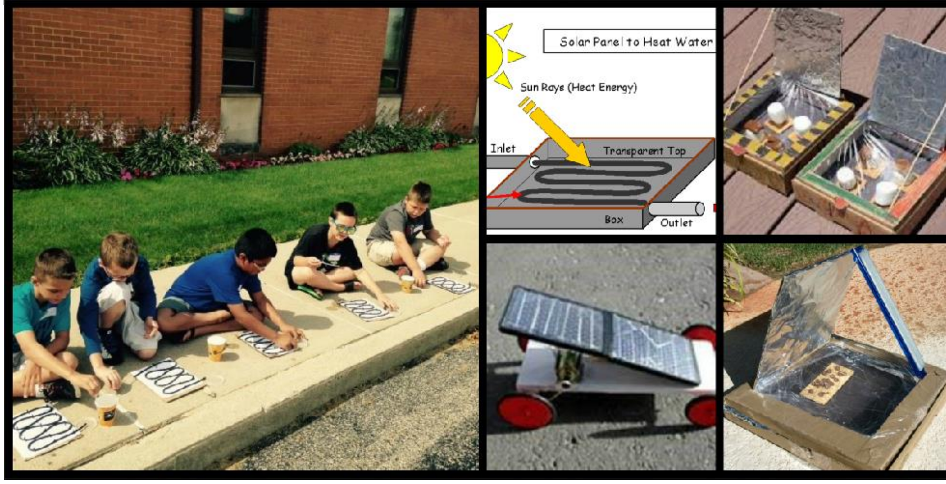
LAUSD
Elementary Engineering

DESIGNING A SOLAR WATER HEATER

Fifth Grade - Earth Science



PURPOSE

IN DESIGNING A SOLAR WATER HEATER CHALLENGE, STUDENTS WILL:

- Plan, design, and create a solar water heater
- Exhibit understanding of relevant science content/concepts
- Construct relevant questions
- Use appropriate materials provided to complete their task
- Determine effectiveness of their design
- Answer the Focus Question: <u>How can we use the engineering design process to create and design a solar water heater?</u>

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Students who demonstrate understanding can:

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

The performance expectation above was developed using the following elements from the NRC document *A Framework for K- 12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to evaluating the merit and accuracy of ideas and methods. • Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem.	**ESS3.C: Human Impacts on Earth Systems** • Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.	**Systems and System Models** • A system can be described in terms of its components and their interactions. - *Connections to Nature of Science* **Science Addresses Questions About the Natural and Material World.** • Science findings are limited to questions that can be answered with empirical evidence.

Connections to other DCIs in fifth grade: N/A

Articulation of DCIs across grade-levels:
MS.ESS3.A ; **MS.ESS3.C** ; **MS.ESS3.D**

Common Core State Standards Connections:
ELA/Literacy -

RI.5.1 Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text. *(5-ESS3-1)*
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. (5-ESS3-1)
RI.5.9 Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. (5-ESS3-1)
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. (5-ESS3-1)
W.5.9 Draw evidence from literary or informational texts to support analysis, reflection, and research. *(5-ESS3-1)*

Mathematics -

MP.2 Reason abstractly and quantitatively. *(5-ESS3-1)*
MP.4 Model with mathematics. *(5-ESS3-1)*

3-5-ETS1 Engineering Design

3-5-ETS1 Engineering Design

Students who demonstrate understanding can:

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems Asking questions and defining problems in 3–5 builds on grades K–2 experiences and progresses to specifying qualitative relationships. ▪ 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. (3-5-ETS1-1) **Planning and Carrying Out Investigations** 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. ▪ Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (3-5-ETS1-3) **Constructing Explanations and Designing Solutions** 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. ▪ Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem. (3-5-ETS1-2)	**ETS1.A: Defining and Delimiting Engineering Problems** ▪ Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5-ETS1-1) **ETS1.B: Developing Possible Solutions** ▪ Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. (3-5-ETS1-2) ▪ At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (3-5-ETS1-2) ▪ Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3) **ETS1.C: Optimizing the Design Solution** ▪ Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3)	**Influence of Engineering, Technology, and Science on Society and the Natural World** ▪ People's needs and wants change over time, as do their demands for new and improved technologies. (3-5-ETS1-1) ▪ Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. (3-5-ETS1-2)

Connections to 3-5-ETS1.A: Defining and Delimiting Engineering Problems include:
Fourth Grade: 4-PS3-4
Connections to 3-5-ETS1.B: Designing Solutions to Engineering Problems include:
Fourth Grade: 4-ESS3-2
Connections to 3-5-ETS1.C: Optimizing the Design Solution include:
Fourth Grade: 4-PS4-3

Articulation of DCIs across grade-bands: **K-2.ETS1.A** (3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3); **K-2.ETS1.B** (3-5-ETS1-2); **K-2.ETS1.C** (3-5-ETS1-2),(3-5-ETS1-3); **MS.ETS1.A** (3-5-ETS1-1); **MS.ETS1.B** (3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3); **MS.ETS1.C** (3-5-ETS1-2),(3-5-ETS1-3)

Common Core State Standards Connections:

ELA/Literacy –

RI.5.1 Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text. *(3-5-ETS1-2)*
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. *(3-5-ETS1-2)*
RI.5.9 Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. (3-5-ETS1-2)
W.5.7 Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. (3-5-ETS1-1),(3-5-ETS1-3)
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. *(3-5-ETS1-1),(3-5-ETS1-3)*
W.5.9 Draw evidence from literary or informational texts to support analysis, reflection, and research. *(3-5-ETS1-1),(3-5-ETS1-3)*

Mathematics –

MP.2 Reason abstractly and quantitatively. *(3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3)*
MP.4 Model with mathematics. *(3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3)*
MP.5 Use appropriate tools strategically. *(3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3)*
3-5.OA Operations and Algebraic Thinking *(3-5-ETS1-1),(3-5-ETS1-2)*

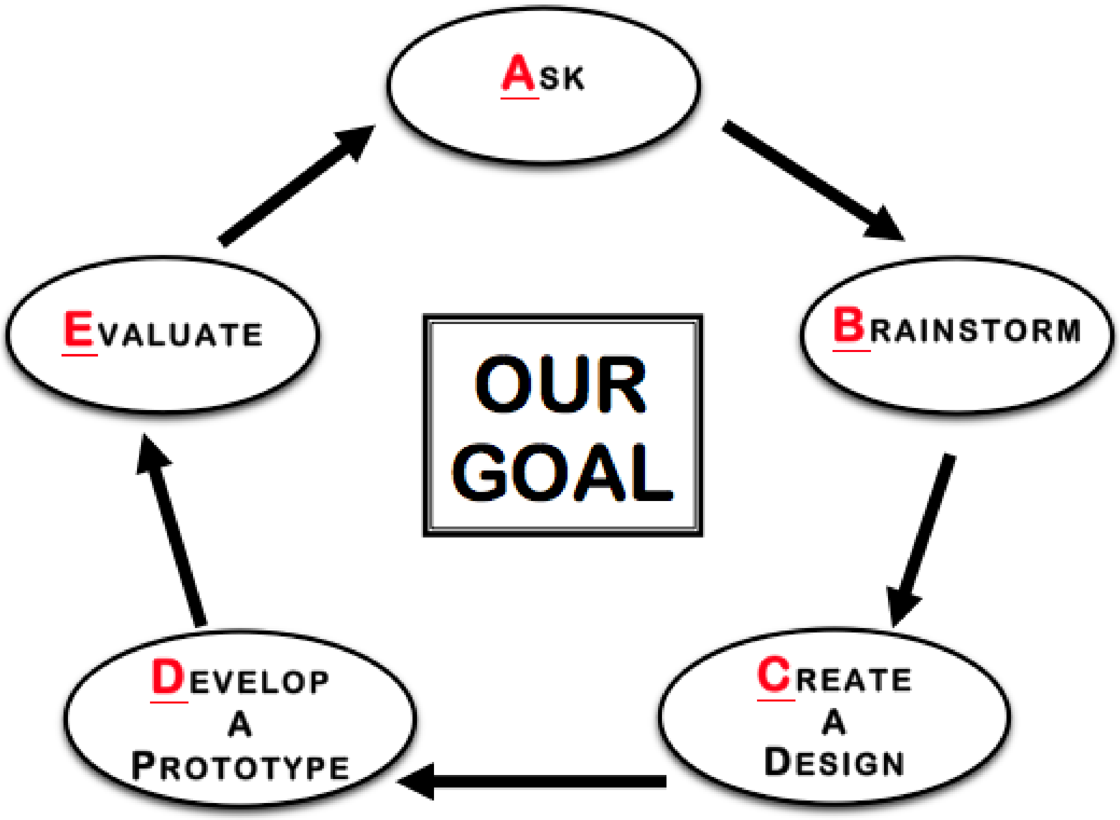
CA ENGLISH LANGUAGE DEVELOPMENT CONNECTIONS

- **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.2** Interacting with others in written English in various communicative forms (print, communicative technology, and multimedia)
- **P1.5.A.3** Offering and supporting opinions and negotiating with others in communicative exchange

SPECIAL EDUCATION (SPED):

To make accommodations or modifications for students with special needs, provide simple directions, instructions, provide multiple opportunities for repetition, make frequent checks for understanding, use visuals to accompany all vocabulary, simplify questions, be specific with sequence and steps, provide opportunity for paraphrasing, and adjust time and pacing.

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.

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)***

MATERIALS

FOR EACH TEAM

- Chart paper & marker for team consensus model
- 1/2 - liter container
- 1/4 - liter container
- 1 container lid with slit
- 1 thermometer, Celsius
- 50-ml syringe
- 1 cardboard sheet
- Trash bags (white and black, cut into 12 x 12 squares)
- Foil
- Black construction paper
- Tape
- Rubber bands
- Timer or stopwatch

FOR THE LESSON

- Individual student engineering notebooks
- "Puerto Rico Struggles with Massive Environmental Crisis," *Boston Globe* article copies (attached to this lesson)
- 2 pitchers of water set out at room temperature

**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

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 Engineering Challenge**
   The challenge will take 3-5 45-minute sessions to complete.
   Choose an appropriate time and place to test design. Solar water heaters work best outdoors in full, direct sunlight.

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."

GUIDING THE ACTIVITY

Students will engage in the Engineering Design Process (EDP)

1. ASK

Setting Up the Context

- "The citizens of Puerto Rico have just experienced a major natural disaster, Hurricane Maria, which 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 this excerpt of the 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.

Present Problem or Need

- The challenge is to 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.

- Have students record the Focus Question in their engineering notebooks - <u>How can we use the engineering design process to create and design a solar water heater?</u>

- Encourage students to come up with their OWN questions about materials, criteria, and constraints.

Present Requirements and Restrictions

- **Requirements** (Criteria) *standards that must be met; rules/directions that must be followed)*:
  - Students must work in collaborative teams of 3 to 4 members.
  - The solar water heater must increase the temperature of 100 mL of water by 10º Celsius in 15 minutes.
  - Solar energy is the only heat source.
  - Students must 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 the container must be integrated into the design.

- **Restrictions** (Constraints) *limitations that keep something from being the best it could be; may be problems that arise or issues that come up*:
    - Use only materials provided at materials station (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 when testing outdoors
    - The slit to the container lid must be accessible in order to be able to insert the thermometer for temperature reading and data collection

2. BRAINSTORM

- Teams evaluate the available materials and determine their usefulness based on their properties.

- Teams discuss how their previously gained knowledge will help in students' design process.

- 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?*

3. CREATE - A - DESIGN

- Each member must draw a design individually, without team member input, into his/her science notebook.
    - Title the page "My design"

- Students should label the parts of their design..

- Team members share designs with one another, compromise, and collaborate in order to create into a "team design."
  - Title the page "Team design"
  - Team members should label the parts of their design

- 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?*
  - *How are you meeting the criteria?*
  - *How are all of the team member's ideas reflected in the consensus model?*

4. DEVELOP - A - PROTOTYPE

- The "Getters" gather the materials listed on the Team Design from the materials table.

- Teams build according to their plan.

- Test design
  - Once teams are ready to test their solar water heaters, guide them to the designated testing area.
  - 100 mL of water will need to be placed in the 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 place their solar water heater in full, direct sunlight on top of the cardboard sheet for 15 minutes.
  - After 15 minutes, teams record the ending temperature of the water within their solar water heater design.

5. EVALUATE

- After testing, 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
    - Retest revised designs
- As you facilitate the process, prompting questions may include:
    - *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?*

- Students will answer the Focus Question in their notebooks.
    - Sentence frames can be used for scaffolding.
    - Encourage students to include information about both their successes and failures.