Exploring Solar Energy

INTRODUCTION

Students are introduced to a form of renewable energy (solar energy) through game play, including related concepts such as measuring solar energy collection and efficiency.

Through application of scientific principles, students will design, construct, and test a solar oven intended to maximize thermal energy transfer. Through the exploration of these concepts, students will learn:

- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.
- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.
- A solution needs to be tested then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

The project is an engineering design challenge; students are asked to create a unique solar oven to complete a cooking task. This challenge necessitates working through a design thinking framework, from identifying needs to constructing a prototype based on a model, and iterating on their unique designs during testing and feedback phases. For more information on Design Thinking, refer to **Appendix A: Design Thinking**.

STANDARDS

Throughout this lesson, when Next Generation Science Standards (NGSS) are explicitly incorporated into activities, they will be color coded as appropriate: Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models	MS-PS3-3	Energy and Matter
Planning and Carrying Out Investigations		Structure and Function
Analyzing and Interpreting Data		
Using Mathematics and Computational Thinking		
Constructing Explanations and Designing Solutions		
Obtaining, Evaluating, and Communicating Information		

KEYWORDS

Solar energy, renewable energy, non-renewable energy, alternative energy, energy transfer, energy, power, cooking, heat, temperature, solar oven, efficiency, graphing, measurement.

TIME

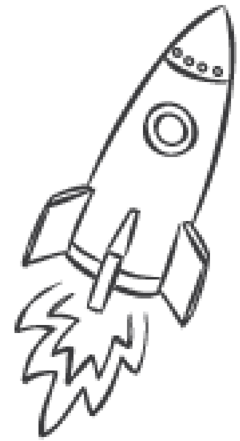
4-5 days

MATERIALS

- Digital access to **Solar Energy Defenders**
- Miscellaneous construction materials for building a solar oven - students can provide additional materials. Examples include:
    - Scissors
    - Tape, glue
    - Cardboard
    - Construction paper
    - Aluminum foil
    - Popsicle sticks
    - Straws
    - Plasticine
    - Styrofoam
- Thermometers (one per student/group)
- Watch or other timing device
- **Appendix B: Exploring Solar Energy Student Workbook**
- **Appendix C: Exploring Solar Energy Project Rubric**

HOW TO DIFFERENTIATE AND ENRICH LEARNING

Knowledge is accessed and built by:



- Watching and listening to videos and presentations
- Discussing and interviewing
- Reading text, articles, and research papers
- Viewing and interpreting images, photos and graphs
- Note taking by writing or voice recording (audio workbook)
- Mind-mapping
- Collecting and tracking real-world data

Knowledge is applied/contextualized, practiced, and understood by:

- Sharing personal stories
- Game play with flexibility for reinforcing/repeat
- Choosing personally relevant research topic or project
- Testing ideas through building, experimenting, and prototyping
- Answering formative (check-in) assessment questions
- Drawing and creating storyboards and diagrams
- Evaluating and incorporating feedback

Knowledge and understanding are demonstrated by:

- Thoughtful reflections and accurate answers in writing or otherwise (journal, test etc)
- Final product uses choice of multi-media (video, website, poster, podcast)
- Creating a product with real-world relevance/applicability
- Creating a product for users/audiences beyond the classroom
- Final product meeting rubric indicators – with student choice for what should be assessed
- Formal oral presentations; participation in campaigns and model displays
- Building model representations for visualizing things that are too small to see
- Collaborating and providing useful/correct feedback to others

Day 1: Introduction & Solar Energy Defenders

On Day 1, students are engaged in the topic of alternative energy by recalling past personal experiences with non-traditional sources of power and energy (e.g., cooking while camping, creating light during a power outage, etc.). This real-world relevance is intended to set the stage for project work later in the lesson. Students will also be asked to access prior learning and knowledge, specifically, concepts from 4-PS3.B (Conservation of Energy and Energy Transfer), in which students learned that light transfers energy from place to place (this will be applied to solar energy) and that energy is present whenever there are moving objects, sound, light, or heat (the presence of solar energy is apparent to students through light and heat from the sun). This introduction to solar energy in theory and in practice will contribute to more sophisticated outcomes at the high school level, including designing a device that works within given constraints to convert one form of energy into another form of energy and calculating energy changes; the activities in this project lay the foundation for these outcomes.

Previous knowledge is shared collectively into a dynamic mind map of concepts and ideas related to energy, which will be visited and expanded upon throughout the lesson. In this way, the mind map becomes a living document of the classes knowledge, both expanding and refining ideas as the lesson progresses.

Day 1 concludes with game play; students access the game **Solar Energy Defenders** on Wonderville.org. This game takes scientific concepts (including maximizing solar energy collection with perpendicular placement of solar panels; understanding how sun angle changes with time of day and the season/time of year; energy measurement in kWh and efficiency) and presents them to students in a fun, engaging manner. The game's purpose is to ward off vampires from the school dance by collecting solar energy during the day, and using this energy to power lasers that can defeat the vampires at night. Games are a powerful tool for student learning and this forms a solid foundation for students before moving into project work. To assess for understanding, students complete the accompanying assessment (found in **Appendix B: Exploring Solar Energy Student Workbook**). It is recommended that teachers review responses to this formative assessment between Day 1 and Day 2, and begin Day 2 with a review of concepts from the game and address misunderstandings apparent in student responses in the assessment. Before beginning project work, it is important that the class understands these game concepts; the assessment can be re-taken and the game played as many times as needed before moving forward.

Components for Day 1:

- **Solar Energy Defenders** (digital game)
- **Appendix B: Exploring Solar Energy Student Workbook**
- **Appendix E: Solar Energy Defenders Assessment Answer Key**

Day 1: Outline

1. Begin by having students share their personal stories with the group: When was a time you were without electricity/power, and needed to cook something? What did you do?
2. Based on student responses, begin to generate a class-wide mind map focused on energy as the central theme, and renewable and non-renewable as two main branches. Revisit this mind map throughout the lesson, adding related concepts and ideas as students add to their knowledge. **Appendix D: Energy mindmap**

Day 1: Outline Continued...

3. Play the Wonderville game **Solar Energy Defenders**
   - Note: Game play states that students need to place solar modules perpendicular to the sun. Recap perpendicular angles if necessary before beginning game play.
4. After game play, to reinforce learning, have students work as individuals or in pairs to complete the assessment found in **Appendix B: Exploring Solar Energy Student Workbook**.
5. Have students share responses and expand upon the energy mind map to reflect new knowledge. Either at the end of Day 1 or at the beginning of Day 2, as a class review the concepts learned during game play as well as student responses on the assessment found in **Appendix B: Exploring Solar Energy Student Workbook**. This assessment is intended as a checkpoint for student understanding and is important as a foundation for project work. Class discussion to correct any potential misconceptions, repeated game play, and revisiting this assessment are encouraged as ways to solidify student understanding and ensure appropriate terms, concepts, and applications are brought forward into the project.

Days 2-5: Solar Oven Project

Spanning approximately four class days (time will vary depending on the group), the solar oven design project is intended to build on the concept first presented at the start of the lesson, when students were asked: When was a time you were without electricity/power, and needed to cook something? What did you do?

Using a design thinking framework (see **Appendix A: Design Thinking**), students will first brainstorm needs (function) and corresponding design features (structure) in an effort to reinforce how function informs structure, and vice versa. They will then draw a model of their solar oven design, labeling with words the design features and illustrating their concept(s). Constructing a prototype using a variety of household and classroom materials will permit students to visualize their solar oven idea in 3D. The prototype will be used for an initial trial and data collection before making amendments based on peer feedback, from which a second trial will again collect data. Comparing trial data results will allow students to see how effective their oven was at raising the internal temperature and heating or cooking their food item. Communicating the reasons for their initial design choices along with their modifications for the revised prototype is an essential skill for students.

Throughout the project, teachers are encouraged to review student work at each phase of the design thinking process as a valuable opportunity for formative assessment. Although the ultimate goal for students is to create a solar oven that will achieve the highest possible temperature inside (i.e., a quantitative goal), there are also critical skills that are assessed on the rubric for project process.

Note: **Appendix B: Exploring Solar Energy Student Workbook** is intended to be submitted along with the three-dimensional solar oven for evaluation against the **Appendix C: Exploring Solar Energy Project Rubric**. Regardless of whether students construct the solar oven as individuals or in groups, they should be assessed as individuals. In order to acknowledge diverse learning styles and/or support students who may need other accommodations, students should also be given the choice to respond to the questions in the workbook in different formats (e.g., video, podcast, other multimedia). Regardless of the medium chosen to present responses, it is important that students understand that their submission must demonstrate understanding and answer the questions as comprehensively as possible.

Components for Days 2-5:

- **Appendix A: Design Thinking**
- **Appendix B: Exploring Solar Energy Student Workbook**
- **Appendix C: Exploring Solar Energy Project Rubric**

Days 2-5: Solar Oven Project Continued...

OUTLINE

1. Present students with the engineering design challenge:

   Create a solar oven that can heat or cook food.

   This should be connected back to the story-sharing on Day 1, when students were asked to recall a time when they had to cook food without electrical power (e.g., camping, during a power outage). Using solar energy as a method for cooking is a viable solution in many parts of the world. Review the guidelines or expectations for the project - these can be used as below, or created as a class:

2. Introduce both **Appendix B: Exploring Solar Energy Student Workbook** and **Appendix C: Exploring Solar Energy Project Rubric** to students. Alternately, students can participate in rubric creation. This will guide project work.

3. **Research:** Have students start by researching solar ovens, recording (in their student workbook) and then sharing their responses to the following questions:
   - What is a solar oven?
   - When or why might a solar oven be used?
   - How are solar ovens designed and built? (Students should find at least 2-3 different designs and identify how the design supports function)
   - How does solar oven design relate to the successful solar panels in **Solar Energy Defenders**?

- The goal is to achieve the highest possible temperature inside the solar oven in a given time period (suggested: 1-2 hours).
- All materials used for the construction of the solar oven must be pre-approved by the teacher (and/or provided directly by the teacher).
- The solar oven must be within given size boundaries (suggested: no smaller than a standard shoe box; no bigger than a standard microwave oven).
- Students can complete the task as individuals or in groups of 2-4 students (note: assessment will be by individual, regardless of choice for construction of the solar oven).
- The task (heating or cooking a food item) is the student's choice (suggested possibilities: cooking a frozen pizza, making a s'more, heating hot chocolate, etc.). Students are expected to provide their own food item(s) on the testing day(s).
- All designs must be able to accommodate a thermometer reading inside the oven, without disrupting the rest of the oven.

It is important to use this as a checkpoint for formative assessment. Review student responses, whether in small groups or as a large class. Check for understanding and clarify any misconceptions around the questions. It can also be a valuable exercise to gather together all the solar oven designs researched (in step 3) to see the diversity of products that are currently available and compare and contrast both structure and function of these designs.

Note: In a traditional design thinking framework, at this initial stage offer empathy, an end user would be interviewed to ask questions such as: What are your needs? What are your current challenges? What things do you like and dislike in ____? It is recommended that, whenever possible, real-world connections are made to increase student engagement and connect them to the community. If possible, students could interview a community member that needs a solar oven, or perhaps someone that uses a commercially available solar oven and is looking for an alternative. This individual would then be approached again after models and/or prototypes are created, to get feedback about whether student designs are meeting their needs - and then revisions to designs would incorporate the end user's perspective.

Days 2-5: Solar Oven Project Continued...

4. **Model:** Students should draw a labeled diagram of their own solar oven concept. This should illustrate their design and identify, in words, what features will be present on the solar oven in order to achieve the best possible results. To further reinforce student understanding of heat and energy transfer, have students use arrows on their model to show how solar energy is collected within the solar oven and predict how heat will be transferred to the food item in the solar oven, as well as what components of the oven itself are maximizing and minimizing heat transfer.
5. Have students share their model with at least one other group (or the entire class), giving peer feedback for amendments and improvements to all designs. Following this feedback, students should return to their models to make changes.
6. **Prototype:** Using approved materials, allow 1-2 class periods for solar oven construction.
7. **Testing:** Solar ovens are best tested at mid-day, when the sun is highest in the sky. Have students place their solar oven outside. For this first prototype trial, they will collect temperature readings only and not use their food item. Use the student workbooks to collect both quantitative data (i.e., temperature readings over time) and qualitative data (i.e., descriptive observations of what occurred over the course of the trial). In synthesizing the data into graph form, students can also create a single, class-wide graph that utilizes all the different data points, as a visual comparison of the changes that happened in temperature over time for each group.
8. **Feedback & Revision:** As a class, discuss what design element(s) made for the more and less successful solar ovens. What worked and what didn't? How does this relate to the knowledge acquired in playing Solar Energy Defenders, and what students learned in their solar oven research? After this initial debrief, have students return to their prototype and make changes, justifying their decisions for why they are making these amendments.
9. **Re-Testing:** Conduct a second trial with the modified solar ovens. This time, students will use their finalized design with a food item to heat or cook. In their qualitative observations, students should record whether the food item was heated or cooked and over what course of time that happened. As before, quantitative data should be compared across groups and students should discuss what worked and what didn't in their designs. Answers should be recorded in the student workbooks; this is also a valuable opportunity for formative assessment by engaging students in discussion to connect their structural choices to how well prototypes functioned.
10. **Presentation:** Each individual/group should be given time to present their final solar oven designs to the class. In this presentation, they should clearly articulate their design choices and justify their decisions, explain their results from testing, and describe any additional changes that they would make to their finalized prototype to improve it even more.
11. For final assessment, have students submit their final solar oven prototype, along with their Student Workbooks, for evaluation against the project rubric.

Day 6+: Optional Extensions

The concepts presented in this lesson can be reinforced through additional activities related to alternative energy, energy transfers, heat and temperature. These can be added on at the completion of the lesson, suggested to students who wish to explore new content areas as an extension, or integrated into other lesson activities.

The activity below builds on alternative energy sources introduced to students in the game **Save The World**. In addition to solar energy, students can select from geothermal, tidal, hydro, and wind to optimize energy production in different areas of the world. Energy source selections are based on environmental constraints, and students learn that one energy source may work extremely well in one area, but not necessarily in other geographies.

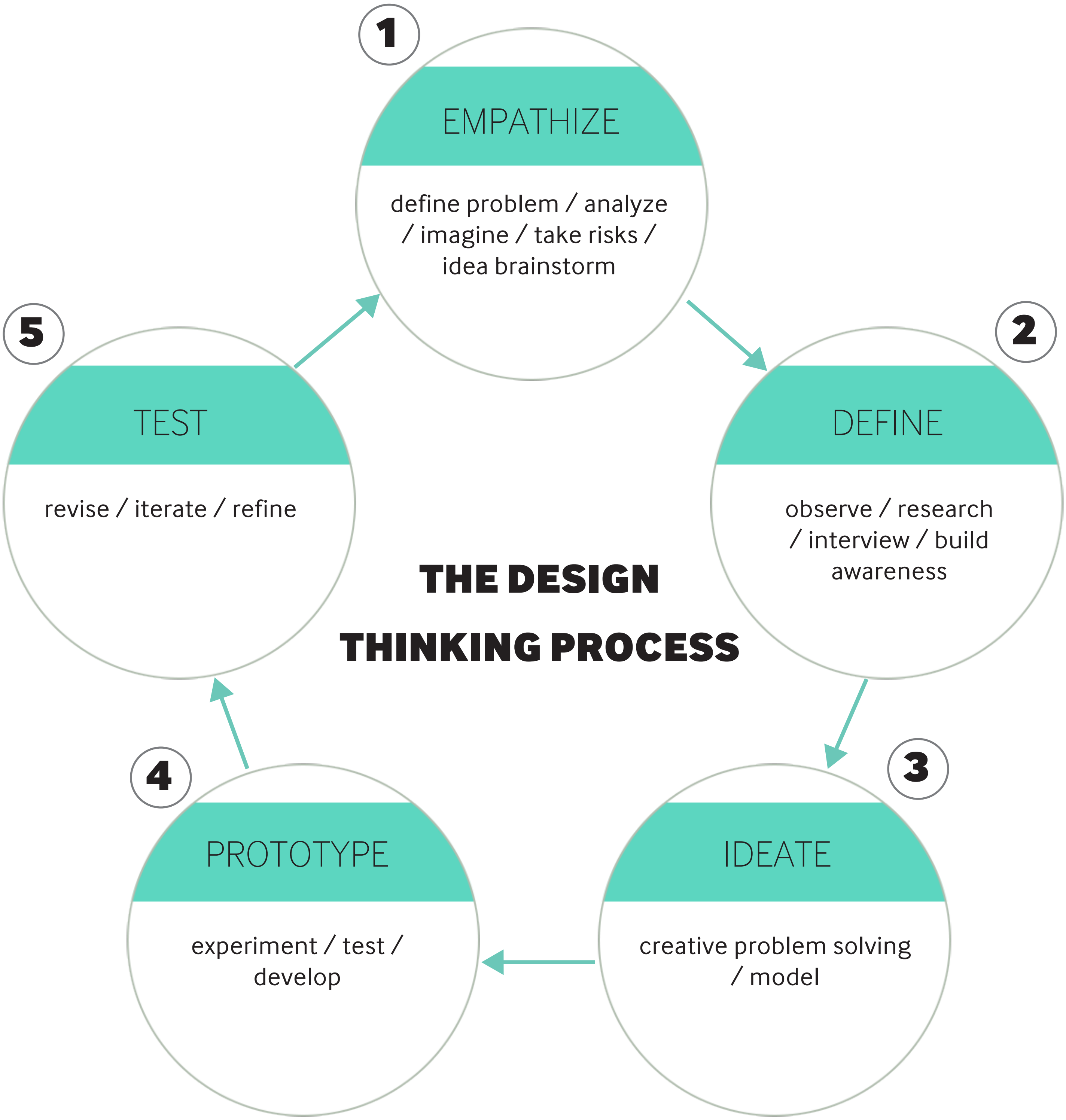
OUTLINE

1. The Wonderville game **Save The World** explores other forms of alternative/renewable energy, in addition to solar energy. Complete the assessment table found in **Appendix F: Save the World Assessment** during game play. Suggested student solutions and responses are provided below.

Other Wonderville.org games and digital resources that can be used to support student learning, and their corresponding content themes are:

Note: To access the following resources a free membership on **Wonderville.org** is needed.

Digital Resources	Content Theme	Description
Bust-A-Myth: Heat and Temperature	Particle movement connected to temperature	We can't see particles in substances, but we know that all substances are made of tiny particles that are constantly in motion. Using this research gadget can help you understand how particles arrange themselves, and how their movement changes based on how heat is applied to a substance.
Heat and Temperature	Heat transfer, design	We can’t see particles in substances, but we know that all substances are made of tiny particles that are constantly in motion. Using this research gadget can help you understand how particle arrange themselves, and how their movement changes based on how heat is applied to a substance.
Poo Power	Alternative energy: biofuels	Is it possible to create energy from poop? In this interactive game, learn how biofuels can be used to power all kinds of stuff. Use the anaerobic digester to generate energy from feces and travel the world setting up new digesters with new feedstocks.
Fission Impossible	Alternative energy: nuclear	Go inside a nuclear power plant reactor and use your keyboard arrows to help neutrons find Uranium-235. In this physics game, you’ll learn the basic principles behind nuclear fission and how we get energy from a nuclear power plant.


1
EMPATHIZE
define problem / analyze / imagine / take risks / idea brainstorm
2
DEFINE
observe / research / interview / build awareness
3
IDEATE
creative problem solving / model
4
PROTOTYPE
experiment / test / develop
5
TEST
revise / iterate / refine
THE DESIGN THINKING PROCESS

WHAT IS DESIGN THINKING?

Design Thinking is a process of discovery used to address real-world problems with innovative solutions. The process draws upon a student's ability to empathize and use their imagination, creativity and reasoning skills. Often used by entrepreneurs and start-ups, the process is now being recognized for its powerful ability to engage students while they solve problems in the classroom.

PHASES

The Design Thinking process is not linear, although it is often represented that way. Rather, it is a cyclical process that encourages trial and error.

> **Empathize** – First, students must identify a problem encountered by an individual or group. Exploring the problem from the end-user's perspective allows them to build an understanding of the challenge. Students should use research and observation to gather as much information as possible on the issue.
>
> **Define** – In the Define stage, students put together the information they gathered during the Empathy stage to define the core problem(s) to be solved. For example, "High school students carry too much weight in their backpacks causing an increase of 20% in visits to chiropractors' offices. Design a chair that alleviates stress on students' backs that can be used in the classroom."
>
> **Ideate** – At this stage, students should be comfortable with the problem they face and have some good ideas on how to move forward. Now students should begin thinking of ways to identify new solutions to the problem. They should also start looking for alternative ways to view the problem.
>
> **Prototype** – Once students have come up with a solution, it is time to create a model. The model begins as an illustration or rudimentary 3D rendering. From this, an initial prototype is built.
>
> **Test** – With the initial prototype, students should present their creation to their peers and gather feedback on their initial design. They can also perform limited tests to observe how the prototype works in the real world.

The Ideate, Prototype and Test phases become iterative, with students working within peer groups or with end users until they have a prototype that successfully addresses their initial defined problem.

ADVANTAGES & STEM CONNECTIONS

Design Thinking encourages learners to be problem solvers and problem finders. It is important for students to learn from failure and to not give up. Because design thinking is an iterative process, first tries are not the last tries, and this instills in students the understanding that mistakes are okay as long as they continue to learn and ask questions. Students also learn to embrace ambiguity, develop creative confidence and most importantly, build empathy.

Design Thinking gives students a chance to see diverse perspectives and appreciate multiple paths to solving a common problem. It promotes critical thinking and evaluation of possible solutions in a collaborative manner, developing essential communication skills. It can also inspire student creativity while approaching real-world scenarios – something that is essential in today's STEM classrooms.

NAME: ________________ **CLASS**: ________________ **DATE**: ________________

EXPLORING SOLAR ASSESSMENT

Question

1. What are some situations when relying on solar energy as the main source of electricity is not a good idea?
   Explain your answer: ____
   ____

2. What kind of cells are used to convert light energy into electricity? (Hint: read "About the Science" under the game!)
   A. Light cells
   B. Photovoltaic cells
   C. Plant cells
   D. Solar electric cells

   Explain your answer: ______________________________
   ____

3. What are some of the factors that impacted your ability to collect solar energy?
   A. Shadows
   B. Time of day
   C. Angle of the panel
   D. Time of year
   E. All of the above
   F. None of the above

   Explain your answer: ______________________________
   ____

4. To get the most from your solar module, you needed to place it perpendicular to the sun. Why is that the best angle?
   ____
   ____
   ____

5. kWh stands for _____ and it is used to measure _____ .
   Explain your answer: ____
   ____

6. What does "panel efficiency" mean?
   ____
   ____

7. Imagine the sun was your only source of energy. For collecting energy, what would likely be your favorite season - and why?
   ____
   ____

NAME: ________________ **CLASS**: ________________ **DATE**: ________________

PROJECT INSTRUCTIONS

Your task? **Create a solar oven that can heat or cook food.**

You may have experienced a time in your life when you needed to eat food and there wasn't a microwave or stove handy. Maybe you were camping, or there might have been a power outage in the city. Even if you haven't faced a situation where there wasn't electrical power handy, there are lots of places in the world that experience this on a regular basis. We are pretty lucky to have electricity just a plug-in away - not everyone can say that!

One solution for cooking food is a solar oven. In this project, you'll work to design a unique solar oven (you can't copy an existing design!) to achieve the highest possible temperature in a given period of time. As a class, you'll go over the "rules," but here are some guidelines for your project:

- The goal is to achieve the highest possible temperature inside the solar oven in a given time period (suggested: 1-2 hours).
- All materials used for the construction of the solar oven must be pre-approved by the teacher (and/or provided directly by the teacher).
- The solar oven must be within given size boundaries (suggested: no smaller than a standard shoe box; no bigger than a standard microwave oven).
- Students can complete the task as individuals or in groups of 2-4 students (note: assessment will be by individual, regardless of choice for construction of the solar oven).
- The task (heating or cooking a food item) is the student's choice (suggested possibilities: cooking a frozen pizza, making a s'more, heating hot chocolate, etc.). Students are expected to provide your own food item(s) on the testing day(s).
- All designs must be able to accommodate a thermometer reading inside the oven, without disrupting the rest of the oven.

Do you think you've got what it takes to create the best solar oven on the planet - or at least in your class? You'll be engineers, designing, testing and modifying your prototype, so remember to be flexible and adapt your ideas as you go! Good luck!

Notes to Students

If you want to present your responses to the questions in this Student Workbook in an alternate format (e.g., podcast, video, other multimedia), this may be an option. Check with your teacher and get approval if you want to submit your Student Workbook in one of these other ways.

NAME: ________________ **CLASS**: ________________ **DATE**: ________________

PHASE 1: EMPATHIZE (RESEARCH)

To start this project, you'll need to do some research to understand more about who uses solar ovens in the real world and answer questions below. Things like, when might a solar oven be handy, and who would use it? What is important to look for in a solar oven design?

What is a solar oven?

____

____

____

Who might use a solar oven? What is important to them?

____

____

____

How are solar ovens designed and built? Find at least 2-3 different designs and then explain:

- How does each one work?
- How is the design connected to its function?
- What are the pros and cons of each solar oven?

____

____

____

____

____

____

____

____

____

NAME: ________________ **CLASS**: ________________ **DATE**: ________________

PHASE 1: EMPATHIZE (RESEARCH) CONTINUED...

Use this space to draw designs of solar ovens that you found in your research.

How does solar oven design connect to the successful solar panels in Solar Energy Defenders? What will you need to consider when building your own solar oven?

____

____

____

____

____

____

NAME: _______________ **CLASS**: _______________ **DATE**: _______________

PHASE 2 & 3: DEFINE AND IDEATE (MODEL)

Now, you'll need to come up with your creative and unique design for a solar oven, based on the information you collected. Use the space below to draw your model. Make sure to use both pictures (illustrate) and words on your model to demonstrate both the structure and function of your solar oven.

Once you've drawn your model, use arrows to show how solar energy is collected within the solar oven and predict how heat will be transferred to the food item in the solar oven, as well as what components of the oven itself are maximizing and minimizing heat transfer.

Note: You will be coming back to this model and making improvements based on your prototype and test results, and from feedback from your peers!

Use this space to draw your model.

NAME: ________________ **CLASS**: ________________ **DATE**: ________________

PHASES 4 & 5: PROTOTYPE AND TEST

Based on your design, use the teacher approved / provided materials to build the first model of your prototype.

Now that you've built your solar oven prototype, you're ready to test it!

Trial 1 - Temperature Only (no food present)

Table Title: ____

Time (min)	Temperature (C/F)
0 (Start)	
10	
20	
30	
40	
50	
60	
70	
80	
90	

Observations (use words to describe what happened during this trial):

____

____

____

NAME: ________________ **CLASS**: ________________ **DATE**: ________________

PHASES 4 & 5: PROTOTYPE AND TEST CONTINUED...

Graph your findings below, labeling the axes and plotting your data.

Revisions: Based on your first trial, the feedback you received from your peers and understanding how other students built their prototype, return to both your model (Phase 3: Ideate) and your prototype and make changes. Use the space below to explain what change(s) you have made to your design, and why you have made these choices.

____

____

____

____

NAME: ________________ **CLASS**: ________________ **DATE**: ________________

PHASES 4 & 5: PROTOTYPE AND TEST CONTINUED...

Trial 2 - Final Test with Food

Table Title: ____

Time (min)	Temperature (C/F)
0 (Start)	
10	
20	
30	
40	
50	
60	
70	
80	
90	

Observations (what you saw; what happened to the food item from start to finish of the trial?):

____

____

____

NAME: ________________ **CLASS**: ________________ **DATE**: ________________

PHASES 4 & 5: PROTOTYPE AND TEST CONTINUED...

Graph your findings on the next page, labeling the axes and plotting your data.

Conclusions: What was different between your first trial and your second? Do you think the changes you made to your prototype affected your results? Why/why not? If you could go back to your model and prototype and make even more changes, what would you do differently? What designs in the class were the most and least effective, and why?

____

____

____

____

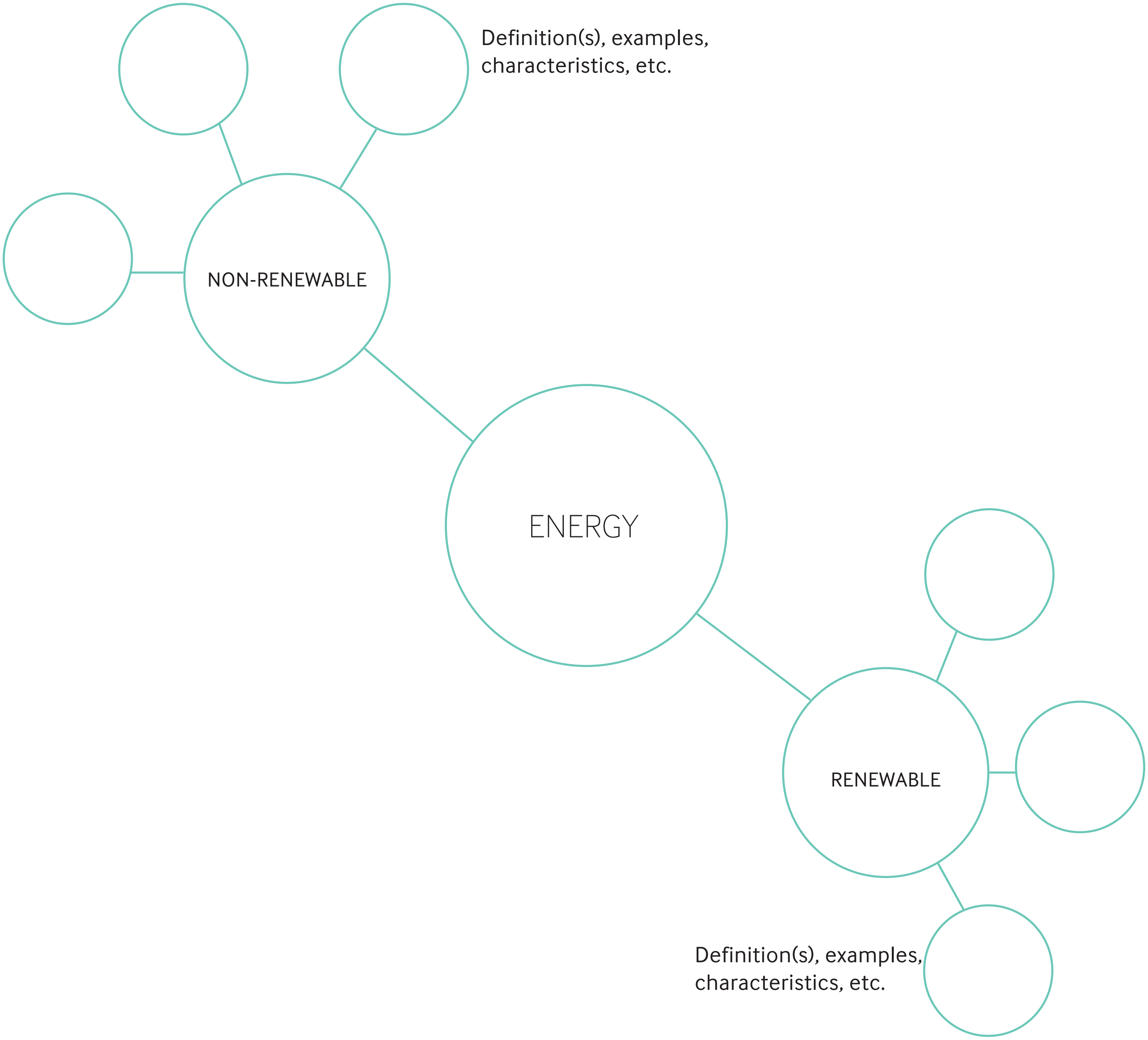
Appendix C: Exploring Solar Energy Project Rubric

How to use this rubric:

- Provide this rubric in advance of starting the project - make sure that students understand evaluation - or, if desired, the indicators can be created collaboratively with students for greater ownership over what they are trying to achieve.
- This rubric can be used both for self-reflection and for teacher evaluation.
- Students can choose which four of the six categories they wish to be evaluated on, for a total of 100%. Teacher comments and feedback is encouraged for all categories, regardless of which scoring categories are selected.

OUTCOMES	Indicators (can be demonstrated in different ways)	Comments and Feedback	Score
Research and self-directed learning	• Makes productive use of resources, including time • Documents information and ideas effectively • Provides clear and complete answers • Shows correct understanding of concepts • Demonstrates understanding of the relationship between function and design		25%
Design and Model	• Shows correct application of ideas and learnings • Provides complete and well thought-out model and plan • Includes clear information on parts and functionality • Design follows the guidelines • Includes creative/original elements		25%
Prototype and Test	• Uses materials, equipment, class space and time adequately and responsibly during the building and testing process • Builds prototype that closely follows the model and design • Carries out all necessary testing • Collects a complete set of data and observations • Analyzes and interprets data fully and correctly		25%
Revision and final product	• Troubleshoots competently and revises model to address test results • Justifies and explains revisions to account for test findings • Changes the prototype as per revised design • Tests final product and collects complete data and observations • Analyzes and interprets new data fully and correctly • Evaluates results and draws thorough and thoughtful conclusions • Final product performs well when tested with food		25%
Collaboration	• Provides useful feedback on other designs • Considers and incorporates feedback and suggestions from others • Makes thoughtful contributions to class discussions and debriefs • Has respectful and productive interactions with others		25%
Communication and Presentation	• Communicates in ways that are logical and effective; to others, can back up ideas and have meaningful and constructive dialogue • Shares and justifies ideas and information clearly and thoroughly • Presents in a confident and engaging fashion showing understanding and competence		25%

Appendix D: Energy



Question | **Suggested Student Responses**

1. What are some situations when relying on solar energy as the main source of electricity is not a good idea?

During the night, during the winter months or in areas where it is overcast or extremely shady/protected from the sun most of the time it may be too difficult to capture solar energy. Solar modules depend on capturing the sun's rays to function. At night, this is not possible. During the winter months, the angle of the sun in the sky is low and it may be difficult to capture as much light - the days are also much shorter. In areas that are shaded or overcast, capture of solar energy may also be difficult due to clouds or objects obstructing the sun's rays.

2. What kind of cells are used to convert light energy into electricity? (Hint: read "About the Science" under the game!)
   A. Light cells
   B. Photovoltaic cells
   C. Plant cells
   D. Solar electric cells

B (photovoltaic cells). Photovoltaic cells use the direct conversion of light into electricity at the atomic level.

3. What are some of the factors that impacted your ability to collect solar energy?
   A. Shadows
   B. Time of day
   C. Angle of the panel
   D. Time of year
   E. All of the above
   F. None of the above

E (all of the above). Sun angle, tilt, shadows, and time of year are all listed as factors that can impact energy collection in the game.

4. To get the most from your solar module, you needed to place it perpendicular to the sun. Why is that the best angle?

A 90 degree (perpendicular) angle maximizes capture of the sun's rays. Placing the panel at 90 degrees to the sun allows the most possible surface area to be exposed to the sun's rays.

5. kWh stands for _____ and it is used to measure _____ .

kWh stands for kilowatt hour and it is used to measure energy. Kilowatt hours is the unit of measurement used in the game to quantify the amount of energy generated.

6. What does “panel efficiency” mean?	Panel efficiency is a percentage that explains how well the module can convert one type of energy (solar) into another (electrical). Efficiency is used to quantify how well a device is at converting one type of energy into another, useful form of energy.
7. Imagine the sun was your only source of energy. For collecting energy, what would likely be your favorite season - and why?	The sun angle increases during the summer months compared to winter - so the summer months would be your favorite. During the summer months, the sun angle (solar altitude) will be greater than during the winter months, when the sun is lower in the sky, and it is easier to capture more solar energy with panels.

Appendix F: Save the World Assessment

Start by playing the game **Save the World**. The world's energy supplies are in crisis, and it's up to you to save the world! This game will teach you all about different power sources, alternative energy, and how we generate electricity to power our lives.

While you are playing the game, track the sources of energy you use in each country. Make sure to describe the environment and explain why your choices were the best for each region!

Region	Energy Source (Type, #)	Where (Environmental Description)	Why?
Canada			
USA			
Norway			
France			
India			
Japan			
New Zealand			

Appendix F: Save the World Assessment Answer Key

Start by playing the game **Save the World**. The world's energy supplies are in crisis, and it's up to you to save the world! This game will teach you all about different power sources, alternative energy, and how we generate electricity to power our lives.

While you are playing the game, track the sources of energy you use in each country. Make sure to describe the environment and explain why your choices were the best for each region!

Region	Energy Source (Type, #)	Where (Environmental Description)	Why?
Canada	Tidal: 2 (+25) - in water Wind: 3 (+20) - on ice	Icebergs and water. Some sun. No grass, shrub or trees.	No change for geothermal (0%) or hydro (0%). Best with tidal (100%) or wind (80%).
USA	Solar: 3 (+25) Wind: 2 (+20)	Mix of farmland/crops and dry rocky/hill area that is exposed.	Capitalize on solar (100%) and wind (80%) with exposed land.
Norway	Tidal: 3 (+25) - in open water Hydro: 2 (+15) - in water	Lots of water, with stream leading towards land (gateway). Rest is shrubby/grass and rocks.	Highest percentage (100%) for tidal. Remaining can capitalize on hydro (60%) if water, wind (68%) if land.
France	Geothermal: 3 (+25) Wind: 2 (+22)	Farmland and crops. Some sunlight in open grassy areas. Little tree cover.	Can't use hydro or tidal (0%) as no water. Best change with geothermal (100%) or wind (88%).
India	Hydro: 1 (+25) Solar: 3 (+20) Wind: 1	Mostly open, dry land - little tree cover. Small stream has gateway for hydro (only one location).	Highest percentages (80%, 100%) for solar and hydro. No tidal potential.
Japan	Solar: 3 (+25) Wind: 2 (+18)	No water visible. About half is urban development (building on high-rises), remaining in shrub/grassy and mountainous.	Highest percentage (100%) for solar, and can be put on top of buildings. Next best (72%) is wind - for land.
New Zealand	Geothermal: 3 (+20) - on land Tidal: 2 (+18) - in water Wind: 1	Mostly shrub/grassy and shady (little solar potential). Some mountainous and some water.	Highest percentages (80%, 72%) for geothermal and tidal. Can't use hydro (0%); solar potential is low.