Integrated STEM Unit Planner

Grade 4 Science
Power a Device

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PreK-12 STEM
Community Training & Assistance Center (CTAC)
Tracy Unified School District

About the Integrated STEM Units

The integrated STEM units are a product of the partnership between Community Training and Assistance Center (CTAC) and Tracy Unified School District (TUSD) in California, funded in part through the Education Innovation and Research (EIR) program of the U.S. Department of Education in 2018. Teacher leaders came together to develop innovative units that align to STEM standards for student learning—namely the Next Generation Science Standards (NGSS) for California Public Schools, the Computer Science Content Standards derived from the national K-12 Computer Science Framework, and the California Common Core State Standards.

Each integrated unit brings together the following:

- an engineering design challenge
- one or more computational artifacts
- core science and math content
- language building opportunities
- engagement supports

Students in each grade level, pre-kindergarten through twelve, engage with the unit for about one or two months as part of their required coursework. The units are integrated and self-contained as a means to provide all students with equitable STEM experiences.

About the Partners

Community Training and Assistance Center (CTAC) is a national not-for-profit organization with a demonstrated record of success in the fields of education and community development. Tracy Unified School District, located in California's Central Valley, serves approximately 15,000 students. Fifty leading teachers from the district contributed to the development of the units. Computer Science integrations resulted with support from the San Joaquin County Office of Education and Bootstrap of Brown University.

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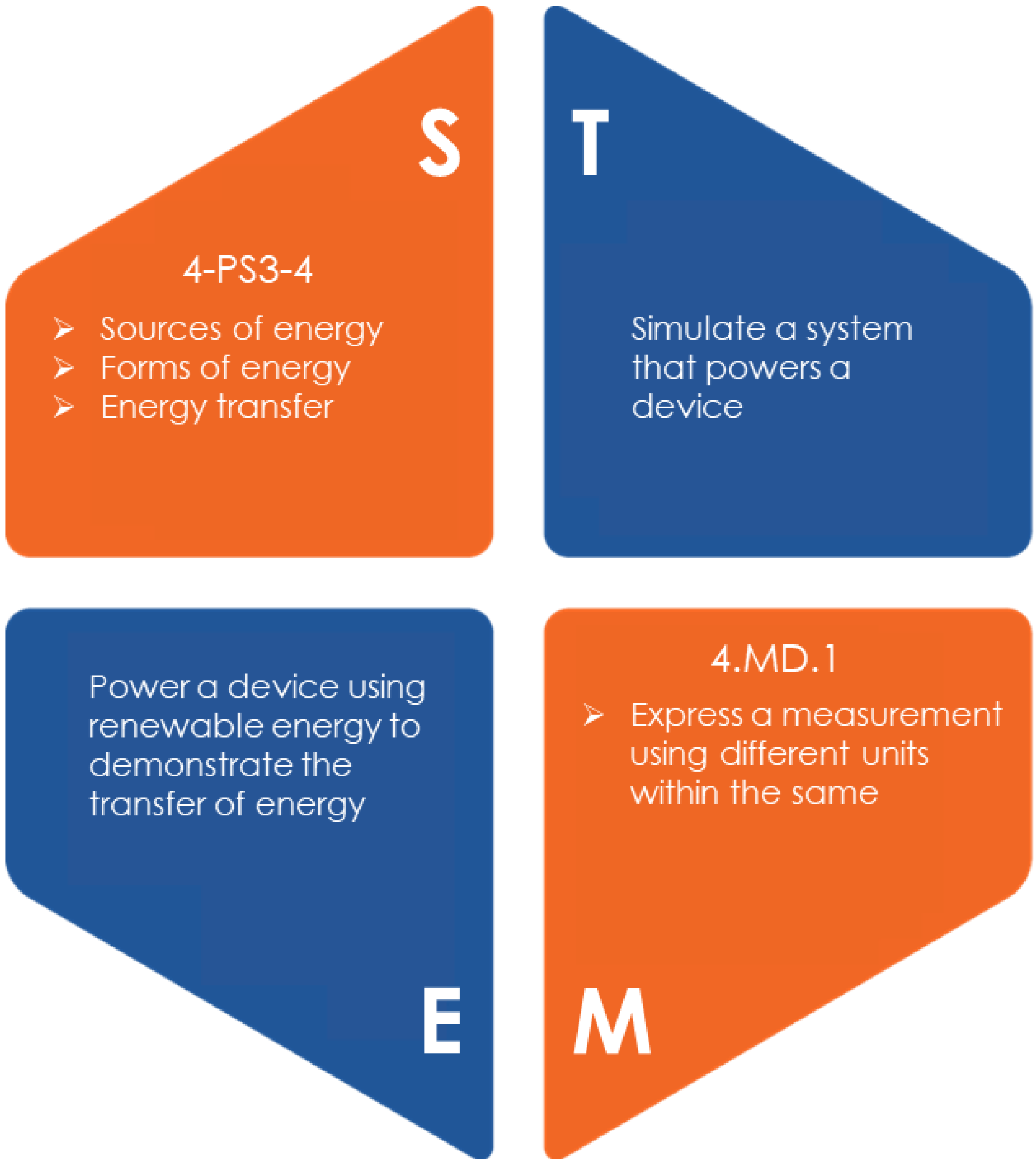
Contents

Big Picture

Unit Emblem



Focal Standard

4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.* [Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.] [*Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.*]

Overview

Sequence 1: Teachers engage students with an anchoring phenomenon by showing the video of "Epic Lightning Storm in Georgia".(Twister Hunter, 2012[i]). The video shows the energy on display during a thunderstorm.

During the entry event, teachers present the driving essential question: How can people convert and use energy with the least impact upon the environment? This question connects the concepts of all the supporting question: How do we get electricity and fuel to run cars and power electronic devices? This is linked to the initial discussion of energy and fuel derived from natural resources and the differentiation between renewable and non-renewable resources.

Students are presented with the initial overview of the design challenge: to create clean energy power using renewable resources. The task is to power a home device using solar energy. Students will ***ask*** questions about the challenge including: How can I build something that can convert energy from one form (solar) to another (battery)?

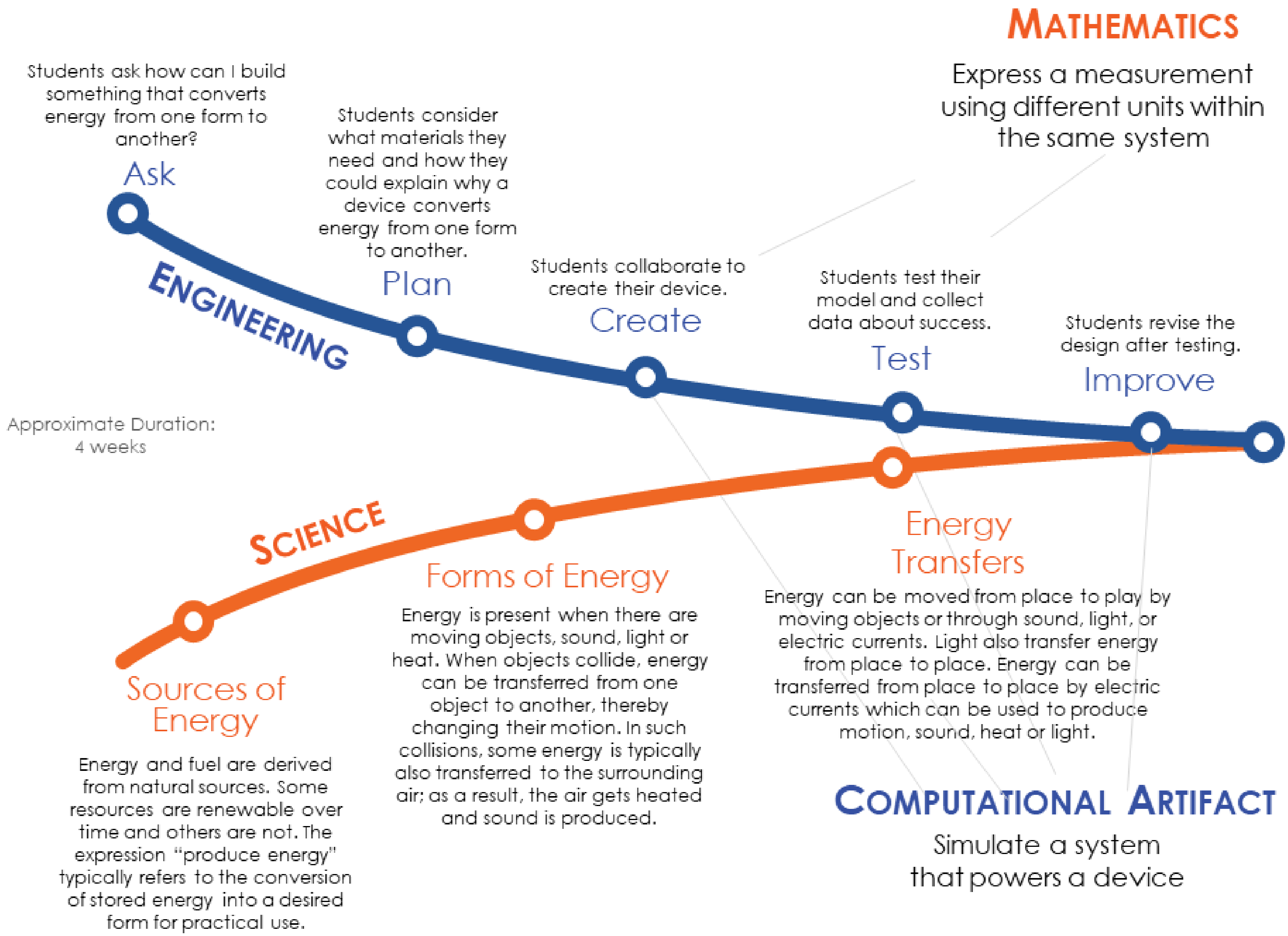
Sequence 2: Students will begin to learn about various forms of energy and how it can be transferred from one object to another. Students will learn about the materials that have been gathered for their challenge and the kind of energy they will be able to create. They will begin to ***plan*** their design, deciding the elements needed for their device.

Sequence 3: Students collaborate with their peers to ***create*** their energy transfer model. This will be supported by learnings about how energy is transferred.

Sequence 4: Students then begin to ***test*** their prototype, collecting data to determine how effective their model is at generating energy. They will use the data to plot outcomes and make decisions about revisions.

Sequence 5: Students reflect on their data and revise the plan to ***improve*** their model and then conduct follow-up tests on their improved energy transfer device. Students will use the computer to simulate the design of the system and prepare presentations of their process and device to their families on "Energy Day".

Integrated Unit Storyline



Integrated Unit Wayfinder

Inventory the experiences of students

Present the anchoring phenomenon

Students collaborate with each other

Students read, hear, and view source material

Students and teachers reflect on the work and processes of students to assess learning progress

Launch design challenge; elicit and record questions students **ask** about the challenge

Facilitate 5E science lesson sequence for sources of energy

Give students time to ***plan*** their design solution

Facilitate 5E science lesson sequence for forms of energy

Provide time and materials for students to ***create*** their design

Embed solving word problems and representing measurements with diagrams

Introduce expectations for computational artifact

Connect students with a STEM-related professional to inform their design solution

Let students conduct ***tests*** of their design solution and collect data

Support students in developing their computational artifact

Facilitate 5E science lesson sequence for energy transfer

Designate time for students to ***improve*** and re-test their design solution

Students write and speak to share their design solution and learning beyond the classroom

Engineering or Computer Science | Math or Science | Student Connections | Ongoing Actions

STEM Dive

Engineering

Design Challenge: Build a useful device for your model home where one form of energy is converted to another.

Type of Engineering: Green Engineering

The Engineering Design Process (EDP) and Engineering Standards

EDP Step	Standard and Grade Band End Points from the *Framework*
Ask *How can I build a device that converts energy from one source to another?*	**3-5-ETS1-1.** 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. • 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)
Plan *Consider what materials they need and how they could explain why a device converts energy from one form to another.*	**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. • 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)
Create *Students collaborate to create their device*	
Test *Students test their model and collect data about success*	**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. • 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) • 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)
Improve *Students revise the design after testing*	

Computer Science (Technology)

Computer Science Integrations

Description of Student Engagement

Students will simulate the design of a system to power a device in Autodesk's Tinkercad.

Computational Artifact

Definition: Anything created by a human using a computational thinking process and a computing device. A computational artifact can be, but is not limited to, a program, image, audio, video, presentation, or web page file. (Source: College Board, 2016)

- Simulation of the device being powered

Hardware

Definition: The physical components that make up a computing system, computer, or computing device. (Source: MDESE, 2016)

- Computer

Software (includes programs, applications, websites, etc.)

Definition: Programs that run on a computing system, computer, or other computing device. (Source: k12cs.org)

- Autodesk's Tinkercad

Standards

- **3-5.DA.8** Organize and present collected data visually to highlight relationships and support a claim.
- **3-5.DA.9** Use data to highlight and/or propose relationships, predict outcomes, or communicate ideas.
- **3-5.CS.2** Demonstrate how computer hardware and software work together as a system to accomplish tasks.
- **3-5.AP.10** Compare and refine multiple algorithms for the same task and determine which is the most appropriate

Science

Focal Standard

4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.* [Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.] [*Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.*]

Related Content Standards

4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. [*Assessment Boundary: Assessment does not include quantitative measurements of energy.]*

4-ESS3-1 Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment. [Clarification Statement: Examples of renewable energy resources could include wind energy, water behind dams, and sunlight; non-renewable energy resources are fossil fuels and fissile materials. Examples of environmental effects could include loss of habitat due to dams, loss of habitat due to surface mining, and air pollution from burning of fossil fuels.]

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a practice or disciplinary core idea.

Anchoring Phenomenon

Teachers engage students with an anchoring phenomenon by showing the video of "Epic Lightning Storm in Georgia".

Content Outline

Below is a content outline for the science content in this unit. It includes the key concepts within the unit along with an approximate number of days it would take to facilitate a sufficient amount of student learning experiences. For each key concept, key learnings appear, which come from the grade band endpoints in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (source: https://www.nextgenscience.org/framework-k-12-science-education). The storyline begins with an anchoring phenomenon.

Key Concept	Key Learnings	# of Days
Sources of Energy	• Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not. (4-ESS3-1, ESS3.A) • The expression "produce energy" typically refers to the conversion of stored energy into a desired form for practical use. (4-PS3-4, PS3.D)	
Forms of Energy	• Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. (4-PS3-2, PS3.B)	
Energy Transfer	• Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (4-PS3-2, PS3.A) • Light also transfers energy from place to place. (4-PS3-2, PS3.B) • Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. (4-PS3-2, 4-PS3-4, PS3.B)	

Science and Engineering Practices	Crosscutting Concepts
1. Asking questions and defining problems **2. Developing and using models** **3. Planning and carrying out investigations** 4. Analyzing and interpreting data **5. Using mathematics and computational thinking** **6. Constructing explanations and designing solutions** 7. Engaging in argument from evidence **8. Obtaining, evaluating, and communicating information**	**1. Patterns** **2. Cause and effect** 3. Scale, proportion, and quantity 4. Systems and system models **5. Energy and matter** 6. Structure and function 7. Stability and change

Note. Bolded items are called out specifically in the standards cluster for this unit.

Mathematics

Description of Student Engagement

Students measure the length of their circuit and express it using different units within a single system of measurement.

Standards for Mathematical Content

4.MD.1. Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz.; l, ml; hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit. Record measurement equivalents in a two-column table. *For example, know that 1 ft is 12 times as long as 1 in. Express the length of a 4 ft snake as 48 in. Generate a conversion table for feet and inches listing the number pairs (1, 12), (2, 24), (3, 36), …*

Standards for Mathematical Practice

MP.1 Make sense of problems and persevere in solving them.

MP.2 Reason abstractly and quantitatively.

MP.3 Construct viable arguments and critique the reasoning of others.

MP.4 Model with mathematics.

MP.5 Use appropriate tools strategically.

MP.6 Attend to precision.

MP.7 Look for and make use of structure.

MP.8 Look for and express regularity in repeated reasoning.

Note. Bolded items are emphasized in this unit.

English Language Arts and Development

Reading Standard: Key Idea and Details

RI.4.1 Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.

RI.4.2 Determine the main idea of a text and explain how it is supported by key details; summarize the text.

RI.4.3 Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text.

Reading Standard: Integration of Knowledge and Ideas

RI.4.7 Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, time lines, animations, or interactive elements on Web pages) and explain how the information contributes to an understanding of the text in which it appears.

Writing Standard: Text Types and Purposes

W.4.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

- 4.2.a. Introduce a topic clearly and group related information paragraphs and sections; include formatting (e.g., headings), illustrations, and multimedia when useful to aiding comprehension.
- 4.2.b. Develop the topic with facts, definitions, concrete details, quotations, or other information and examples related to the topic.
- 4.2.c. Link ideas within categories of information using words and phrases (e.g., another, for example, also, because).
- 4.2.d. Use precise language and domain specific vocabulary to inform about or explain the topic.
- 4.2.e. Provide a concluding statement or section related to the information or explanation.

Writing Standard: Production and Distribution of Writing

W.4.4 Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, and audience (Grade-specific expectations for writing types are defined in standards 1 – 3).

Writing Standard: Production and Distribution of Writing

W.4.7 Conduct short research projects that build knowledge through investigation of different aspects of a topic.

Speaking and Listening Standard: Comprehension and Collaboration

SL.4.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on Grade 4 topics and texts, building on others' ideas and expressing their own clearly.

Unit Vocabulary

The following terms reflect the core vocabulary students should understand and use in this unit.

- **convert**: To convert means to change from one form or function to another. (Source: https://www.merriam-webster.com/dictionary/convert)
- **energy**: Energy is usable power or the resources (as oil) used to produce usable power. (Source: https://www.merriam-webster.com/dictionary/energy)
- **environment**: The environment is the complex of physical, chemical, and biotic factors (such as climate, soil, and living things) that act upon an organism or an ecological community and ultimately determine its form and survival. (Source: https://www.merriam-webster.com/dictionary/environment)
- **fossil fuel**: A fossil fuel is a general term for organic materials formed from decayed plants and animals that have been converted to crude oil, coal, natural gas, or heavy oils by exposure to heat and pressure in the earth's crust over hundreds of millions of years. (Sourced from the EPA[1]: https://bit.ly/38KvR1D)
- **generate**: To generate means to produce (something) or cause (something) to be produced. (Source: https://www.merriam-webster.com/dictionary/generate)
- **-hydro root word**: Hydro is used as a prefix to indicate water or water-related.
- **motor**: A motor is a machine that produces motion or power for doing work. (Source: https://www.merriam-webster.com/dictionary/motor)
- **non-renewable**: Energy resources that are non-renewable have a limited supply and will not be replaced naturally. These include things such as oil, coal, and gas. (Source: adapted from FWS[2]: https://bit.ly/3tn7mRn)
- **pollution**: Pollution is caused by substances that make land, water, air, etc., dirty and not safe or suitable to use. (Source: https://www.merriam-webster.com/dictionary/pollution)
- **renewable**: Energy resources that are renewable are continuously recreated such as energy created by the wind, the sun, water, and geothermal (from the earth's heat). (Source: adapted from FWS: https://bit.ly/3tn7mRn)
- **resource**: A resource is supply of materials, energy or goods that can be used by others. Natural resources are those materials humans can use that exist in the environment.
- **turbine**: an engine whose central driving shaft is fitted with a series of winglike parts that are spun by the pressure of water, steam, or gas, (Source: https://www.merriam-webster.com/dictionary/turbine)

[1] EPA = Environmental Protection Agency
[2] FWS = U.S. Fish and Wildlife Service

Assessment Tools

Student Experience Inventory

Teachers can use the following prompts with students prior to the beginning of the unit or early in the unit in order to learn about students' experiences that relate to the unit. Teachers can make informed instructional decisions based on this learning, enabling tailored opportunities for students to make their own meaning.

Student Prompts

1. What kind of toys have you seen that move?
2. Tell about an object you have (or have used) that has a lot of light. (Could additionally prompt to see what natural and human-made sources of light they have experienced.)
3. Tell me about a time you felt an object getting warmer.
4. Tell about an object that you have (or have used) that makes sound.
5. How do you get around? (Additional prompts: walking, biking, skateboarding, buses, cars, trains, airplanes)

Aligned Learnings

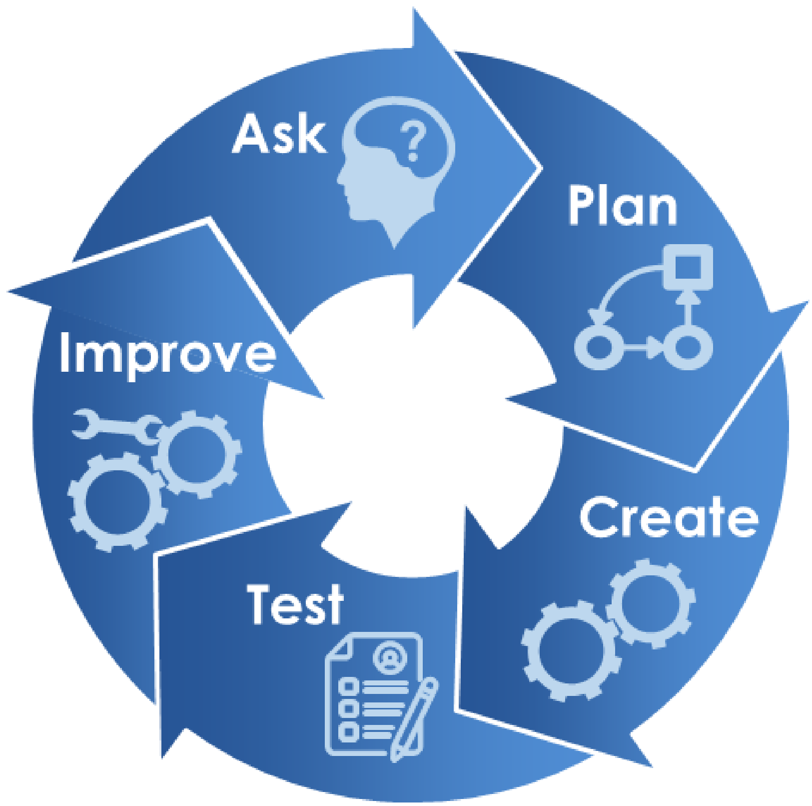
1. Responses to this item provide insight into students' experiences with various toys and interactions with energy transfers. 4-PS3-2, 4-PS3-4
2. Responses to this item provide insight into students' experiences with light energy. 4-PS3-2, 4-PS3-4, 4-ESS3-1
3. Responses to this item provide insight into students' experiences with thermal energy. 4-PS3-2
4. Responses to this item provide insight into students' experiences with sound as energy. 4-PS3-2, 4PS3-2
5. Responses to this item provide insight into students' experiences with objects in motion and their energy sources. 4-ESS3-1, 4-PS3-4

Student Self-Assessment of Engineering

Improve:
Here is what would make my design better and why…

Ask:
Here is what I am wondering about before I plan my design…

Plan:
Here are my design ideas for the project…



Test:
Here are the data I collected…

Create:
Here is what I think about what I made compared to what I planned, and here is what I think will happen when I test it…

I am doing the work of a green engineer.

One-Point Design Challenge Rubric

Criteria serve as a primary reference point throughout the engineering design process. Teachers use the criteria **to communicate expectations** and **to guide students**. With teacher guidance, students use the criteria to inform and reflect on their work.

Approaches Expectations *Notes on how to improve the project*	**Meets Expectations** *Criteria indicating success*	**Exceeds Expectations** *Notes on how project goes beyond expectations*
	Engineering Students participate in the 5-part engineering design process, use data, and make thoughtful improvements to their design. (3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3)	
	Computer Science Students create a simulation of a system that powers a device. (3-5.DA.8, 3-5.DA.9, 3-5.CS.2, 3-5.AP.10)	
	Collaboration Students give and receive input with kindness and honesty. (SL.4.1)	
	Communication Students speak and write about their ideas clearly using accurate vocabulary (W.4.2, W.4.2.a-e). Students share thoughts, read, and listen to learn from others. (SL.4.1)	
	Science Students describe different types of energy, their sources, and transfer of energy. Students build a device that transfers energy from one type to another. (4-ESS3-1, 4-PS3-2, 4-PS3-4)	

Engagement

Community and Career Connections

During the unit, students engage with STEM professionals who can inform students' work at some point during the engineering design process. The interaction with STEM professionals serves a few purposes:

- Expose students to STEM as it applies in various careers
- Enrich student learning through collaborating with STEM professionals
- Help students see themselves doing the actual work of STEM

Below are a few potential STEM-related professionals that align to one of California's 15 industry sectors for Career and Technical Education:

- **Mechanical Engineer** (Engineering and Architecture)
- **Wind Farm Worker or Manager** (Energy, Environment and Utilities)
- **Solar Panel Installer** (Energy, Environment and Utilities)

The interactive experience will ideally be co-constructed by the teacher and professional. In coordinating with the professional, a few questions appear below that can be used to guide the planning and live interaction with students:

- **Mechanical Engineer** (Engineering and Architecture)
  - What kinds of machines do you design?
  - How are the things you create powered?
  - What do you consider when thinking about making a design more environmentally friendly?
  - What does a typical day on the job look like?
  - What is one problem you are currently facing in your day-to-day work?
- **Wind Farm Worker or Manager** (Energy, Environment and Utilities)
  - What factors go into deciding what will be a good wind farm site?
  - How big are the windmills and are there different kinds for different locations?
  - What are the most likely problems with the equipment on your windfarm?
  - How much energy is generated by a typical wind farm?
  - What does a typical day on the job look like?
  - What is one problem you are currently facing in your day-to-day work?
- **Solar Panel Installer** (Energy, Environment and Utilities)
  - How do you decide where to place solar panels?
  - Are there ever houses where solar panels really cannot work?
  - What are key tools and knowledge required for your job?
  - What is one problem you face in your day-to-day work?

Materials List

The items in the materials list below reflect total quantities for a class of 32 students, allowing for 8 groups of 4 students.

Permanent Equipment (classroom totals):

- ☐ 32 solar cells
- ☐ 32 motors
- ☐ 32 fan blades
- ☐ 1 wire set (including 180 feet of wire and wire clippers)
- ☐ 32 D cell batteries
- ☐ 32 light bulbs

Distance Learning Modifications

In distance learning, the design challenge will be conducted by students individually at home. Student collaboration will need to occur remotely with a modified materials list.

Modified Materials List (student totals):

- ☐ 1 solar cell
- ☐ 1 motor
- ☐ 1 fan blade
- ☐ 2 alligator clips
- ☐ 1 wire set including six wires each measuring 1 foot/12 inches
- ☐ 1 D cell battery
- ☐ 1 light bulb

Endnotes

[i] Twister Hunter. (2012, April 9). *Epic lightning storm in Georgia.* YouTube. https://www.youtube.com/watch?v=SCLblwbE5LE