ENERGY

Grade 4 - Engineering

TRAINER GUIDE

CONTENT AND PEDAGOGY
PROFESSIONAL DEVELOPMENT

Smithsonian
Science Education Center

The **Smithsonian Science Education Center** (SSEC) is an education organization within the Smithsonian Institution. The SSEC's mission is to transform K–12 *Education Through Science*™ in collaboration with communities across the globe. The SSEC promotes authentic, interactive, inquiry-based K–12 STEM teaching and learning; ensures diversity, equity, accessibility, and inclusion in K–12 STEM education; and advances STEM education for sustainable development. The SSEC achieves its goals by developing exemplary curriculum materials and digital resources; supporting the professional growth of K–12 teachers and school leaders; and conducting outreach programs through LASER (Leadership and Assistance for Science Education Reform) to help schools, school districts, state education agencies, and ministries of education throughout the world implement inquiry-based science education programs.

The **Smithsonian Institution** was created by an Act of Congress in 1846 "for the increase and diffusion of knowledge . . ." This independent federal establishment is the world's largest museum, education, and research complex and is responsible for public and scholarly activities, exhibitions, and research projects nationwide and overseas. Among the objectives of the Smithsonian is the application of its unique resources to enhance elementary and secondary education.

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Grade 4—Engineering

Trainer Guide

INTRODUCTION

In 2019, the US Department of Education awarded the Smithsonian Science Education Center an early-phase Education Innovation and Research (EIR) grant to support the development, implementation, and initial evaluation of evidence-based innovations to improve student achievement. The project, called Smithsonian Science for North and South Carolina Classrooms (PR# U411C190055), took place between October 2019 and September 2024 in third-, fourth-, and fifth-grade classrooms in North and South Carolina.

Between 2020 and 2023, participating teachers in implementation schools received curriculum professional development tied to two Smithsonian Science for the Classroom curriculum modules and content and pedagogy professional development tied to the content of each module to implement in their classrooms. The Center for Research in Educational Policy (CREP) at the University of Memphis evaluated the impact of these modules and professional development on student achievement using standardized assessments, classroom observations, and teacher focus groups.

This guide was developed as a support for trainers leading content and pedagogy professional development for fourth grade teachers implementing the Smithsonian Science for the Classroom Engineering module *How Can We Provide Energy to People's Homes?*

HOW TO USE THIS TRAINER GUIDE

This guide shares important ideas and strategies for effectively delivering content and pedagogy professional development in connection with a Smithsonian Science for the Classroom module with educators. The professional development plan is outlined within a table on the following pages. The first column notes approximate timing for each activity and connections to standards or pedagogical strategies. The second column provides the trainer with additional directions in concise bullet points.

ROOM SETUP

To set up a classroom for this workshop:

- Move tables or desks so groups of three or four participants can work together.
- Locate the nearest restrooms and evacuation routes.
- Make sure speakers are working.
- Post a piece of chart paper labeled "Parking Lot" for participants to record questions and ideas for follow up later.

WORKSHOP OVERVIEW

This trainer guide provides direction on facilitating the sessions highlighted in the table below.

Day 1		Day 2	
10:00 a.m.	Welcome Session	**10:00 a.m.**	Engineering Content Session 2
11:00 a.m.	Misconceptions and Student Work	**12:00 p.m.**	Lunch
12:00 p.m.	Lunch	**12:45 p.m.**	Reflections
12:45 p.m.	Misconceptions and Student Work, continued	**1:30 p.m.**	Break
1:30 p.m.	Break	**1:45 p.m.**	Concurrent Sessions: Planning Ahead and Principal's Meeting
1:45 p.m.	Engineering Content Session 1	**2:30 p.m.**	School Breakouts
3:45 p.m.	Wrap Up	**3:15 p.m.**	Closing Session
4:00 p.m.	Adjourn	**4:00 p.m.**	Adjourn

SCIENCE CONCEPTS AND STANDARDS

See Appendix 1 for the complete state standards listed here.
‡ NGSS/SC science standards refer to both NGSS and the most recent 2021 SC Science Standards.

Sessions	Science Concepts	Standards
Day 1: Energy	**1.1. What Is Energy?** Using the Making Meaning routine, groups will create a common definition to use when discussing energy.	**NC:** 4.P.3.1 **NGSS/SC‡:** 4-PS3-2
	1.2. Types of Energy Groups will make claims about which examples of energy are kinetic and which are potential energy.	**NC:** 4.P.3.1 **NGSS/SC:** 4-PS3-2
	1.3. Measuring Kinetic Energy Groups will discuss ways kinetic energy is measured in different forms, such as sound and light.	**NC:** 4.P.3.2 **NGSS/SC:** 4-PS3-1, 4-PS3-2, 4-PS4-1

Day 2: **Electricity in the US**	**2.1. Electricity Basics** Electricity is the flow of electrons, meaning it can not be stored. The energy must be transformed into another type of energy.	**NC:** N/A **NGSS/SC:** 4-ESS3-1
	2.2 Generation in the US The United States uses a wide variety of resources to create electricity, depending on the area.	**NC:** N/A **NGSS/SC:** 4-ESS3-1, 4-ESS3-2
	2.3 Problems and Solutions The US electricity grid has many weaknesses and reasons that individuals may wish to remove themselves from the grid or try to change the grid.	**NC:** N/A **NGSS/SC:** 4-ESS3-1, 4-ESS3-2

MISCONCEPTIONS AND STUDENT WORK

Throughout this professional development, the trainer leads the sessions as a facilitator (modeling the teacher role) with teachers acting as learners. Though the content is designed for adult learners, the practices used by the facilitator may be used with grades 3-5 students.

SESSION GOALS

- Identify common misconceptions in student work.
- Increase understanding of where misconceptions come from and grow.
- Categorize student misconceptions based on their origin and impact on student learning.

AGENDA AND TIMING

Sections	Minutes	Materials/Notes
Housekeeping and Introductions	20 minutes	• Chart paper
Reflections	10 minutes	• Chart paper
Conceptual Change	30 minutes	• *Good Thinking!* video
Lunch	45 minutes	
Misconception Identification	45 minutes	• Chart paper • Sticky notes • Colored dot stickers (5 colors) • Markers • “Misunderstanding Misconceptions” article

Timing	Key Points
Housekeeping and Introductions 20 minutes	**Introductions** Welcome participants to your session. Remind them that this professional learning workshop is meant to be an experience for adult learners to support their understanding of pedagogical content knowledge underlying a Smithsonian Science for the Classroom module. next page →

Timing	Key Points
	Educators may feel some discomfort as they are confronted with the limits of their own content understanding, just as their students do. Reassure them that this is part of the learning process and that it may help them build empathy for the students in their classrooms. **Icebreaker Activity** Participants introduce themselves through an icebreaker activity. Ask each participant to share what they remember about the last time they were taught this subject. **Housekeeping** Preview the agenda. Verify the safety protocols in the classroom and locate the nearest restrooms, fire exit, and tornado shelter.
	Establish the Tone for the Day Divide participants into small groups and ask them to think about what they want to achieve today. What norms do they think will encourage a positive learning environment? Introduce group norm ideas: • Be brave • Be present • Ask questions • Be respectful Have each small group discuss the suggested norms and add to the whole group list of norms. Once everyone has added their ideas, ask if there are any changes, additions, or modifications that need to be made. Once the discussion is finished, this will be the social contract the group abides by for the next two days.
Reflections 10 minutes	Have participants turn to their shoulder partner and discuss their successes and challenges when teaching these units. Pairs can also discuss how they overcame challenges they faced. After partners have had time to talk, ask them to share their main points with the whole group. Record the main ideas on chart paper so everyone in the room can benefit from the shared learning.

Timing	Key Points
Conceptual Change 30 minutes	Ask participants to write down in their notebooks their ideas in response to the following questions: • How would you describe a scientific misconception? • How do you think student preconceptions can affect their understanding of new scientific concepts? Introduce the *Good Thinking!* Conceptual Change video. *Good Thinking!* is a video series created by the Smithsonian Science Education Center to support K–12 science educators through targeted short-format videos that explore common student ideas and misconceptions about a range of science topics such as energy, chemical reactions, and natural selection, as well as pedagogical subjects such as student motivation and the myth of left- and right-brained people. Explain that the video we're about to watch is about conceptual change and explores the way students learn and develop new conceptual understanding, and shows how student misconceptions can be uncovered and addressed as part of effective learning. Show *Good Thinking!* Conceptual Change (run time: 6:26) https://s.si.edu/4dfqcQS Debrief the video by asking the participants to share how the video changed their definition of misconceptions and how preconceptions affect new learning. Have participants share anything else they found interesting or helpful. Before ending the session, let participants know that in the next session they will have a chance to explore student work and identify misconceptions. If your group is small and you're done before lunch, introduce the Keeley framework to allow more time for exploring student work after lunch.
Lunch 45 minutes	

Timing	Key Points
Keeley Framework 10 minutes	Hand out the "Misunderstanding Misconceptions" article by Page Keeley. In the article, Keeley introduces a loose framework of five types of misconceptions: conceptual misunderstanding, factual misunderstanding, naïve idea, vernacular misconceptions, and fragmentary knowledge. These different types represent a misconception based on where it comes from, how it is expressed, and what impact it has on continued learning. Understanding which type of misconception students have can assist in determining where the misconception is coming from and what the impact on learning might be.
Exploring Student Work 30 minutes	To help prepare for content sessions and future implementation, have table groups read student work and mark misconceptions with colored dot stickers, indicating which type from the framework they think the misconception falls into. Each misconception could be multiple categories in the framework.
Wrap Up 5 minutes	Ask participants to write misconceptions they found and their category from the framework on sticky notes and post them on a piece of chart paper. Let the group know they will revisit these ideas tomorrow, after they have completed the content sessions.
Trainer Note: Possible Misconceptions	Some misconceptions participants may identify include: • Energy is mainly associated with humans. • Energy is created instead of transformed. • Renewable resources do not have damaging effects on the environment. • There is one "right" answer. • They only need to consider one possible solution to a problem. • Electrical current is "consumed" by a light bulb or other electric-powered device.

CONTENT SESSION 1:

Energy

SESSION GOALS

- Develop a meaningful definition of "energy" based on prior knowledge and group learning.
- Identify and address existing misconceptions.
- Clarify misconceptions about types of energy.
- Think critically about types of energy.
- Explain the relationships between wave amplitude, frequency, and the wavelength and energy.
- Quantitatively measure sound and electromagnetic waves.
- Identify and explain potential injuries caused by sound and electromagnetic waves.

AGENDA AND TIMING

Sections	Minutes	Materials/Notes
1.1 What Is Energy?	40 minutes	• Chart paper
1.2 Types of Energy	20 minutes	• Chart paper
Break	10 minutes	
1.3 Measuring Kinetic Energy	60 minutes	• Make sure internet connection is working and YouTube is accessible • Virtual oscilloscope • Virtual tone generator • Chart paper • Sticky notes (yellow and blue)

1.1 What Is Energy?

40 minutes

Timing	Key Points
Introduction 5 minutes	1. Introduce the topic and science concepts that will be covered in this section. 2. Share any safety information. Clarify expectations about participation and breaks. 3. As a starting point, ask participants to rank their understanding of energy and related concepts using a scale of 1 to 5 or a series of emojis. Have participants share out their ranking using the scale of choice. This is a great time to ask for clarification on how they are feeling and what they are confused about. 4. The scientific definition of "energy" is the ability to do work. While that definition has a specific meaning, it does not encapsulate all the things we mean when we discuss energy. To better explain what we mean when we use the term energy, we will use the Making Meaning thinking routine from Project Zero. (See Appendix 2 for more information about Project Zero and an example.)
Making Meaning, Step 1 5 minutes	Divide participants into smaller groups of four to six people. On a whiteboard app or chart paper, have each person in the group contribute a single word about energy. Each word must be unique.
Making Meaning, Step 2 5 minutes	Have each small group participant add on to someone else's word with another word or short phrase.
Making Meaning, Step 3 10 minutes	The group will now make connections between the words and phrases by drawing lines between them and adding short explanations about why they are connected.
Making Meaning, Step 4 5 minutes	The group will add questions about the focus question, "What is energy?"

Timing	Key Points
Making Meaning, Step 5 5 minutes	On chart paper, each person will write their own answer to the question, "What is energy?" As more answers are shared, participants are encouraged to adjust their own answers or respond to others.
Wrap Up 5 minutes	Pull everyone back to the large group. From the answers provided, choose about three different answers to share. Ask the group how they feel about these answers, how they differ from their own, what they would add or take away, etc.

1.2 Types of Energy

20 minutes

Timing	Key Points
Energy Sort 5 minutes	1. Energy can be categorized as either kinetic or potential. Potential energy is stored energy that has the "potential" to cause action, while kinetic energy is moving energy. 2. In small groups, have participants categorize the following types of energy* as kinetic or potential: • Electrical • Thermal • Gravitational • Radiant (includes but is not limited to light) • Chemical • Nuclear • Elastic • Motion *This is not a comprehensive list.
Discussion of Energy Sort 15 minutes	1. Have participants share any energy type they were not sure where to place. Ask participants to provide a claim of where the energy should be placed, any evidence they have, and their reasoning about how the evidence supports their claim. next page →

Timing	Key Points
	2. Claim-evidence-reasoning: • A claim is a statement that answers a question or a problem. • Evidence is the data collected to support the claim. • Reasoning is a justification that connects the evidence to the claim. It's a logical explanation of how the evidence supports the claim, based on scientific rules or principles. 3. Participants may be wary of sharing for fear of not knowing all the answers. If this occurs, ask the group where they placed electrical energy. This is a large category that contains both kinetic energy, such as electricity (the movement of electrons), but also potential energy, like static electricity before it discharges, where the energy is based on the arrangement of the electrons. Tell them we will talk more about electricity in tomorrow's section. 4. It is not a problem if you don't know the answer to a specific question. We can work together to find an answer, or we may find a bigger question. 5. For the example energies given, the potential energy forms are gravitational, nuclear, elastic, and chemical. 6. The kinetic energy forms are motion (such as a motor), thermal (movement of atoms), and radiant (movement of electromagnetic waves).
Wrap Up	In elementary grades, we generally focus on kinetic energy because they have not reached the appropriate point to introduce the supporting chemical reactions and physics knowledge.

1.3 Measuring Kinetic Energy

60 minutes

Timing	Key Points
Introduction 5 minutes	1. Facilitate a discussion to answer, "What are some ways we measure kinetic energy? What are we actually measuring?" 2. Possible answers include: • Motion—speed • Thermal—degrees Celsius • Electricity—amps • Light—intensity • Sound—volume
Modeling Temperature 5 minutes	1. Each of these units is measuring a specific element. For example, thermal energy is based on how fast atoms are moving. If energy leaves the system, the atoms slow down. If energy enters the system, the atoms speed up. One example of this is the change between states of matter in water. You will use a video that shows children acting as a model. • Show this video: https://youtu.be/Fw_r0HzoAlw • Alternative video: https://youtu.be/kGO0AnqVmD0 2. After showing the video, debrief with the group about what the video models and any other observations they would like to share. 3. The kids are using a model where they act as water atoms. As energy is added to the system, they move faster and can spread out farther, but as energy leaves the system, they move slower and come closer together. 4. Some motion energy is similar in that it goes either faster or slower as energy is added or removed from the system. But some motion energy moves in waves, such as light and sound. 5. Other measurements, like electromagnetic waves and volume, measure the movement of particles in the air. This movement is represented as a wave, which can be drawn and measured.

Timing	Key Points
Measuring Sound 15 minutes	1. Volume and tone are actually measures of the compression of air particles. This compression and refraction pattern can be represented by waves. 2. Explain that to represent sound waves, we use an oscilloscope. Use an online oscilloscope with a live feed, such as https://academo.org/demos/virtual-oscilloscope/ 3. Make sure to allow microphone access and show what a speaking voice or many voices looks like on an oscilloscope. 4. Ask, “Does this readout mean anything to anyone?” Allow the groups some time to explore the tool to see if they can figure out what the different wave patterns mean. 5. Explain, we are going to continue to explore sound energy using the oscilloscope, but instead of using our voices, which can have many sounds at once, we will use single tones to explore. Let’s start with two different tones. Ask, “How do we keep this a fair test so we can see the effect of one variable?” 6. Switch to an oscilloscope with a keyboard, such as: • http://www.physics-chemistry-interactive-flash-animation.com/electricity_electromagnetism_interactive/oscilloscope_description_tutorial_sounds_frequency.htm • You will need to download the simulation in either .exe (Windows) or .app (Mac) and launch the simulation from your computer. In this simulation set both knobs (V/div and ms/div) to 1. 7. Play a low tone and show the oscilloscope pattern. Then play a higher tone. Ask: • What observations are there? • Which had more energy? • Why do we think that is? next page →

Timing	Key Points
	8. A higher tone means a higher frequency or the wave is moving faster. Like shaking a rope, it takes more energy to move something quickly than slowly.
Volume 5 minutes	1. Explain, now the group will look at volume. To have a fair test, we will change only the volume of the tone. Play a midrange tone at the current volume. Then turn up the volume and play the tone again. Ask: • What happened this time? • Did anything interest or surprise you? 2. Volume is the amplitude of the wave, or how large the wave is.
Measuring Electromagnetic Waves 20 minutes	1. The same rules about frequency and amplitude also apply to other forms of energy that move in waves, like water and light. When studying light, the frequency corresponds to types of electromagnetic waves. Visible light is in the middle of the spectrum, similar to the sounds we can hear. Within the visible light spectrum, we use the candela (cd) as a unit to measure luminous intensity. 2. In elementary grades, there is a lot of focus on the visible light spectrum, which is a very specific range of wavelengths. Ask: • What are some things we know about the visible light spectrum? (It reflects, it goes through clear items, etc.) • How do you think lowering the energy/making the waves slower would change the properties? • How do you think increasing the energy would change the properties? next page →

Timing	Key Points
	3. On the lower end of the electromagnetic wave spectrum, there are radio, microwave, and infrared waves. These waves have lower frequencies and thus less energy. Ask: • With less energy than the visible light waves, do you think these waves could be reflected using a mirror, like visible light? (Probably. These large waves do not have enough energy to travel through most mirrors. Instead, they bounce off like light.) • Do these lower energy waves have the potential to hurt humans? (Yes, but it takes a longer exposure time and intensity than higher frequency waves.) 4. On the higher end of the spectrum, there are X-rays, gamma, and ultraviolet rays that have more energy. Ask: • With more energy than the visible light waves, do you think these waves could be reflected using a mirror, like visible light? (Probably not. These waves have lots more energy and can move through objects more easily. There are still materials that block these waves, like lead and concrete.) • Do these higher energy waves pose a danger to humans? (Yes. Even limited exposure to the higher frequency waves can cause cell damage or change the DNA of cells, causing cancer.)
Questions 5 minutes	Address any questions the group may have about the content or ideas in general. If you are not able to answer them, have the participants place questions in the parking lot to be answered later.
Reflection 5 minutes	Learner Reflection Wrap up the session by having a general conversation to debrief the session as learners. Ask questions such as: • Any questions about the content covered in the session? • What new learning did you encounter today? • What misconceptions did you debunk today? next page →

Timing	Key Points
	Teacher Reflection Wrap up the session by having a general conversation to debrief the session as teachers. Ask questions such as: • Where can you tie these concepts back to the curriculum module? Address content and practices. • Any misconceptions that teachers may expect from their students on the science concepts covered in the session? Exit Ticket Ask participants to record their "sunshines and blues" for the day on yellow (sunshines) and blue (blues) sticky notes and add them to a piece of chart paper before leaving for the day.

CONTENT SESSION 2:

Electricity in the US

SESSION GOALS

- Define electricity as "the flow of electrons."
- Identify and address existing misconceptions.
- Identify resources used to generate electricity in the United States.
- Differentiate between methods that use electromagnetic induction and those that do not.
- Develop a model of the local electricity grid.
- Identify potential problems in getting electricity to people's homes.
- Identify possible solutions to identified problems.

AGENDA AND TIMING

Sections	Minutes	Materials/Notes
2.1 Electricity Basics	30 minutes	• Chart paper divided into Know • Wonder • Learned
2.2 Generation in the US	60 minutes	• 1 computer per pair
Break	10 minutes	
2.3 Problems and Solutions	20 minutes	• Chart paper • Markers

2.1 Electricity Basics

30 minutes

Timing	Key Points
Introduction 5 minutes	Share any safety information. Clarify expectations about participation and breaks.
Observing Lightning 5 minutes	1. You will show the video of slow-motion lightning multiple times. Play https://www.youtube.com/watch?v=y5M5bJeiwBk through to 24 seconds. next page →

Timing	Key Points
	2. The first time you show the video, ask participants to simply observe. After the first showing, ask a few questions about what is going on, like: • What does the video show? • What do you see? • With the knowledge that we are focusing on electricity, why are we watching this video? 3. Show the video again. This time ask participants: • What is happening? • Why do you think this is happening? 4. Have participants complete the Know and Wonder sections of the Know, Wonder, Learned (KWL) chart
Discovering Electricity 10 minutes	**Discovering Electricity** 1. Lightning is a form of electricity and it is the first form scientists studied. Records from Ancient Greece show 7th-century scientist Thales of Miletus studying to figure out what made lightning and if it could be recreated. He did manage to recreate the bolts in a smaller way by rubbing furry objects together. We now call this static electricity, which is what happens with lightning. 2. Show this video that explains how lightning happens: https://www.tiktok.com/@thephysicshouse/video/6906750424569679110?is_copy_url=1&is_from_webapp=v1 3. After the video, have participants update their KWL chart. 4. Introduce the teaching tip about the difference between top-down and bottom-up approaches. • The traditional way of teaching scientific terminology is the top-down approach. • The bottom-up approach provides students with an opportunity to observe the natural world. By identifying objects, comparing similarities and differences, categorizing them, and defining terminologies, students can better understand the scientific concepts. This is what scientists do, and it's also a strategy for ELL students.

Timing	Key Points
Key Electricity Points 5 minutes	1. Lightning can help us describe many aspects of electricity. Use the video and participants' prior knowledge to discuss whether electricity can be stored. 2. Key point 1: Electricity cannot be stored. It must be used in the moment. When we talk about storing energy, we are actually using the electricity to cause chemical changes in the case of a battery, or using the electricity to move things for future use. Part of the reason electricity cannot be stored is because it is the physical movement of electrons, which happens in the moment. 3. Key point 2: Electricity is the flow of electrons. Because electricity is the flow of electrons, electricity is directional. Electrons can be pulled using magnets (which we will discuss in a moment) or, in the case of static electricity, electrons move from an area of high electron concentration to an area with fewer electrons. 4. Key point 3: Electricity is directional.
Wrap Up 5 minutes	1. Have participants update their KWL chart. 2. While lightning is a strong form of static electricity, it is hard to predict and control. For the electricity we use at home, we rely on different methods to generate electricity: electromagnetic induction and chemical energy creation.

2.2 Generation in the US

60 minutes

Timing	Key Points
Generation Method Sort 5 minutes	1. In this professional development, we will stick to discussing electromagnetic induction methods because they are the main form of electricity generation used in the United States. 2. Have participants share ways they think electromagnetic induction is used to create electricity. 3. Wind, geothermal, coal, and hydropower are all used as energy sources to create electromagnetic induction. Biomass can be used for electromagnetic induction and can also be used on a small scale for chemical means of induction. Researchers are working on making that type of biomass fuel into a larger scale system.
What Is Electromagnetic Induction? 5 minutes	1. A small-scale electromagnetic induction generator, which participants should be familiar with from their module, is the hand generator. 2. Ask participants about their experience with hand generators in the classroom: • What do you do to make it work? • Any fun student observations? • What do you think is happening? 3. Show https://youtu.be/JwuO9XrH_aI?si=cKlpagYYja8s6Fig&t=203 3:23 through 4:03. This is a large model of what the components are in the hand generator. It is made of two permanent magnets and a coil of wire that is spun using the crank.

Timing	Key Points
Electromagnetic Induction Explained 5 minutes	This is a light explanation of how electromagnetic induction works. This could be turned into an entire graduate school course, but we're going to stick with the basics. • Electromagnetic induction is the process of creating an electrical current (moving electrons) by moving a coil of wire through magnets. • There is a coil of copper wire inside the magnetic field of the permanent magnets. • The copper wire is full of free electrons that move if they are pulled or pushed. • Each electron has a magnetic moment, due to the spin of the electron. Each electron has either a northern or a southern moment, represented by N or S. • As the coil or the magnets move, the electrons are pushed away from the same magnetic force or pulled toward the opposing magnetic force. These pushes and pulls cause the electrons to shift, creating a flow of electrons, which is electric current.
Large-Scale Electromagnetic Induction 5 minutes	1. Electric generator plants work the same way as the small hand generators but have many more coils of wire and are turned by more powerful forces than hand cranks. They also tend to have electromagnets instead of permanent magnets because it is hard to find magnets that are large enough or powerful enough to create a magnetic field large enough for the size of the coils. 2. In the large generators the handle is replaced by a turbine or rotor. This is what the kinetic energy source pushes against.

Timing	Key Points
Generation Systems 10 minutes	1. Introduce the idea of a system. Ask, "What is a system?" • "System" is a very important concept in science, and it is a concept that is widely used and implemented in scientific concepts as well as in the procedure of doing science, technology, engineering, and math—which is called a crosscutting concept (CCC) in NGSS. • Show a short video about systems: https://www.youtube.com/watch?v=vyldH1qExsc through 4:33. • Explain what a system is, the boundaries of a system, and the components and interactions of a system. 2. In breakout groups, groups of participants will research how one energy resource is used to create electricity, then give a brief overview to the whole group. 3. All the systems are similar in that energy is used to turn an axle to rotate either the copper coils or an electromagnet. However, some energies directly turn a turbine or an axle, while others are burned to turn water into steam, which then turns a turbine. 4. After each group has presented, help the groups debrief to find similarities, differences, and interesting features.
What Fuels Am I Using? 5 minutes	1. Using https://www.epa.gov/egrid/power-profiler#/SRVC or a similar site, have participants find out what fuels are used in their area. Ask: • Does this information surprise you or is it expected? • How does your usage compare to the national averages or to local communities? 2. Both North Carolina and South Carolina are served by Dominion Energy, which has additional resources at: https://www.dominionenergy.com/our-company/making-energy

Timing	Key Points
How Is Electricity Distributed? 10 minutes	1. As discussed earlier, electricity cannot be stored. It must be used immediately. The United States uses a system made up of power plants, transmission lines, substations, and distribution lines to distribute electricity as needed. 2. Show https://youtu.be/nbPmsBmo03Y. 3. The grid needs to be carefully balanced. Too much electricity and elements could overload and break. Too little and there is not enough for the customers, causing brownouts or blackouts. 4. To prevent damage, power plants regularly update their technology and security. Generators used to be controlled by switches, knobs, and dials. Current power plants are controlled by a bank of computers to carefully monitor electricity on the grid and respond quickly to changes.
Your Grid 10 minutes	1. The US grid is made up of smaller, regional grids. Generally, the regional grids do not interact much with one another, but they can be used to balance each other out if there is a problem at a power station or other elements of the grid. 2. Use https://www.eia.gov/state/maps.php to have participants explore their local grid. Start by removing all layers and then marking all the power stations. 3. Ask participants to use this tool and their observations to draw a basic model of their local grid system by identifying the components and interactions between them. 4. Have participants share their system models and ask: • Do the stations you see match the fuel your area is using from the earlier discussion? • What patterns do you notice in power station placement?

Timing	Key Points
Grid Alternatives 5 minutes	1. Ask, "Does this mean every business and residence in the United States uses electricity from the grid? What about people who are not near cities or do not agree with the power stations using fossil fuels?" 2. There are options for how you interact with the grid. Most people in the US are just on the grid. They use the power from the grid and try to control their electricity use through small steps like turning off lights, using LEDs, smart thermostats, etc. 3. Net zero is when your individual property is able to generate all the power you need but you are still connected to the grid for safety reasons, not being able to make electricity at certain times (like night), convenience, etc. 4. Being off grid means your property cannot receive electricity from the grid, and you must make all the electricity you need. Someone might be off grid because of their physical location and inability to connect, or because of their personal opinions and beliefs.

2.3 Problems and Solutions

20 minutes

Timing	Key Points
Identifying Problems 5 minutes	1. Have breakout groups identify problems with the current system on chart paper. Some problems might include: • Physical breakage of grid components • Too much electricity generation • Too little electricity generation • Moral opposition to fuels used • Lack of fuels 2. Have groups share out their ideas and synthesize a few problems for brainstorming solutions.

<table>
<tr><th>Timing</th><th>Key Points</th></tr>
<tr><td>Identifying Solutions
5 minutes</td><td>1. Using the same chart paper, have participants brainstorm solutions for these problems.

2. Examples could include:
Physical breakage of grid components
Put components underground
Make components stronger
Lack of fuels
Diversify fuel options
Connect with more areas
3. These are the types of problems electric companies work to solve every day. A solution that might work in one area may not work in another, and a solution could lead to new problems.</td></tr>
<tr><td>Questions
5 minutes</td><td>Address any questions the group may have about the content or ideas in general. If you are not able to answer them, have the participants place questions in the parking lot to be answered later.</td></tr>
<tr><td>Reflection
5 minutes</td><td>Learner Reflection

Wrap up the session by having a general conversation to debrief the session as learners. Ask questions such as:
Any questions about the content covered in the session?
What new learning did you encounter today?
What misconceptions did you debunk today?
This is also a good time to revisit and update the KWL chart one last time.

Teacher Reflection

Wrap up the session by having a general conversation to debrief the session as teachers. Ask questions such as:
How confident are you feeling about the science concepts underlying the module How Can We Provide Energy to People's Homes?
Where can you tie these concepts back to the curriculum module? Address content and practices.
Any misconceptions that teachers may expect from their students on the science concepts covered in the session?
Any other general questions?</td></tr>
</table>

REFLECTIONS

Before this session, consolidate the misconceptions from the first day into a number appropriate for your group.

SESSION GOALS

- Identify common misconceptions in student work.
- Increase understanding of where misconceptions come from and grow.
- Categorize student misconceptions based on their origin and impact on student learning.

Timing	Key Points
Addressing Misconceptions 30 minutes	1. Refer back to the misconceptions that were collected in the first session. 2. Break into small groups and have each group select a misconception to work on. 3. Give the groups time to discuss the misconceptions, what factors are part of the misconception, and how they might address it in the classroom based on their experiences during the content sessions or other resources they may have access to. Ideally groups are leveraging activities from their Smithsonian Science for the Classroom modules. 4. Have groups share out.
Grade Level Planning 15 minutes	Discuss what the next school year looks like, including when teachers might implement the lessons, what testing is upcoming, if there are any interesting resources available, etc.
Exit Ticket	Ask participants to record their “sunshines and blues” for the day on yellow (sunshines) and blue (blues) sticky notes and add them to a chart paper before leaving for the day.

APPENDIX 1: SCIENCE STANDARDS

NORTH CAROLINA SCIENCE ESSENTIAL STANDARDS

4.P.3.1 Recognize the basic forms of energy (light, sound, heat, electrical, and magnetic) as the ability to cause motion or create change.

4.P.3.2 Recognize that light travels in a straight line until it strikes an object or travels from one medium to another, and that light can be reflected, refracted, and absorbed.

SOUTH CAROLINA COLLEGE- AND CAREER-READY SCIENCE STANDARDS 2021/NEXT GENERATION SCIENCE STANDARDS

4-PS3-1 Use evidence to construct an explanation relating the speed of an object to the energy of that object.

4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS4-1 Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.

4-ESS3-1 Obtain and combine information to describe that energy and fuels are derived from natural resources and how their uses affect the environment.

4-ESS3-2 Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

APPENDIX 2: PROJECT ZERO— MAKING MEANING

Project Zero is a group at the Harvard Graduate School of Education. The mission of Project Zero is to understand and enhance learning, thinking, and creativity for individuals and groups in the arts and other disciplines; essentially studying how people learn and what systems of thinking can increase understanding and use.

Through years of research, Project Zero has identified a series of practices that help individuals show their thought process and collaborate with others as they learn. In this professional development, we use the Making Meaning thinking routine, as described in the book *The Power of Making Thinking Visible*. Other routines can be found at: http://www.pz.harvard.edu/thinking-routines.

The Making Meaning thinking routine is intended to have participants engage with one another to develop a meaning for a concept, idea, or topic by engaging in a five-step process.

Step 1: Each person in the group responds to the chosen idea with one word. Words can only be added once.

Step 2: Individuals add an additional word or phrase to the existing words to elaborate on the current ideas.

Step 3: Working together, the group draws lines or otherwise indicates connections between words. Short phrases can be added to help show connections.

Step 4: Individuals add questions about the topic or current connections.

Step 5: Individuals create their own definition in response to the concept, idea, or topic. Individuals share their definitions with the whole group.

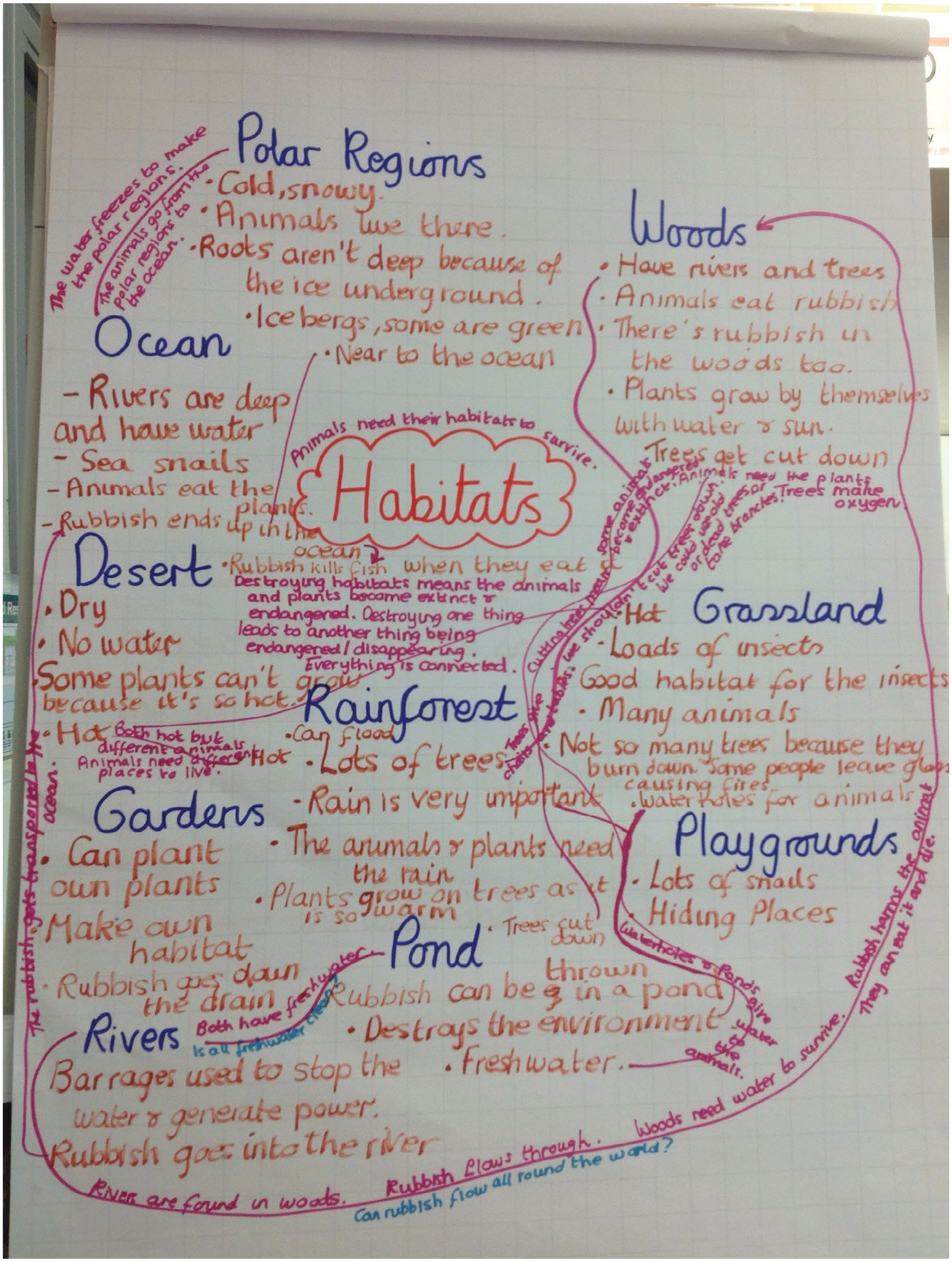

Figure 1. Making Meaning thinking routine example (Credit: Nicola Moloney (@PYPNicola) Twitter, https://twitter.com/PYPNicola/status/877229963136692225/photo/1).

REFERENCES

Keeley, Page. (2012). Misunderstanding Misconceptions. *Science Scope*, *35*(8), 12-15. Retrieved from https://static1.squarespace.com/static/5f09c80930b545063d089cc6/t/6170b127b00027733b5f07fc/1634775336010/Misunderstanding+Misconceptions.pdf

Project Zero. (2022). *Project Zero's Thinking Routine Toolbox*, Harvard Graduate School of Education. https://pz.harvard.edu/thinking-routines

www.ssec.si.edu

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