Lesson 1: How do microwave ovens function, and why does their structure affect wireless signals?

Previous Lesson *There is no previous lesson.*

This Lesson

Anchoring Phenomenon

3 days

We read an article about an interesting trend--people are storing their phones, keys, and other electronic devices in their microwave ovens. We observe a Bluetooth speaker paired to a device playing music inside a closed microwave oven and notice that the sound skips. We read the Microwave Oven Manual, and then safely heat food and make additional observations. We make initial individual models, and revise them based on peer feedback. We create an initial consensus model, build a Driving Question Board, and brainstorm future investigations and data we need.

Next Lesson *We will study the Microwave Oven Manual and infer that the oven's magnetron produces microwave radiation. We will watch a video, read about the magnetron, and use energy transfer models to connect new ideas about fields to our prior understanding. We will wonder how the changing electric fields connect to waves, and decide to investigate waves.*

BUILDING TOWARD NGSS

HS-PS2-5, HS-PS4-1, HS-PS4-2, HS-PS4-3, HS-PS4-4, HS-PS4-5, HS-ESS2-4

What students will do

1.A Develop and revise a model of a microwave oven that explains how the components of the system function to heat liquid/food, and how and why these structures could affect a Bluetooth signal. (SEP: 2.3; CCC: 6.2; DCI: PS4.B.2, PS4.C.1)

1.B Ask questions and brainstorm investigations about the structure and function of technologies and phenomena that rely on electromagnetic radiation to transfer energy. (SEP: 1.4, 3.1; CCC: 5.2, 6.2; DCI: PS4.B.2, PS4.C.1)

What students will figure out

- The structure of a microwave oven blocks or somehow affects wireless signals, but not completely.
- The function of a microwave oven is to heat (transfer energy into) liquid/food.

- Using a microwave oven requires attention to safety.

Lesson 1 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	10 min		**NAVIGATE: INTRODUCE THE ANCHOR PHENOMENON AND CONDUCT DEMONSTRATION #1** Present an article about how people are storing phones, keys, and other electronic devices in their microwave ovens. Make observations of a speaker paired to a device that is inside an unplugged microwave oven.	A-C	"*Microwave Storage*", Demo #1: Playing Music Through a Microwave Oven
2	10 min		**MOTIVATE THE SECOND DEMONSTRATION AND DISCUSS SAFETY** Talk about the function of a microwave oven to motivate observing it while it is running. Discuss possible risks.	D-E	
3	15 min		**READ THE MICROWAVE OVEN MANUAL AND DEBRIEF** Direct students to read the *Microwave Oven Manual*. Discuss safety precautions for running the microwave oven. Elicit initial ideas from the manual.	F-H	*Microwave Oven Manual*, colored pens (red and blue), chart paper, chart markers
4	10 min		**CONDUCT DEMONSTRATION #2 AND NAVIGATE TO THE NEXT CLASS PERIOD** Heat a plate of nachos inside the microwave oven and make observations. Navigate by forecasting modeling.	I	Demo #2: Heating Nachos in a Microwave Oven
					End of day 1
5	12 min		**NAVIGATE AND CREATE INITIAL MODELS** Direct students to create initial models of the microwave oven system individually.	J	
6	13 min		**EXCHANGE PEER FEEDBACK ON INITIAL MODELS** Have students switch models with a partner and fill out the *Initial Modeling Peer Feedback* handout. Direct them to give, receive, and incorporate feedback with their partner.	K-M	*Initial Modeling Peer Feedback*, colored pens (green and red and purple), 1" x 1" sticky notes, M-E-F poster (created in *Earth's Interior Unit*)
7	15 min		**BUILD THE INITIAL CONSENSUS MODEL** Develop an initial consensus model in a Scientists Circle. Elicit ideas about system components and then about energy, forces, and matter changes.	N	chart paper, colored markers (purple and green and red)

8	5 min	**NAVIGATE: ASSIGN HOME LEARNING** Assign the task of asking friends and family about their experiences with microwave ovens and wireless technology.	O	*L1 Home Learning*
				End of day 2
9	8 min	**NAVIGATE: BROADEN TO RELATED PHENOMENA** Debrief the home learning. Create a poster of phenomena related to wireless signal distortion and microwave ovens.	P	*L1 Home Learning*, chart paper, chart markers
10	10 min	**BROADEN TO RELATED TECHNOLOGY** Consider why a microwave oven is unique. Brainstorm and keep track of related technology.	Q-R	Initial Consensus Model poster, chart paper, chart markers
11	15 min	**DEVELOP THE DRIVING QUESTION BOARD** Write initial questions for the Driving Question Board individually, then build the DQB as a class.	S-T	3” x 3” sticky notes, permanent marker (black), chart paper, chart markers, Initial Consensus Model poster
12	10 min	**CONSIDER IDEAS FOR FURTHER INVESTIGATIONS AND DATA** Brainstorm ideas for investigations and data that will help answer our questions about microwave ovens and related technology. Create a poster of these ideas.	U	chart paper, chart marker
13	2 min	**NAVIGATE WITH AN EXIT TICKET** Complete an exit ticket about structure and function.	V	piece of 8.5” x 11’ paper for exit ticket
				End of day 3

Lesson 1 • Materials List

	per student	per group	per class
Demo #1: Playing Music Through a Microwave Oven materials		• microwave oven • Bluetooth speaker paired to a device that can play music	
Demo #2: Heating Nachos in a Microwave Oven materials			• microwave-safe plate • 1 cup of tortilla chips • 1 cup of shredded cheese • microwave oven • infrared thermometer • oven mitts • indirectly vented chemical splash goggles • science notebook • Precautions Before Using the Microwave Oven poster
Lesson materials	• "*Microwave Storage*" • science notebook • *Microwave Oven Manual* • colored pens (red and blue) • *Initial Modeling Peer Feedback* • colored pens (green and red and purple) • 1" x 1" sticky notes • *L1 Home Learning* • 3" x 3" sticky notes • permanent marker (black) • piece of 8.5" x 11' paper for exit ticket		• chart paper • chart markers • M-E-F poster (created in *Earth's Interior Unit*) • colored markers (purple and green and red) • Initial Consensus Model poster • chart marker

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to students' notebooks.

Review the unit front matter for an overview of how disciplinary core ideas, crosscutting concepts, and science and engineering practices are developed in this unit.

If you would like to elicit suggestions for what music to play during the first demonstration, gather ideas before class so you can vet them ahead of time to make sure the songs are appropriate for the classroom.

Prepare chart paper for the posters you will make in this lesson:

- Precautions Before Using the Microwave Oven
- Related Phenomena and Technology
- Initial Consensus Model
- Ideas for Data and Investigations We Need
- Driving Question Board

Make sure the class Community Agreements poster (created in *OpenSciEd Unit P.1: How can we design more reliable systems to meet our communities' energy needs? (Electricity Unit)*) is hung where students can see it. If you are teaching this unit without having developed these agreements yet, spend at least 15 minutes developing them as described in *Electricity Unit*. This scaffold is not referenced explicitly here because this unit falls near the end of the Physics course, but it should be available for reference in case students encounter interpersonal conflict or need to be reminded of an agreement that is not being followed.

Make sure the Matter, Energy, and Forces (M-E-F) poster (created in *OpenSciEd Unit P.2: How forces in Earth's interior determine what will happen to its surface? (Earth's Interior Unit)*) is hung where students can see it. If you are teaching this unit without having developed this resource yet, we recommend creating one as described in *Developing the M-E-F Poster*.

Day 1: Demo #1, Playing Music Through a Microwave Oven

- **Group size:** Whole class.
- **Setup:** You will need to provide a device (e.g., a computer, smartphone, tablet, or such) capable of pairing to a Bluetooth speaker. If the device is too large to fit in the microwave oven (e.g., a desktop computer), you can conduct the demonstration by putting the speaker in the oven instead. Establish the connection between the speaker and the device before class, and test the demo procedure ahead of time to determine when students will notice the sound interference. You may need to move the speaker more than 10 feet away from

the oven to produce a noticeable effect.

- **Safety:** Keep the microwave oven unplugged for this demo to ensure that nobody accidentally turns it on, which would destroy the device and possibly the oven.

Any electrical power cords used near water must be plugged into a GFCI-protected circuit. A GFCI temporary power cord or power strip must be provided for this use.

- **Storage:** Unplug the microwave oven when not in use, and store it where students cannot access it.

Day 1: Demo #2, Heating Nachos in a Microwave Oven

- **Group size:** Whole class.
- **Setup:** Gather chips and cheese or similar food items. Ensure students are able to view the containers before and after the food is heated in the microwave oven.
- **Safety:** Use oven mitts when handling anything that has been in the microwave oven. Use indirectly vented chemical splash goggles when removing hot food or drinks from the oven. Keep students who are not wearing protective equipment at a safe distance (a minimum of 15-20 feet) from the food until it is cool.

Any electrical power cords used near water must be plugged into a GFCI-protected circuit. A GFCI temporary power cord or power strip must be provided for this use.

- **Disposal:** Throw away all food after the lab. Water can be poured down the drain.
- **Storage:** Unplug the microwave oven when not in use, clean the inside after the lab, and store it where students cannot access it. Clean any plates and containers and store them in the classroom.

Lesson 1 • Where We Are Going and NOT Going

Where We Are Going

Because this is the first lesson in a new unit, the goal is not to establish any ideas associated with the relevant DCIs (PS4), but rather to elicit student ideas related to that DCI. The DCI elements that students will be thinking about in this lesson include:

- **PS4.B.2** When ~~light or longer wavelength~~ electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). ~~Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.~~ (HS-PS4-4)
- **PS4.C.1** Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world ~~(e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them~~. (HS-PS4-5)

This lesson presents students with an opportunity to apply their ideas about waves and energy transfer to explain how a microwave oven heats liquid/food, and whether radiation can cause harm to humans. It sets the stage for students' initial models and questions that will motivate further explorations into these and related phenomena.

Although all students should be familiar with a microwave oven, it is possible that some have not experienced firsthand how various foods heat up in this device. For this reason, the demonstrations provide a shared example of energy transfer within a microwave oven and elicit other student experiences with heat transfer. Students should already have an understanding of energy transfer and modeling tools to create energy transfer diagrams (as developed in *Electricity Unit*). They should also understand that waves transfer energy, and that the waves' speed is affected by the medium they are passing through (ideas developed in *Earth's Interior Unit*). In the first lesson set of this unit, we review various characteristics of waves that will help students understand how electromagnetic waves work.

Students encounter several terms in this lesson: *antenna, Bluetooth, wireless, microwave oven, microwave radiation*, *electromagnetic radiation, arc.* It is OK to let students use these terms imprecisely in this lesson, as they try them out and share their experiences. Over the next several lessons, we will co-develop meanings for these words. **Do not** ask students to define or keep track of any words in their Personal Glossaries until after your class has developed a shared understanding of their meaning.

Throughout this unit, the materials use the phrase "heating up" in the microwave oven, which is an imprecise term. This was an intentional choice, to support student sensemaking by using everyday language. Though professional scientists and engineers might prefer to use terms such as a rise in temperature or an increase in average kinetic energy, encouraging the use of everyday and hybrid language lowers the barriers for students from diverse linguistic backgrounds to engage in scientific discourse and complex sensemaking. "Heat" is not used as a noun in this unit, only as a verb to denote what we observe when thermal energy transfers.

Where We Are NOT Going

Some students may have heard about radiation as something dangerous. One goal of this lesson is to surface those ideas, not to refute them. Students may or may not know that there are many different types of radiation. Accept all ideas about radiation and risk at this point. In this unit, we will focus only on electromagnetic radiation, not radioactivity.

LEARNING PLAN for LESSON 1

1 · NAVIGATE: INTRODUCE THE ANCHOR PHENOMENON AND CONDUCT DEMONSTRATION #1

10 min

MATERIALS: Demo #1: Playing Music Through a Microwave Oven, "*Microwave Storage*", science notebook

Introduce a new phenomenon with a short reading. Tell students you have an article about an interesting trend: people are storing their phones, keys, and other electronic devices in their microwave ovens.

Present **slide A**. Distribute a copy of "*Microwave Storage*" to each student and give them 5 minutes to read it. Elicit 1-2 ideas about the prompt on the slide:

- *Why would someone want to put their phone or car keys in a microwave oven?*

Listen for students to suggest that the microwave oven blocks or otherwise affects electronic signals, such as Wi-Fi and Bluetooth.

Suggest that we could put a phone or other device in a microwave oven and try to connect to it from outside the oven. Show students the Bluetooth speaker and the device you have chosen to play music. Make sure the device and the speaker are paired properly, and get ready to play a song. ✱

Turn and talk to make predictions. Present **slide B**. Ask students to turn and talk about the prompts:

- *What do you predict will happen when we try to connect to the device while it is inside the microwave oven (when it is off)?*
- *What experiences or ideas support your prediction?*

Elicit 1-2 ideas. Accept all ideas.

Make Notice and Wonder charts. Present **slide C**. Direct students to make a T-chart in their science notebook as shown. Tell them we will use this chart to keep track of all our observations and wonderings as we explore this new phenomenon.

Play music over the wireless connection and record observations. Place the device in the microwave oven and play music so it connects to the speaker. Keep the speaker outside the oven and close the oven door. Move the speaker around the outside of the oven, and then slowly move it away. You should begin to hear more skips and jumps in the sound as you move farther away. Have students record their observations in their chart.

✱ ATTENDING TO EQUITY

Relevance: Give students the opportunity to bring their authentic selves into the science classroom by eliciting suggestions for what music to play. Gather ideas before class so you can vet them ahead of time to make sure the songs are appropriate for the classroom. Allow students to enjoy the music for a minute before asking them to make observations.

SAFETY PRECAUTIONS	**Do not run the microwave oven when there is an electronic device inside.** To avoid any accidents, unplug the oven from the power source before the demonstration.

2 · MOTIVATE THE SECOND DEMONSTRATION AND DISCUSS SAFETY

10 min

MATERIALS: science notebook

Turn and talk to motivate running the microwave oven. Present **slide D**. Ask students to turn and talk about the prompt:

- *What do you know about how microwave ovens function to heat food that could help explain why the structure of a microwave oven affects wireless signals?*

After a minute, elicit 1-2 initial ideas. Accept all ideas. Listen for students to mention waves, electronics, radiation, or heat. If they mention anything about safety or risks associated with the microwave oven, highlight these ideas by saying, *Has anybody else heard that microwave technology might have risks?*

Navigate to the next slide by saying, *Before we turn the oven on, let's pause to consider any safety risks.*

SAFETY PRECAUTIONS	**Do not do the demonstration yet.** Do not use the microwave oven in the classroom until students have read and understood the manual.

Discuss possible risks. Present **slide E**. Elicit 1-2 ideas in response to the prompts:

- *What experiences or ideas do you have that suggest microwave technology might pose a risk?*
- *Where could we find more information about how to use this microwave oven safely?*

Encourage students to add any questions to their Notice and Wonder chart. This will ensure that questions about the potential risks of using a microwave oven end up on the Driving Question Board. Then say, *We take safety very seriously. Any time we work with something electronic, the best way to find out how to use it safely is to read the manual.*

3 · READ THE MICROWAVE OVEN MANUAL AND DEBRIEF

15 min

MATERIALS: *Microwave Oven Manual*, colored pens (red and blue), chart paper, chart markers

Read and annotate the manual in partners. Distribute a copy of the *Microwave Oven Manual* to each student. Present **slide F**. Review the close reading protocol:

- *In red, underline the safety precautions we should always follow when using the microwave oven.*
- *In blue, circle ideas that could help us figure out how the microwave oven functions, and why it affects wireless signals.*
- *Record any wonderings that the manual raises for you on your Notice and Wonder chart.*

Give students 10 minutes to read through the manual with a partner and make annotations. Make sure they put the manual in their notebooks, as it will be a valuable reference throughout this unit.

Discuss safety precautions. Present **slide G**. Ask students what they figured out from the manual about any safety precautions we should take. Title a piece of chart paper "Precautions Before Using the Microwave Oven" and create a public record of their ideas. This poster should remain visible for the rest of the unit and be added to when new safety concerns arise.

Make sure the following ideas are on the poster in some form before moving on:

- Never run the microwave oven empty.
- Never run the microwave oven with the door open.
- Always run the microwave oven with something that you know will absorb the energy.
- Anything we put in the microwave oven needs to be microwave-safe.
- Be careful not to burn yourself on something you have put in the microwave oven.
- Use safety goggles and oven mitts when removing hot things from the microwave oven.

Elicit initial ideas from the manual. Present **slide H**. Elicit student ideas and wonderings based on the manual, using the prompts on the slide:

- *What ideas could help us figure out how the microwave oven functions, and why it affects wireless signals?*
- *What else in the manual do you notice/wonder about?*

Listen for ideas, noticings, and questions related to the following:

- It is safe to use small pieces of aluminum foil inside the microwave oven.
- It is important that food has some moisture to absorb the energy from the microwave oven.
- Electromagnetic radiation is in the microwave oven.

Suggest that we run the oven and make more observations, now that we know how to do so safely.

ADDITIONAL GUIDANCE	Students may be confused by the term *microwave*, as it is often used to mean "microwave oven." In this unit, the appliance is referred to as a *microwave oven*, and the electromagnetic waves as *microwave radiation*. We recommend modeling this terminology in class to help students make that distinction. If they use the word *microwave* ambiguously, help them clarify their thinking with a question such as, *When you say "microwave," are you talking about the microwave oven, or about the microwave radiation that is referred to in the manual?*

4 · CONDUCT DEMONSTRATION #2 AND NAVIGATE TO THE NEXT CLASS PERIOD

10 min

MATERIALS: Demo #2: Heating Nachos in a Microwave Oven

Prepare a plate of nachos. Fill a microwave-safe plate with chips and top them with cheese. Place the plate in the microwave oven and close the door. Ask students whether they feel we have addressed all the safety precautions on our poster. Listen for them to point out that we are not running the oven empty, and in particular, that cheese seems to have some moisture, although chips are dry.

Run the oven and make observations. Present **slide I**. Hand out indirectly vented chemical splash goggles and have students gather around the oven with their notebooks, at least 10 feet from the oven door to prevent burns from splatter if the cheese is hot when the nachos come out. Run the oven for 30 seconds. Direct students to record their observations in their Notice and Wonder charts.

Wearing oven mitts, take the plate of nachos out of the oven. Use a thermometer to make sure the temperature of the cheese is below 130 degrees Fahrenheit before letting students look more closely.

SAFETY PRECAUTIONS

Do not run the microwave oven empty. Do not run it for more than 30 seconds at a time. To prevent burns, use oven mitts when taking items out of the oven. Use a thermometer to make sure the temperature of anything that has been heated is below 130 degrees Fahrenheit before letting students approach.

Navigate by forecasting modeling. Before students leave, say that in the next period, we will make a model of the microwave oven that can explain our observations.

End of day 1

5 · NAVIGATE AND CREATE INITIAL MODELS

12 min

MATERIALS: science notebook

Navigate. Ask students to briefly look back in their notebooks at their observations, noticings, and wonderings. Elicit 1-2 ideas of observations that we are puzzled by. Then say, *Let's see if we can make a model that will explain our observations and help us understand what we still need to know.*

Create initial models. Present **slide J**. Read the directions aloud: *Make a model of the parts and interactions in the system that will explain:*

- *how the microwave oven heats liquid and food*
- *why the music was affected when the device was inside the microwave oven, especially when the speaker was farther away*

Give students 10 minutes to work on their models individually in their notebooks.

6 · EXCHANGE PEER FEEDBACK ON INITIAL MODELS

13 min

MATERIALS: science notebook, *Initial Modeling Peer Feedback*, colored pens (green and red and purple), 1" x 1" sticky notes, M-E-F poster (created in *Earth's Interior Unit*)

Use the handout to evaluate a partner's models. Distribute a copy of the *Initial Modeling Peer Feedback* handout, colored pens, and sticky notes to each student. Direct them to switch models with a partner to provide peer feedback. Point out the M-E-F poster as a reference.

Present **slide K** and then **slide L**, reading the directions aloud:

- *What frames (matter, energy, forces) did your partner use to develop their model? Do you agree with the way your partner applied these frames? Where you agree, place a small check on the model to indicate a change in matter (red ✓), a transfer of energy (green ✓), or evidence of forces (purple ✓).*
- *How well does your partner's model explain how the microwave oven functions to heat liquid and food? How well does your partner's model explain why the music was affected when the device was inside the microwave oven, especially when the speaker was farther away? Use sticky notes to indicate the areas where you have questions, and write your specific questions on the sticky notes.*

Give students about 7 minutes to provide feedback using the handout.

Give, receive, and incorporate feedback. Present **slide M**. In partners, have students take turns discussing the feedback they gave and listening carefully to their partner's feedback, for about 5 minutes. Then, have students work individually to incorporate the feedback into their own models.

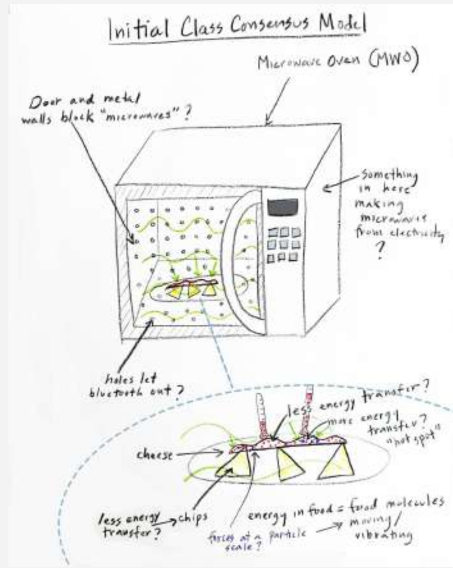
ASSESSMENT OPPORTUNITY	**What to look for/listen for in the moment:** Listen and look for students to give feedback specifically around matter, energy, and forces in the model, and then focus on these elements in their revision (SEP: 2.3): • matter changes (liquid/food heating up) (DCI: PS4.B.2) • energy transfer (into liquid/food, maybe through waves, radiation, or particles) (DCI: PS4.B.2) • forces (most likely, that they are missing from the model) **What to do:** Move around the room and use probing questions to clarify students' ideas about matter, energy, and forces. **Building toward: 1.A.1** Develop and revise a model of a microwave oven that explains how the components of the system function to heat liquid/food, and how and why these structures could affect a Bluetooth signal. (SEP: 2.3; CCC: 6.2; DCI: PS4.B.2, PS4.C.1)

7 · BUILD THE INITIAL CONSENSUS MODEL

15 min

MATERIALS: chart paper, colored markers (purple and green and red)

Form a Scientists Circle. Present **slide N**. Title a piece of chart paper "Initial Consensus Model". Remind students what we want our model to explain: how the microwave oven heats liquid and food, and also why the music was affected when a wireless device was inside the oven, especially when the speaker was farther away.



Elicit ideas about components. Begin developing the consensus model by asking students about the components of the microwave oven that they included in their models. After a student shares, ask the rest of the class whether they agree that the component should be included. If there is consensus, sketch that component on the poster. If not, indicate this with question marks on the poster.

Elicit ideas about energy transfer and forces. Once the important components of the system are sketched out (e.g., the oven's basic structure, the electric cord, something electronic behind the keypad, and so forth), ask students about the interactions they represented in their models:

- Clarify after each suggestion whether they are describing energy or forces, or aren't sure.
- Use **purple** to represent forces and **green** to represent energy, to match the M-E-F model built previously.
- When students describe how these interactions change matter (heating, deforming, and so forth), use **red** to show how the matter changes.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Listen for students to suggest the following components and interactions as part of the model (SEP: 2.3):

- a structure that is creating microwave radiation inside the microwave oven (CCC: 6.2; DCI: PS4.C.1)
- liquid/food heating up, represented as energy transfer or particles of matter speeding up (the function of the microwave oven) (CCC: 6.2; DCI: PS4.B.2)

What to do: If the model is missing components that explain how the oven heats liquid/food, ask students to consider how the device's structure might determine how it performs that function. If the model is missing an explanation of what is affecting the Bluetooth signal, ask students how the function of the microwave oven might determine what its structures are.

Building toward: 1.A.2 Develop and revise a model of a microwave oven that explains how the components of the system function to heat liquid/food, and how and why these structures could affect a Bluetooth signal. (SEP: 2.3; CCC: 6.2; DCI: PS4.B.2, PS4.C.1)

8 · NAVIGATE: ASSIGN HOME LEARNING

5 min

MATERIALS: *L1 Home Learning*

Assign home learning. Present **slide O**. Distribute a copy of the *L1 Home Learning* to each student, and go over the prompts before they leave:

- *Ask your friends and family about their experiences with microwave ovens and wireless technology.*
    - *What ideas or questions do they have about microwave technology?*
    - *Do they prefer to cook with a microwave oven, or with a different device? Why?*
    - *What other experiences have they had of a wireless signal being distorted?*

End of day 2

9 · NAVIGATE: BROADEN TO RELATED PHENOMENA

8 min

MATERIALS: *L1 Home Learning*, chart paper, chart markers

Debrief the home learning and record related phenomena. Present **slide P**. Pose the prompts to debrief the home learning:

- *What related phenomena have we experienced or heard about in which a wireless signal is distorted?*
- *What other phenomena related to microwave ovens have we experienced or heard about?*

On a piece of chart paper, create a T-chart with the left column titled “Related Phenomena”. Leave the right column blank; it will eventually be titled “Related Technology”. As students share out, make a public record on the chart.

10 · BROADEN TO RELATED TECHNOLOGY

10 min

MATERIALS: science notebook, Initial Consensus Model poster, chart paper, chart markers

Motivate a closer look at the technology. Present **slide Q**. Use the prompts to have students consider what technology makes microwave ovens unique:

- *Would another type of cooking device affect a wireless signal the same way as the microwave oven? Why or why not?*
- *Add any wonderings that come up to your Notice and Wonder chart.*

Point students to the Initial Consensus Model poster for ideas. Accept all ideas at this point, but highlight ideas about radiation, light, or energy transfer.

Brainstorm and record related technology. Present **slide R**. Title the right side of the T-chart poster "Related Technology", and use the prompts on the slide to complete it with students' ideas:

- *What are some other human-made technologies that you think might use similar structures or mechanisms to function?*
- *How do you know?*

Your completed poster may look something like the image at the right.

11 · DEVELOP THE DRIVING QUESTION BOARD

15 min

MATERIALS: science notebook, 3” x 3” sticky notes, permanent marker (black), chart paper, chart markers, Initial Consensus Model poster

Develop questions for the DQB. Present **slide S**. Distribute 3” x 3” sticky notes and a permanent marker to each student. Ask students to develop questions on the stickies for the DQB on their own, using the resources listed on the slide.

Build the DQB. Gather students in a Scientists Circle and hang a piece of chart paper where everyone can see it. Present **slide T**. Tell students they will take responsibility for facilitating the process of building the DQB. Ask for a volunteer to start the process, following the directions on the slide to elicit questions and put them on the chart paper. Assign 1-2 students to take on the role of choosing new volunteers and keep up the momentum if the process slows. Listen while the class builds the DQB.

Title the DQB. Once everyone has contributed to the DQB, ask, *Can we articulate a main question that we will answer by investigating all these questions?* Listen for ideas like “How does technology that uses radiation work?” or “Why does the structure of a microwave oven block wireless signals?”

When a potential driving question arises, repeat it aloud, and ask, *Do you think that by answering this question, we’ll have answers to most of the questions on our Driving Question Board?* Look for agreement using a show of hands, and then write the chosen question at the top of the DQB with a chart marker.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- questions about related phenomena or technology (e.g., the Sun, a radio, a bad cell phone signal, an X-ray machine, something else that generates radiation) (SEP: 1.4; DCI: PS4.B.2, PS4.C.1)
- questions that use energy and matter to seek a mechanistic explanation (e.g., “How does a microwave oven transfer energy to food?”) (SEP: 1.4; CCC: 5.2)
- questions that relate the structure of the microwave oven (or a related technology) to its function (e.g., “How do the holes in the door help the microwave oven work?” or “What structures are in the microwave oven that make radiation?”) (SEP: 1.4; CCC: 6.2; DCI: PS4.B.2, PS4.C.1)
- questions about how distance affects microwave radiation or wireless signals (SEP: 1.4; DCI: PS4.B.2, PS4.C.1)

What to do:

- Remind students about the resources they can look at to write questions about, including their Notice and Wonder charts, the Initial Consensus Model poster, and the Related Phenomena and

Technology poster.

- Students will have a chance to brainstorm investigations after making the DQB. Consider making another pass at the DQB after this brainstorm, when they are thinking more directly about investigations and what they might be able to answer in class.

Building toward: 1.B.1 Ask questions and brainstorm investigations about the structure and function of technologies and phenomena that rely on electromagnetic radiation to transfer energy. (SEP: 1.4, 3.1; CCC: 5.2, 6.2; DCI: PS4.B.2, PS4.C.1)

12 · CONSIDER IDEAS FOR FURTHER INVESTIGATIONS AND DATA

10 min

MATERIALS: science notebook, chart paper, chart marker

Brainstorm ideas for investigations and data. ✱ Present **slide U**. Have students individually brainstorm ideas for investigations and data and write them in their notebook, as shown on the slide.

After 3-4 minutes, title a piece of chart paper “Ideas for Investigations and Data We Need”. Elicit ideas and write them on the poster. Listen for ideas such as:

- We could try putting the phone in a different metal box.
- We could take apart the microwave oven.
- We could research other technologies.
- We could try heating various kinds of foods in the microwave oven.
- We could measure the temperature of water outside the microwave oven.
- We could measure the radiation inside and outside the microwave oven.
- We could wrap something in various materials and heat it in the microwave oven.
- We could try other kinds of signals in the microwave oven (e.g., Wi-Fi, LTE, 5G, FM/AM radio).

✱ STRATEGIES FOR THIS INITIAL IDEAS DISCUSSION

Use talk strategies to draw out a variety of ideas from a larger pool of students. If it feels like they don’t have any more ideas, count to 10 in your head to give them more time to consider. Use questions to push their thinking to new contexts and help them make connections to their experiences. For example, if they are only talking about the speaker, say, *We definitely want to investigate the microwave oven. Could we do any investigations in class to answer some of our questions about technology that we think is related?*

13 · NAVIGATE WITH AN EXIT TICKET

2 min

MATERIALS: piece of 8.5” x 11’ paper for exit ticket

Assign the exit ticket. Tell students that scientists and engineers often examine the structure of something to figure out how it functions, or consider the function of something to figure out how it is structured. ✱

Present **slide V**. Distribute a piece of 8.5” x 11” paper to each student and pose the prompts on the slide as an exit ticket:

- *What is an investigation we could do that could help us understand more about the structure of a microwave oven? What could this investigation tell us?*
- *What is an investigation we could do that could help us understand more about the function of a microwave oven? What could this investigation tell us?*

Collect the exit tickets as students leave class.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Look for students to recognize that structure and function are different by suggesting:

- an investigation related to what is inside the microwave oven (e.g., dissecting a microwave oven, studying the schematics, looking at a Faraday pouch) (SEP: 3.1; CCC: 6.2)
- an investigation related to what the microwave oven does (e.g., running the microwave oven and measuring the temperature of liquid/food inside, measuring the radiation, doing more investigations with wireless signals) (SEP: 3.1; CCC: 6.2)

What to do: Read through the exit tickets and treat this as a pre-assessment opportunity for the focal crosscutting concept of Structure and Function and the focal practice of Designing Investigations. If students struggle to identify potential investigations, be ready to provide the maximum amount of scaffolding around this practice in future lessons. If they easily identify investigations, consider fading the provided scaffolding more quickly.

Building toward: 1.B.2 Ask questions and brainstorm investigations about the structure and function of technologies and phenomena that rely on electromagnetic radiation to transfer energy. (SEP: 1.4, 3.1; CCC: 5.2, 6.2; DCI: PS4.B.2, PS4.C.1)

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING STRUCTURE AND FUNCTION

The crosscutting concept of Structure and Function is intentionally developed across this unit. In grades 6-8, students analyzed complex natural and designed structures and systems to determine how they function. Now, in high school, they should be ready to infer the functions and properties of natural and designed objects and systems from their overall structure and the way their components are shaped and used. In earlier units, students considered how the molecular substructures of their various materials affect their function in the contexts of breaking/bending rock, and vehicle safety.

In this unit, students will look closely at the structures of several kinds of objects to infer their function, which is to produce or receive electromagnetic radiation. Here, we set students up to think about structure and function by asking them to consider how we can answer our questions about the structure and function of designed objects (a Bluetooth speaker, wireless device, and microwave oven).