Lesson 12: How are our wireless electronic devices designed to use EM waves to reliably communicate different types of information?

Previous Lesson *We wondered how EM radiation is used to create and store digital images. We read about how the interactions of X-rays with matter can be harnessed to create images of the internal structure of our body, and the advantages and disadvantages of digital and conventional radiography. We wondered how EM radiation is used in wireless communication to transmit information.*

This Lesson

Investigation

2.5 days

We develop different ways to send messages with EM waves using a simulation. We develop a model for how this system works and compare it to digital communication systems. We gather information from multiple sources in various formats from four different stations. We integrate this information with our model to summarize how our wireless electronic devices are designed to use EM waves to reliably communicate different types of information.

Next Lesson *We will return to the Driving Question Board to take stock of where we have been and what questions we have answered. We will work through an assessment task in which we evaluate two social media posts about 5G radiation, and we will use our model for EM radiation to argue from evidence about whether this technology is safe.*

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

12.A Integrate information from multiple sources in various formats (manipulatives, diagrams, text, and a model) to communicate how modern electronic devices use the principles of wave behavior and wave interactions with matter to transmit and capture so much and so many different types of information reliably. (SEP: 2.6, 8.2; CCC: 2.3, 4.3; DCI: PS4.A.2, PS4.C.1)

What students will figure out

- Wireless communication systems use computers (chips) and antennas to transmit information over long distances.
- These waves are produced and detected (absorbed) by changes in the movement of electrons in antennas.
- The majority of modern wireless communication uses binary code (digital transmission) to represent information, such as text, audio, photos/video, and location.
- Binary code is a combination of “on” and “off” states; it can be represented in EM radiation by varying the energy in the wave, using changes in amplitude or frequency to communicate “on” and “off”.
- Computers can translate digital information sent by wireless digital signals in electronic form, and store it (on hard drives).
- Any EM radiation signal can be received by anyone within range.
- If a wireless message is encrypted, only the intended receiver can decode the information.

Lesson 12 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		**NAVIGATE** Take stock of EM radiation uses we can explain and those we have yet to fully explain. Identify types of information that can be transferred wirelessly.	A-C	piece of 8.5" x 11" paper
2	12 min		**SEND INFORMATION USING WAVE BEHAVIOR** Recall a simulation from a prior lesson, and use it to develop a way to distinguish which of three possible messages is sent via movement of an electron in a receiving antenna.	D-G	piece of 8.5" x 11" paper from previous activity, computer, https://phet.colorado.edu/sims/cheerpj/radio-waves/latest/radio-waves.html?simulation=radio-waves
3	7 min		**COMPARE DIFFERENT WAYS TO SEND INFORMATION** Describe and compare different ways groups communicate different messages.	H-I	piece of 8.5" x 11" paper from previous activity, computer, https://phet.colorado.edu/sims/cheerpj/radio-waves/latest/radio-waves.html?simulation=radio-waves
4	8 min		**DEVELOP A MODEL** Develop a model representing the parts and interactions in the system and the steps we need to take to send a message using EM radiation from one person to another.	J	Class Wireless Communication Model poster, pre-made poster cutouts, tape
5	7 min		**COMPARE DIFFERENT WAYS TO SEND INFORMATION** Play a message in Morse Code. Identify the parts and limitations of our communication system. Identify equivalent parts in wireless communication devices.	K-N	computer, https://www.youtube.com/watch?v=_J8YcQETyTw&list=PLSLDxqPb5NQk_ycmM_f15j2bra2JGaaZA&index=6, Class Wireless Communication Model poster, pre-made poster cutouts, tape
6	6 min		**REVISE THE CLASS MODEL** Revise the class model to represent common structures and functions of modern wireless communication devices. Identify four questions we want to answer that are related to gaps in the model.	O	Class Wireless Communication Model poster, pre-made poster cutouts, tape

End of day 1

7	2 min		**NAVIGATE** Review the four questions we want to explore.	P	completed Class Wireless Communication Model poster
8	43 min		**GATHER INFORMATION FROM THE STATIONS** Visit the four information stations in small groups.	Q	*Communicate Information*, *Gather Station Information*
					End of day 2
9	20 min		**NAVIGATE AND INTEGRATE INFORMATION IN AN INDIVIDUAL SUMMARY** Integrate information from multiple sources to answer the lesson question in an individual writing task.	R	*Communicate Information*, *Gather Station Information*, completed Class Wireless Communication Model poster, markers
10	5 min		**NAVIGATE** Turn and talk about the trade-offs in using higher frequency EM radiation for communication purposes.	S	the spectrum of *Unknown material with identifier: pr.l9.ref* from Lesson 9
					End of day 3

Lesson 12 • Materials List

	per student	per group	per class
Lesson materials	• *Communicate Information* • *Gather Station Information* • science notebook	• piece of 8.5" x 11" paper • piece of 8.5" x 11" paper from previous activity • computer • https://phet.colorado.edu/sims/cheerpj/radio-waves/latest/radio-waves.html?simulation=radio-waves	• Class Wireless Communication Model poster • pre-made poster cutouts • tape • computer • https://www.youtube.com/watch?v=_J8YcQETyTw&list=PLSLDxqPb5NQk_ycmM_f15j2bra2JGaaZA&index=6 • completed Class Wireless Communication Model poster • markers • the spectrum of *Unknown material with identifier: pr.l9.ref* from Lesson 9

Materials preparation (20 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.

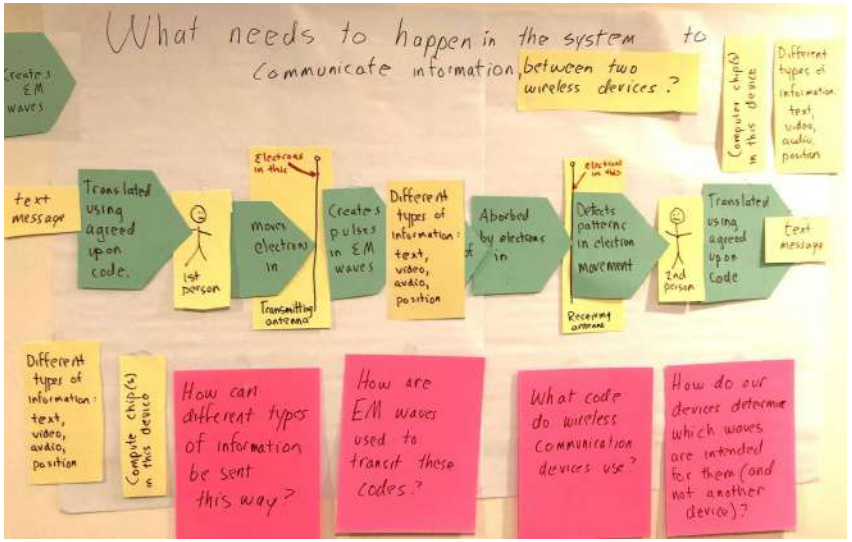
Three-hole-punch all readings so they can be added to students' notebooks.

Make 1 copy of each of these per student:

- *Communicate Information*
- *Gather Station Information*

Prepare 2 pieces of chart paper to be the Class Wireless Communication Model poster, titled with the question "What needs to happen in the system to communicate information?" Use 3 colors of paper to make cutouts, sized to fit and annotated, as shown in the image below. In the example, yellow represents parts of the system, green represents steps or interactions in the

system, and pink represents the 4 questions related to the system. You will interactively tape different combinations of these pre-made cutouts on the poster at different points in the class discussion on day 1. This allows you to remove and reuse the cutouts so you can reassemble them on the poster with your next class.



Make sure the spectrum of *Unknown material with identifier: pr.l9.ref* from Lesson 9 is visible for reference.

Test the simulation from Lesson 4 that students will use again in this lesson:
https://phet.colorado.edu/sims/cheerpj/radio-waves/latest/radio-waves.html?simulation=radio-waves

Test the video that you will present:

https://www.youtube.com/watch?v=_J8YcQETyTw&list=PLSLDxqPb5NQk_ycmM_f15j2bra2JGaaZA&index=6

This is a 2.5-period lesson. Together, Lessons 12 and 13 take 4 periods, with the transition halfway through the third period.

Make 1 copy of each of these consumables per group of 4 students:

- *Digital Audio Recording*
- *Creating Digital Images*
- *Encoding Text Messages*
- *Navigation with EM Radiation*

The copies listed below are for 2 sets of the 4 stations--8 stations total--that the groups of 4 will rotate through. If you have a class larger than 32 students, modify the directions below to produce 12 stations.

The following are permanent references at each station (1 apiece), so you may want to put them in sheet protectors. Make 8 copies of each of these:

- *Digital EM Communication*
- *Pairing and Encryption*
- *Microwave Radiation Communication*
- *Encoding Media Jigsaw*

Make 2 more permanent reference copies of *Pairing and Encryption* and 2 more copies of *Materials for Pairing and Encryption* on heavier, more durable paper if possible, for Stations 2 and 6 (1 apiece; shown below). Cut out the cards printed on the latter, and make the decks indicated in the directions.

Put these additional supplies at each station. Remember these are 2 of each of the 4 stations, for 8 stations total.

- Stations 1 and 5:
    - 4 copies of *Digital EM Communication*
    - 2 of the slinky spring setups from Lesson 2
- Stations 2 and 6:
    - 4 copies of *Pairing and Encryption*
    - the above cutouts from *Materials for Pairing and Encryption*
- Stations 3 and 7:
    - 4 copies of *Microwave Radiation Communication*
    - 2 computers
- Stations 4 and 8:
    - 4 copies of *Encoding Media Jigsaw*

Lesson 12 • Where We Are Going and NOT Going

Where We Are Going

This lesson is designed to coherently build ideas related to the following disciplinary core ideas (DCIs):

- **PS4.A.2 Wave Properties.** Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be ~~stored reliably in computer memory and~~ sent over long distances as a series of wave pulses. (HS-PS4-2, HSPS4-5)
- **PS4.C.1 Information Technologies and Instrumentation.** 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)

In this lesson, students integrate multiple sources from four information stations, presented in various media or formats (e.g., visually, quantitatively) as well as in words, to answer the lesson question. The 40 minutes allocated represents a transition to more sustained engagement in obtaining information related to SEP8, which students will encounter more frequently in the next (and last unit) of the course sequence, *OpenSciEd Unit P.4: Meteors, Orbits, and Gravity (Meteors Unit)*.

Students co-develop definitions for the following words in this lesson: *binary code, encryption, digital signal.* In the Jigsaw readings, they encounter a subset of these words: *bits, amplitude-shift keying, frequency-shift keying, Global Positioning System* (or *GPS*), *unicode (universal code), metadata.* **Do not** post any words or ask students to add them to their Personal Glossaries until after the class has developed a shared understanding of their meaning.

The readings are aligned with the HS-PS4-5 Performance Expectation and help students prepare for the Lesson 13 transfer task.

Where We Are NOT Going

Some of the readings make brief references to analog versus digital forms of communication, but understanding the fundamental differences between these is not a focus of this lesson.

LEARNING PLAN for LESSON 12

1 · NAVIGATE

5 min

MATERIALS: piece of 8.5" x 11" paper

Recall our intention to investigate communication as a use of EM radiation. Present **slide A**. Discuss the prompt on the slide:

- *Was communication one of the uses of EM radiation that we identified as having fully explained, or was it one that we still needed to investigate further?*

Listen for students to identify this as one we needed to investigate further.

Compare types of information. Present **slide B**. Discuss the prompts:

- *What kind of information can our modern wireless communication devices transmit to other devices?*
- *What kind of information do we think was sent in the first long-distance wireless message, in 1898?*

For the first prompt, listen for students to mention text, photos, movies, songs, documents, our voices, and live video. For the second prompt, listen for them to mention words/text and maybe sounds. If they agree on words/text only, move on. If they suggest that maybe it was sounds as well, validate that voice and text were the first two forms of information communicated wirelessly; the first one developed was text-based communication, and sound came shortly after.

Brainstorm types of text messages long ago. Present **slide C**. Read the text at the top aloud, and then discuss the prompt as a class:
In the next few years after 1898, long-distance wireless communication was still limited to relatively few places. People used it to send relatively short text messages.

- *What types of really short messages do you think people would have sent back then?*

Accept all responses. Record each example on the board, to make a list for students to pick from in the next activity. Three examples are enough, but feel free to list more. Potential examples include:

- Send help.
- Happy birthday!
- Can I come visit?
- I sent you a package.
- Arriving at noon.
- Payment received.

Suggest that we consider how we could send any of these messages to someone far away using EM radiation. Cue students to work with a partner, taking a minute to select three of the messages listed on the board and write them on a piece of paper.

2 · SEND INFORMATION USING WAVE BEHAVIOR

12 min

MATERIALS: piece of 8.5" x 11" paper from previous activity, computer, https://phet.colorado.edu/sims/cheerpj/radio-waves/latest/radio-waves.html?simulation=radio-waves

Recall our work with a prior simulation. Present **slide D**. Discuss the prompt:

- *What did we change in the system to transfer different amounts of energy from the transmitting antenna to the receiving antenna?*

Listen for the following ideas:

- We changed the amplitude.
- We changed the frequency.
- We changed the speed of the electron in both cases.

If students do not mention changes in frequency or amplitude, display https://phet.colorado.edu/sims/cheerpj/radio-waves/latest/radio-waves.html?simulation=radio-waves and show them the variables in the simulation that we could manipulate.

Consider changes in the receiving antenna. Present **slide E**. Discuss the prompt:

- *What changes did we observe in the receiving antenna?*

Listen for the following ideas:

- changes in how much the electron moved up and down
- changes in how frequently the electron moved up and down
- changes in how fast the electron moved up and down

Consider how to send information from one antenna to another. Present **slide F**. ✱ Give students a minute of individual think time to consider the prompt:

- *How could we use the changes in the electron in the transmitting antenna to send any of the 3 messages you chose to the receiving antenna?*

Develop and test a communication system using the simulation. Present **slide G**. Review the directions and share the simulation link with the class: https://phet.colorado.edu/sims/cheerpj/radio-waves/latest/radio-waves.html?simulation=radio-waves. Each pair of students will use the simulation with a single computer to come up with a way to use movement of the electron in the receiving antenna to identify which message one student in the pair has sent to the other.

Listen for ideas such as:

✱ ATTENDING TO EQUITY

Providing extended think time on a prompt before discussing with a partner or the class can help students generate a larger set of their own ideas to bring to a new task or discussion. Some students benefit from this additional time to organize their thoughts before sharing.

- no waves/pulses coding for a break between one message and a new one
- number of pulses coding for a specific message
- differences in amplitude coding for a specific message
- differences in frequency coding for a specific message
- combinations of any of the prior three ideas coding for a specific message

ADDITIONAL GUIDANCE	As you monitor student efforts, keep in mind that some might find it tricky to interpret the signals their partner is sending. That is a desirable outcome, as it will be identified as an important reliability-related limitation in this system.

3 · COMPARE DIFFERENT WAYS TO SEND INFORMATION

7 min

MATERIALS: piece of 8.5" x 11" paper from previous activity, computer, https://phet.colorado.edu/sims/cheerpj/radio-waves/latest/radio-waves.html?simulation=radio-waves

Demonstrate different communication systems. Present **slide H**. Direct students' attention to the instructions on the slide. Recruit a volunteer partner pair to demonstrate their system. Encourage the receiver to look away and close their eyes as the transmitter points to the message on the board that they are going to send, so the rest of the class knows what it is.

Then have the pair demonstrate using the simulation to communicate the message. Have the receiver share what the message was. If they were successful in their transmission, ask the receiver to describe how they knew this was the message. If they were not successful, ask them why it was hard to tell.

Ask for a show of hands from those who used a similar system. Then ask for a volunteer pair who developed a different system. Again, have them demonstrate their system. Repeat this once more, or have other pairs describe how their system is different. After the third example, point out that this demonstration shows we could design a variety of systems to send messages wirelessly, and provides us with a few examples of the possibilities.

Evaluate our communication systems. Present **slide I**. Discuss the two prompts as a class, as shown in the table below.

Suggested prompt	Sample student response
What are the limitations of the communication systems we just developed?	It would be hard to use if there were lots more types of messages you want to send. It is kind of slow for how many messages you can send in a certain amount of time (e.g., a minute). It is kind of hard to interpret sometimes--you can easily miscategorize or misinterpret how the electron moved.
What would be the characteristics of a better communication system?	It could send many more types of messages. It would be faster.

> It would be easier to interpret differences in electron movement.

Suggest that because we identified limitations of these communication systems as well as characteristics of a better system, it may be helpful to develop an initial model of the parts and interactions in those we designed, so we can compare any future improvements to this initial model.

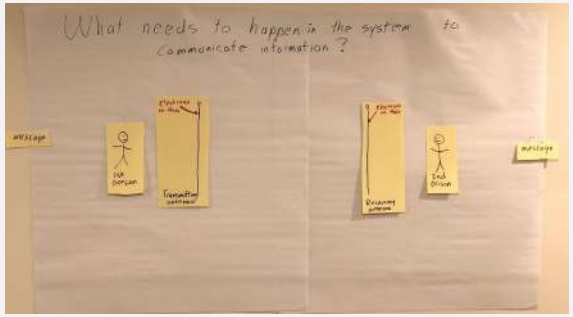
4 · DEVELOP A MODEL

8 min

MATERIALS: Class Wireless Communication Model poster, pre-made poster cutouts, tape

Develop a class consensus model. Present **slide J**. Direct students' attention to the Class Wireless Communication Model poster (with only the title on it at this point). Generate a consensus model of the parts in the system, using the slide's first prompt:

- *What parts did we need in the system to send a message using EM radiation wirelessly from one person to another?*

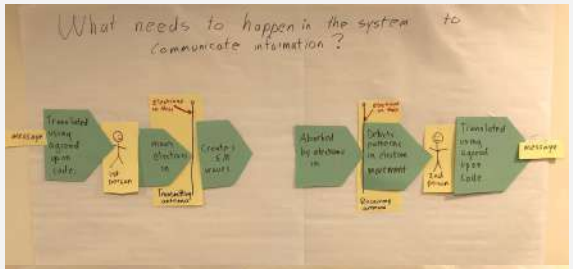


Listen for students to suggest most of the following ideas:

- a code for messages
- a message to be sent
- a first person (to translate and send the coded message)
- a transmitting antenna
- electrons moving in the antenna in different ways
- EM radiation
- a receiving antenna
- electrons that move in the antenna in response to EM radiation
- a second person (to receive and translate the coded message)

Tape (temporarily) the related cutouts you made for the parts of the system to the poster. Then discuss the second prompt on **slide J**:

- *What needed to happen in our system to communicate information?*



Cue students to consider the interactions/steps happening between each part, working left to right in the model. As they identify them, tape the related cutouts to the poster.

Ask how the speed of the waves in the simulation compares to the speed that all EM waves travel. Students will say the latter is much, much faster.

Emphasize that we should acknowledge this important limitation in developing this model, as it is based on our use of a simulation to study the phenomenon. We know that in the actual phenomenon, an EM wave travels at the speed of light, which means the changes in the wave happen extremely fast. Therefore, it is hard to visualize them without a simulation, like ours, to slow things down so we can manipulate and interpret the patterns indirectly.

Suggest that we note this travel speed on the poster, to remind us of an advantage of using EM radiation to transmit information--namely, how quickly it can be received after it is sent.

5 · COMPARE DIFFERENT WAYS TO SEND INFORMATION

7 min

MATERIALS: computer, https://www.youtube.com/watch?v=_J8YcQETyTw&list=PLSLDxqPb5NQk_ycmM_f15j2bra2JGaaZA&index=6, Class Wireless Communication Model poster, pre-made poster cutouts, tape

Compare EM radiation communication with another communication system. Present **slide K**. Read the text aloud and discuss the prompt as a class:
An earlier form of long-distance communication used a digital code to transmit information. Let's observe an example of this.

- *What types of patterns do you notice in the signal?*

Show the video https://www.youtube.com/watch?v=_J8YcQETyTw&list=PLSLDxqPb5NQk_ycmM_f15j2bra2JGaaZA&index=6. Have students share the patterns they noticed. They will describe short- and long-duration sounds and flashes of light separated by pauses (no light or sound), and different sequences of these. Present **slide L**. Read the text aloud and discuss the prompt:
A 4-word question was the message being sent in the previous example. This was the question: What do you notice?

- *How could the patterns we observed have communicated such a complex question?*

Students will likely say they must be using some kind of code. Accept all responses.

Introduce Morse code. Present **slide M**. Give the class a minute to read the text and study the code.

Discuss the pulses we observed. Present **slide N**. Discuss the prompt:

- *What sort of waves were we detecting each time we saw or heard a short or long signal pulse?*

Students will say light waves and sound waves. Point out that though the light appeared to be either on or off, the length of time varied. Every time we saw the light, that was due to EM radiation in the part of the spectrum for visible light. This radiation was reaching our eyes during the entire time we saw that pulse, and no radiation in that part of the spectrum reached our eyes when we saw darkness.

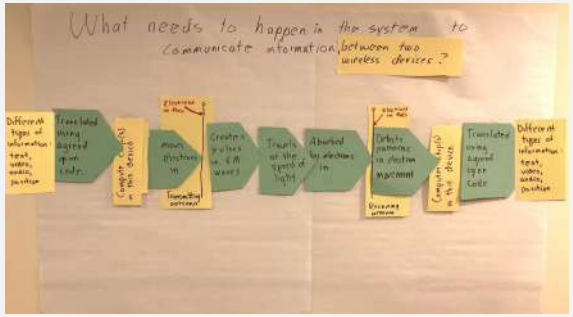
Remind students that a sound wave at the frequency we heard was also reaching our ears the entire time we heard each sound pulse, and no sound wave at that frequency was reaching our ears when the pulse was off. Emphasize that in both cases, even though there are waves transmitting information, we perceive the state of the pulse to be either on or off for a certain length of time. Explain that this way of structuring wave pulses, so they can be interpreted as being in either an on or off state, is considered digital code.

6 · REVISE THE CLASS MODEL

6 min

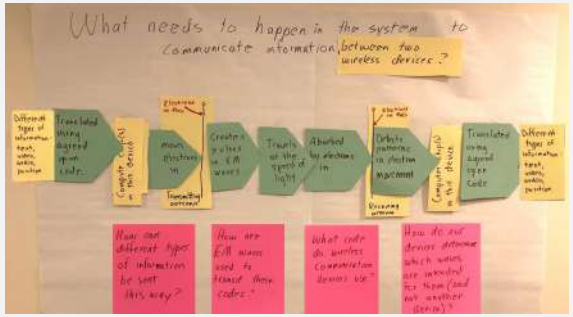
MATERIALS: Class Wireless Communication Model poster, pre-made poster cutouts, tape

Introduce structures and functions of modern wireless devices. Present **slide O**. Read the text aloud:
Modern computer chips use a digital code to store, encode, transmit, detect, and decode information.
Devices that communicate wirelessly use antennas to send and receive billions of EM pulses per second, which allows them to send and receive many kinds of information quickly.



Revise our model. Refer the class to the previous Class Wireless Communication Model poster. Point out that computer chips replace the function of people, encoding and decoding digital signals much faster and more reliably than people alone are able to. Cover each person in the model with the cutout labeled “computer chips in this device”. Cover the cutout labeled “creates EM waves” with the cutout labeled “creates pulses in EM waves”. Suggest that we update the question on the poster to reflect what the model is explaining now, and cover the question mark at the end with the cutout labeled “between two wireless devices”.

Ask students to recall, *What kind of information did we say can be transmitted to, from, and between our modern wireless communication devices?* Students will again mention things like text, photos, movies, songs, documents, voices, and live video. Cover each cutout labeled “message” with the cutouts labeled “different types of information: text, video, audio, position”.



Point out that this initial model of how wireless electronic devices use EM waves still has a lot of gaps. For example, it doesn’t explain (1) how these different types of information are encoded and decoded, nor (2) what that code is, nor (3) how any particular device can figure out which messages are meant specifically for it, nor (4)

how responses are communicated back in the opposite direction. Suggest that we record these gaps under our model in the form of questions to investigate next time. Add the four questions noted above to the poster.

Remove the cutouts before the next class so you can build this poster again. Save the completed poster after your final class, and post it in the room as a reference for the rest of the lesson.

End of day 1

7 · NAVIGATE

2 min

MATERIALS: completed Class Wireless Communication Model poster

Remind the class where we left off. Display **slide P**. Ask what our new sub-questions were that we wanted to explore when we left off with our model last time, and where we recorded them. They should reference the Class Wireless Communication Model poster with the questions written on it.

8 · GATHER INFORMATION FROM THE STATIONS

43 min

MATERIALS: *Communicate Information*, *Gather Station Information*, science notebook

Assign groups and starting stations. Distribute the *Communicate Information* and *Gather Station Information* handouts to each student. Divide the class into eight groups of 4. Assign each group a starting station to explore. Present **slide Q**. Give students a minute to review the directions on the slide.

Emphasize that after visiting the four stations, gathering information, and recording it on the *Gather Station Information* handout, they will then synthesize all that information independently in the next class period to communicate an individual response that explains the Driving Question Board's entire section related to the question "How are our wireless electronic devices designed to use EM waves to reliably communicate different types of information?" Point out that they will use the *Communicate Information* handout to do this. Answer any questions they have at this point.

Distribute a copy of *Digital Audio Recording*, *Creating Digital Images*, *Encoding Text Messages*, and *Navigation with EM Radiation* to each group of 4. Explain that these are consumables for their group and they can write on them when they reach Stations 4 and 8. Instruct each person in each group to take a different reading for now, so they are ready to use it for the Jigsaw activity at that station. ✱

✱ ATTENDING TO EQUITY

These readings are written at different reading levels and vary in length. You may wish to allow students to self-select their readings based on interest before dividing them into groups. Or, at your discretion, assign them into intentional, mixed-ability reading groups, with the students who need more reading support along with students who do not need the extra support.

Remind students to save their notes from the stations on *Gather Station Information* in their science notebooks to be ready as a reference next time. ✱

Creating Digital Images, *Encoding Text Messages*, and *Navigation with EM Radiation* are the most complex. *Digital Audio Recording* is most accessible to all reading levels.

✱ ATTENDING TO EQUITY

Supporting emergent multilinguals: Students should be encouraged to record their ideas using linguistic modes (e.g., written words) and nonlinguistic modes (e.g., drawings, tables, graphs). This is especially important for emerging multilingual students because making connections between written words and nonlinguistic representations helps students generate richer explanations of how digital communication works.

End of day 2

9 · NAVIGATE AND INTEGRATE INFORMATION IN AN INDIVIDUAL SUMMARY

20 min

MATERIALS: *Communicate Information*, *Gather Station Information*, science notebook, completed Class Wireless Communication Model poster, markers

Develop an individual summary. Present **slide R**. Refer students to the Class Wireless Communication Model poster created on day 1. Point out that this model had lots of gaps, but now we have had a chance to gather information to help fill them in.

Emphasize that instead of simply answering the sub-questions, they should try to synthesize everything we have figured out together, in service of a larger question, as shown on the slide:

- *How are our wireless electronic devices designed to use electromagnetic waves to reliably communicate different types of information?*

✱ ATTENDING TO EQUITY

Reminding students that diagrams can augment ideas we are trying to communicate through written text reaffirms that they can choose to use the

Review the redirections on the *Communicate Information* handout. Instruct students to take about 20 minutes to complete their individual responses, referencing their notes on the *Gather Station Information* handout. Encourage them to include diagrams or sketches to illustrate their thinking if it helps to augment their written summary.

Collect both *Communicate Information* and *Gather Station Information* when the time is up.

representations that are most useful for making their thinking visible.

ASSESSMENT OPPORTUNITY

What to look for/listen for: See *Summarizing Stations Key*.

What to do: See *Summarizing Stations Key*.

Building toward: 12.A Integrate information from multiple sources in various formats (manipulatives, diagrams, text, and a model) to communicate how modern electronic devices use the principles of wave behavior and wave interactions with matter to transmit and capture so much and so many different types of information reliably. (SEP: 2.6, 8.2; CCC: 2.3, 4.3; DCI: PS4.A.2, PS4.C.1)

10 · NAVIGATE

5 min

MATERIALS: the spectrum of *Unknown material with identifier: pr.l9.ref* from Lesson 9

Consider using high-frequency EM radiation in communication technologies. Say, *If we look at the electromagnetic spectrum, we see that we use low-frequency EM radiation for communication.* Present **slide S**. Read the text aloud:
Scientists and engineers have argued that using even higher frequency EM radiation in future wireless communication technologies could provide some advantages.

Then have students turn and talk about the prompt:

- *What might be some trade-offs in using higher frequency EM radiation to send and receive information?*

After 2 minutes, emphasize that they should be ready to explore this question further in the next lesson, which includes a related transfer task as an individual summative assessment point.

Additional Lesson 12 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA	**CCSS.ELA-LITERACY.WHST.11-12.2:** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. Students write an informative text that integrates information about multiple technical processes as well as fundamental scientific mechanisms related to wave behavior when they complete their summary on the *Gather Station Information* handout.