Digitized Signals

8.7

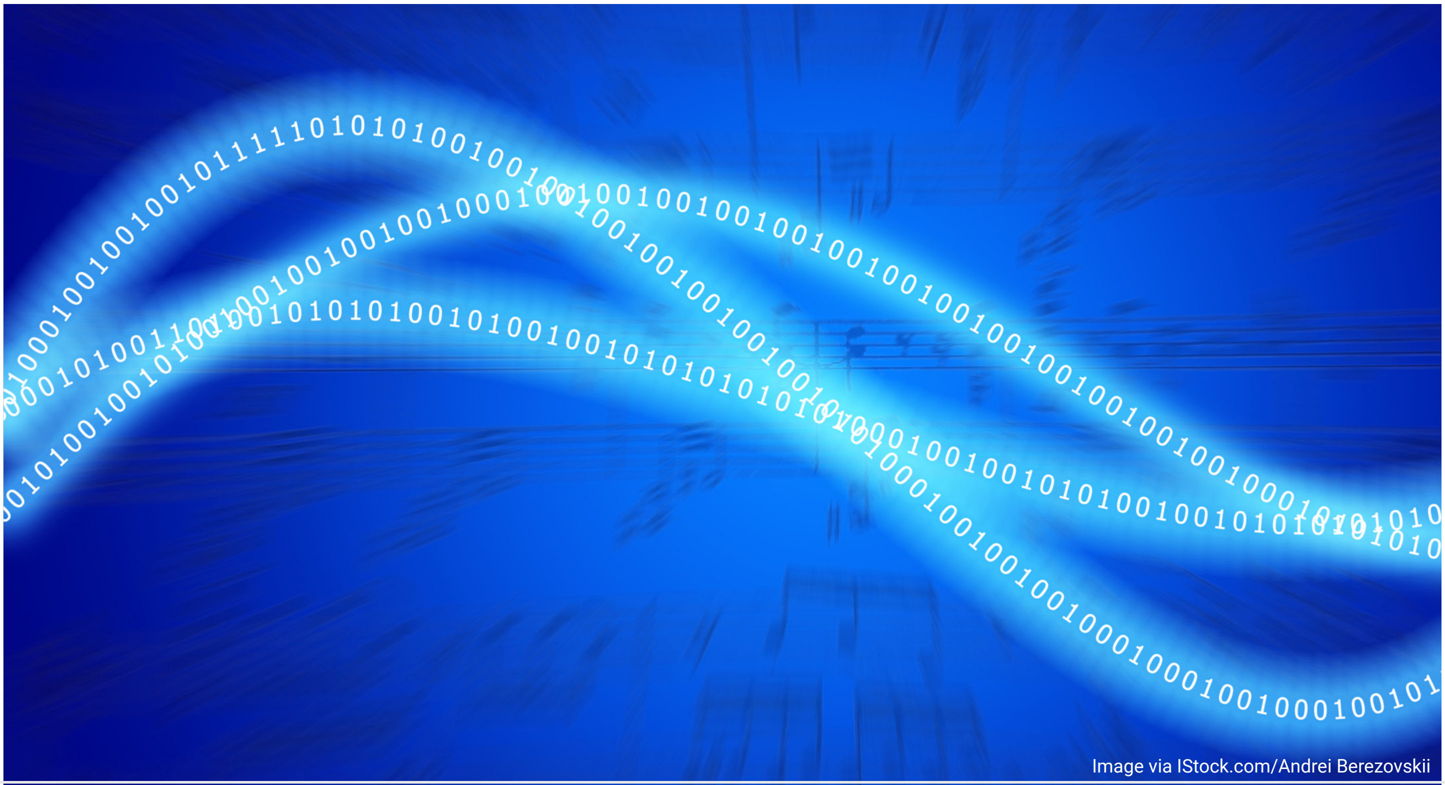

Image via IStock.com/Andrei Berezovskii

Anchoring Phenomenon

Numerous reports suggest an increase in white shark encounters* in the United States in recent years and the public is worried.

Lesson Concept

Carry out an investigation to model reliability of information flow for a device that encodes and transmits information within a system.

Investigative Phenomenon

Some signals are reliable and some are not.

Standards

Refer to Appendix 8.7 for NGSS, CCSS (ELA), and California ELD standards.

*Encounters include sightings and census estimates, as well as physical interactions between humans and sharks.

Storyline Link

In the previous lesson, students built an understanding that tracking devices that monitor white sharks use both acoustic (sound) waves and radio waves. They further explored that acoustic/sound waves attenuate in salt water and require a medium for transmission.

Students in this lesson embark on a journey of the development and application of wireless technology and compare wireless phones with tracking devices, considering reliability of signals and the encoding of information for transmission. Students practice with a binary code to understand how they can transmit a message and apply that understanding back to REMUS (and other tracking devices). They move on to understand that the tags that are on the white sharks, whose signals are picked up by receivers, begin as analog signals but are then encoded into digital signals before they are sent to researchers. Students are asked to consider which is the most reliable type of tag and which will have the most information by considering limitations of data. They will seek to improve precision and accuracy of data, and determine similarities and differences in findings. During this lesson, students apply understanding that systems may interact with other systems, may have sub-systems, and may be a part of larger complex systems. They will understand that models can be used to represent systems and their interactions such as inputs, processes, and outputs and information flows within systems.

In the next lesson, students will consider the challenge of actually tagging a white shark for study and how aerial surveys of white sharks misreport shark size thanks to the phenomenon of light distorting our perception of objects.

Throughout the lesson, a flag (▶) denotes formative assessment opportunities where you may change instruction in response to students' level of understanding.

8.7 Digitized Signals

Time

90 minutes

Part I	20 minutes	Engage
Part II	25 minutes	Explore
Part III	45 minutes	Explain

Materials

Whole Class

- ❑ Chart paper
- ❑ Sticky notes
- ❑ *Ericsson: The History of Wireless Communication* video, https://www.youtube.com/ watch?v=X5jPoQzEh-M

Per Group of 4

- ❑ Slinky® or wave modeling spring

  Slinky® is a registered trademark of Poof-Slinky, LLC.

Individual

- ❑ Science Notebook
- ❑ 8.1.H2: Scientist Communication Survival Kit (from Lesson 8.1: Shark Encounters)
- ❑ 8.1.H3: My Shark Encounter Claim Chart (from Lesson 8.1: Shark Encounters)
- ❑ 8.1.H4: Crosscutting Concepts for Middle School Students (from Lesson 8.1: Shark Encounters)
- ❑ 8.7.H1: Binary Code

Teacher

None

Advance Preparation

1. Prepare copies of **8.7.H1: Binary Code** for every student. (Step 11 of Procedure)
2. Preview video, *Ericsson: The History of Wireless Communication*. (Step 4 of Procedure)

Procedure

Part I

Engage (20 minutes)

Question and define limitations and reliability of shark tracking systems encoding and transmitting information.

1. Start by sharing the Nature of Science concept (consider posting in the room): "Advances in technology influence the progress of science and science has influenced advances in technology." Ask students, "What questions do you have about these words and their meaning from the statement?" and give time for students to discuss as a group. Go around the room asking students to share any real world examples from science and technology that support this statement.

2. Ask students to review what they now understand about different types of tracking devices, and their respective waves, that are used to study white sharks, as well as any questions that remain. Ask (and ideally point to a similar student question), "How might the information collected by each of those devices get to a researcher?" Encourage students to refer back to the models they built in their Science Notebook in Lesson 8.6: Tags and Waves. Ask a few students to share their thinking with the class.

3. Point out that there's a connection between the information a tracking device uses and other devices students use to transmit information. Give students a few minutes to consider prior knowledge of wireless technology applications in their everyday life experiences and record in their Science Notebook. Ask, "What are some things you might have seen on TV or in a movie that use wireless technology?" Then brainstorm a list of wireless devices such as cell phones, radios, WiFi Internet, walkie talkies, drones, remote controls, garage door openers, remote controlled cars, laser tag, pet tracker chips, satellites, earbuds, speakers— and SHARK TRACKING DEVICES!—and chart for the room.

4. As scientists think about tracking devices and how to improve them so we can get better information on white sharks, it's plausible that students might be involved in improving these devices in the future. Ask students, "What do you think the future holds for wireless technology applications?"

   Student responses should include the following: *more devices, more people using them, and more applications made available with new technology.*

   Ask students to consider what problems may arise as more devices are used by more people and scientists and as more devices use wireless technology. To give students a context for wireless communications leading up to the idea for smartphones, view the video, *Ericsson: The History of Wireless Communication*, from the archive of Ericsson at Centre for Business

History, Stockholm, Sweden. Ask students to record any *aha*'s and questions as they watch the video.

5. Following the video, lead students into a discussion of how competition among so many wireless devices today could impact their use. In the discussion, specifically ask students, "What makes a good or bad connection between receivers and transmitters?" and, "What makes a good or bad Internet connection or cell phone call?" Together, generate criteria for a good and bad connections and chart.

   Here are some ideas that students may come up with:

   - *Strong signal strength as indicated by the wireless symbol or bars on computer or phone*
   - *High-speed downloads, connection is consistent and fast*
   - *Calls don't drop or end suddenly*
   - *Don't see a loading error message on a webpage*
   - *Able to transmit different types of data from audio, video, and text*

6. Make an argument dealing with wireless technology such as,

   "The school has reliable WiFi because I am always able to connect to the Internet."

   a. Ask the students to analyze that statement. First, as a class, define the term *reliability* and reflect on what reliability means with respect to evaluating a wireless system. Ask students, "What makes a wireless device trustworthy (valid) in its performance?" "How can we determine if a device works consistently well? What evidence would count as a wireless device working consistently well?" Have a brief discussion.

   TEACHER NOTE

   Trustworthy and *reliability* are both terms that can take on many meanings depending on their context. In this case, a reliable signal is one that is consistent and that will not fail in the middle of a signal. A trustworthy (valid) signal is one in which all data transmitted is controlled in an orderly fashion, and is received in the correct order and is intact. At this point in the lesson, students may only be able to refer to the reliability aspects of a signal as that has been a part of their life experiences.

   b. Ask students to reflect on the statement, "The school has reliable WiFi because I am always able to connect to the Internet," and challenge it, considering what was just discussed as a class. Make sure each student has a sticky note, index card, or small piece of paper that can be moved so eventually students can see the ideas together. Ask students to record one piece of evidence they have for disagreeing with the statement. As a class, compare statements and make sure you have four different kinds of evidence that would challenge the initial argument given. Students might offer responses such as the following:

- *It crashes.*
- *It's slow.*
- *I can't go to some websites.*
- *Not all web-based programs work.*
- *I lost data.*
- *I can't stream a video.*

This exercise gives students the opportunity to participate in a discussion about reliability with a system that they already know, school WiFi, before they are asked to discuss a system with which they are less familiar, shark tracking systems, in Step 8.

7. Let students know that they will be using the crosscutting concept Systems and System Models. Ask students to reference this in **8.1.H4: Crosscutting Concepts for Middle School Students** and take a few minutes to model use with Systems and System Models, using a similar discussion pattern previously done for Patterns in Lesson 8.1: Shark Encounters, Step 7.b. Ask students to clarify what the "systems" and "subsystems" were for the shark tracking devices they had learned about in Lesson 8.6: Tags and Waves. After sharing an example with the whole class, give students a few moments as a group to consider others. ▶ As students work throughout the remainder of this lesson, consider where they are in their understanding of the different systems of shark tracking devices and other devices that transmit information by using **8.1.H4: Crosscutting Concepts for Middle School Students** as a rubric. As students work, they may need encouragement to utilize prompts in the On-Target column.

8. Give students the following prompt, "Shark tracking devices are similar systems that use wireless technology, too. Given the considerations you just thought of, what would you need to consider for all of the sub-systems of shark tracking devices to be reliable?" Ask them to come up with a list of possible characteristics that the tracking device should have to be considered reliable. Make sure to remind them that there can be more than one device that is being used to track a shark and to recall the video from Lesson 8.6: Tags and Waves, *NGSS Learning Sequence: Jawsome* from the CSULB Shark Lab.

9. Students might offer responses such as:

   - *It crashes.*
   - *It's slow.*
   - *The tag is not interfacing with the computer.*

- *Salt water is interfering with tags/signals.*
- *There is a problem with the satellite interface.*

TEACHER NOTE

From the video students should have realized that it is not always just one single device that is doing the tracking—there is always a transmitter and a receiver. For example, there can be a tag on a shark that REMUS is following and picking up data from, a tag on a shark's dorsal fin and a satellite picking up and relaying data to a computer in the office of a scientist, or a tag on a shark and a hydrophone receiver picking up and relaying data to a computer in the office of a scientist.

Procedure

Part II

Explore (25 minutes)

Students analyze and interpret data to predict the validity of encoding and decoding signals between a shark tracking device and receiver.

In order to understand trustworthiness (or validity), students need to first understand how the information gets encoded before it is transmitted. As we speak into our phones or as the tracker picks up information from a shark, how does that information change in this process? The process of changing information from an analog signal to a digital signal is called *encoding*.

10. Ask students, "You want to write a message to a friend in the class but you don't want others to be able to read it. How might you do this?" Students should suggest this can be done with some sort of code that others do not know but the receiver of the message understands.

11. Give students a copy of **8.7.H1: Binary Code** and have them write their name in code without putting their name on the paper. Collect the papers, shuffle them, and then "send" the message to another student by passing out the papers. Have the students then decode the name on the paper they receive, and return it to the person whose name is on the paper.

12. After students have received their own paper back, have them discuss the following at their table and record their answers in their Science Notebook:

    a. What limitations were there in encoding your name?

    b. What limitations were there in decoding the name that you were given?

    c. How could you accurately determine if you were given the proper encoded name (other than knowing that it was your own handwriting)?

    d. What limitations are there in encoding, sending, and decoding information with this system?

e. How could you improve upon the precision and accuracy of encoding, sending, and decoding information with this system?

13. Ask students to transition from thinking about how this encoding and decoding worked with their name to how effective it would be for a shark tracking device. Ask them to discuss and write about the following in their Science Notebook:

    a. Given the limitations in encoding and decoding your name, predict limitations that would arise when encoding and decoding signals between a shark tracking device and a receiver.

    b. What cause and effect relationship helps you predict this limitation?

    ▶ Be sure to gauge whether or not students are understanding limitations of data analysis and how better methods lead to precision and accuracy of data before moving on.

Procedure

Part III

Explain (45 minutes)

Students analyze and interpret data to determine how the scale of a system encodes and transmits information.

14. Ask students, "How do you think we could represent the code that you used for your names with the numbers 1 and 0 (a digital signal)?" Allow students to have a conversation with their groups to determine the best way to represent the information being transferred. If students are unsure of how to represent the information, the following questions can guide the conversation:

    a. How could you represent that in wave form with a Slinky®?

    b. *What would the closed box be?

    c. *What would the open box be?

    d. How would you represent a break in the letters?

    e. How can you represent the 0? Why is it important to just not have a pulse?

    f. How would you let the processor (the person receiving the message) know that the name has ended?

    *Closed and open boxes refer to what students used in **8.7.H1: Binary Code**.

TEACHER NOTE

The students should be guiding the conversation about how to represent the digital signal in a wave form. It is not too big of a leap for them to determine that sending one wave could be used to represent the 1.

15. Based on the students' conversation of how to model the digital signal, ask students what type of data is transmitted to a tracking device like REMUS? They should recall that many trackers have information sent to them acoustically but then the information needs to be converted to a digital signal for either downloading or sending. So what do each of the signals look like?

    As students model the input, processing, and output of different wave types for this type of messaging system, they should refer back to **8.1.H4: Crosscutting Concepts for Middle School Students** (from Lesson 8.1: Shark Encounters) for the different parts of systems and subsystems. Give each person a role:

    1. Input: the student holding one end of the Slinky® and who will be producing the wave pulse (the message)
    2. Receiver: the student holding the other end of the Slinky®
    3. Processor: the student who will be trying to decipher the message
    4. Output: the student who will be writing down what the receiver is interpreting

Digital Signals

16. If students were not able to come up with a set of procedures themselves, help by pointing out that digital signals are either an "off/0" or "on/1," which is a discrete set of information. For this, a single pulse will represent a one and two pulses will represent a zero. Based on the students' procedures to represent the signal, the zero should be represented by two pulses because without a pulse the processor will not be certain if it is a number or a break in the numbers. (It doesn't really matter if kids come up with a plan different from 0/1. It's more likely they will say a signal is on/off. It's OK to let them proceed and then have a discussion about using 0/1 to represent that at a later time when they are sharing understanding.)

17. Without the student who is the processor, ask the members of the group to come up with either a name that is encoded using the binary code or to come up with a 10 digit stream of ones and zeros. The output student should record these numbers.

Number										
Received Number										

18. Have the students lay the stretched out Slinky® down on the ground with the Input and

Receiver students holding on to either end. The Processor student should be sitting on the ground with their hand on the ground with their palm facing the Slinky®. Have the Input student send one pulse around 20 cm to the Receiver to make sure that the Processor can feel the pulse. Decide if any adjustments are needed (for example, making a larger pulse or having the Processor move closer).

19. Have the Processor close their eyes while the Input student is sending the decided upon 10 digit stream of ones and zeros by "pulsing" down the Slinky® to the Receiver, waiting one second between numbers. After each number, the Processor should state whether they think it is a one or a zero.

20. When the stream of numbers is complete, the Input should send three quick pulses to indicate that the message is complete (and that the Processor student can open their eyes again).

21. The students should then record what the numbers were and what the Processor thought they were in their Science Notebook. And then switch roles so that all students can experience the role of the Processor. Each time, the stream of ones and zeros should be changed and recorded.

TEACHER NOTE

During this part, the actual amplitude of the wave does not matter so long as the Processor knows that a wave has passed. This is one of the reasons that a digital signal is more reliable than an analog signal. (It is discrete data.)

Analog Signals

22. Ask students how they might use the same Slinky® and a similar process to send a signal with more continuous data (analog). Allow students to have a conversation with their groups to determine a procedure to do so.

23. During this part of the Explain activity, students will represent an analog signal with various amplitudes (a continuum of data/information). A set of four amplitudes should be predetermined that are different enough for the receiver to determine the difference, for example: 10 cm, 20 cm, 30 cm, 40 cm.

24. Once again, have the group come up with a message, this time of amplitudes of waves without the Processor knowing the message.

Amplitude										
Received Amplitude										

25. Practice sending various amplitudes down the Slinky® before the Processor closes their eyes.

After everyone is reasonably comfortable, have the Processor close their eyes and send the message as was done in the digital signal activity. After each pulse, the Processor should state out loud what the amplitude was and the next pulse should be sent. At the end of the message, the Input should send three quick pulses to indicate the end of the message and signal to the Processor to open their eyes.

26. Switch roles and have a new message generated.

TEACHER NOTE

During this part, the amplitude of the wave DOES matter. It will be much more difficult for students to actually get all of the amplitudes correct. This lack of certainty represents the “noise” or static in the signal. The amplitude of the waves represents a more continuous set of data that can be sent.

27. After all students have experienced each of the roles, encourage discussion within the group on the following questions. Monitor student discussion and ask probing questions to redirect thinking if necessary. Encourage students to use evidence recorded in their Science Notebook as a basis for their ideas.

    - What was the input for the signals (both digital and analog) and what did each represent?
    - What were the similarities and differences between the types of signals?
    - What was the process for sending each of the signals (both digital and analog) and what were the similarities and differences between them?
    - What was the output for each of the signals (both digital and analog) and what were the advantages and limitations of each?
    - How do you think you could improve upon the sending of the signals (input) to be more precise (digital or analog)?
    - How do you think you could improve upon the processing of the signals to be more precise (digital or analog)?
    - Recall that the tags that are on the white sharks that are received by REMUS are analog signals. Predict why you think these analog signals are encoded into digital signals before they are sent to researchers?
    - SPOT and PAT tags are digital signals. Acoustic tags are analog signals, but then need to be encoded to digital. Which do you think is the most reliable type of tag? Why?
    - Which type of tag can hold the most information? Why?

28. Have students respond to the following in their Science Notebook, letting them know you will

be providing sticky-note feedback (as described in Lesson 8.1: Shark Encounters):

- How do you think you could improve upon the sending of the signals (input) to be more precise (digital or analog)?
- How do you think you could improve upon the processing of the signals to be more precise (digital or analog)?
- SPOT and PAT tags are digital signals. Acoustic tags are analog signals, but then need to be encoded to digital. Which do you think is the most reliable type of tag? Why?
- Which type of tag can hold the most information? Why?

TEACHER NOTE

If students are talking about it, ask them to revisit **8.1.H3: My Shark Encounter Claim Chart** from lessons 8.1–8.6 and add any new information that could be used to support any of the claims and subsequent evidence and reasoning. The writers, however, thought it would be a stretch to modify based on this lesson. Students will be prompted to revisit it again after Lesson 8.8: Light, Which Way Does It Go?

Note: The lesson was adapted from "Teaching Electromagnetic Waves Used in Communication Technologies." by Tretter, Thomas. *Science Scope*, Oct. 2014, pp. 78–86. Copyright 2014 by NSTA.

Accommodations

There will be variation in the prior knowledge students have around wireless technology, due to the digital divide. Pull up images from the Internet of wireless devices mentioned (or use realia) for the brainstorm in the Engage such as cell phones, radios, WiFi Internet, walkie talkies, drones, remote controls, garage door openers, remote controlled cars, laser tag, pet tracker chips, satellites, earbuds, or speakers. This will also be helpful for English Learners.

Allow multiple viewings of the video. The first time, have students to view it to get a sense of the purpose. Then, show the video a second (or even third time) to help students focus on important details that can be recorded in their Science Notebook and discussed.

Ensure students are clear on the meaning of key vocabulary such as *encode*, *decode*, *binary code*, *digital* and *analog*. Use word parts to reinforce meaning: *encode*—prefix *en* means in or within; *decode*—prefix *de* means separation; *binary*—prefix *bi* means two. To create a concrete depiction of *analog* vs *digital*, show a visual image of a clock with moving hands for *analog* contrasted with a *digital* clock set to the same hour (just numerals).

Lastly, students having difficulty with the model for input, processing, and output of different wave types, should be invited to repeat the task. This can assist them in coming up with a set of procedures.

References

CSULB Shark Lab (2017, July 18). *NGSS Learning Sequence: Jawsome*. Retrieved from https://youtu.be/CajgBDBOkLk

Ericsson (2011, August 26), *The History of Wireless Communication*. Retrieved from https://www.youtube.com/watch?v=X5jPoQzEh-M

Tretter, Thomas. “Teaching Electromagnetic Waves Used in Communication Technologies.” *Science Scope*, Oct. 2014, pp. 78–86.

Toolbox Table of Contents

8.7.H1	Binary Code	8.7.15

Binary Code

A	■□■■	■■■□
B	■□■■	■■□■
C	■□■■	■■□□
D	■□■■	■□■■
E	■□■■	■□■□
F	■□■■	■□□■
G	■□■■	■□□□
H	■□■■	□■■■
I	■□■■	□■■□
J	■□■■	□■□■
K	■□■■	□■□□
L	■□■■	□□■■
M	■□■■	□□■□
N	■□■■	□□□■
O	■□■■	□□□□
P	■□■□	■■■■
Q	■□■□	■■■□
R	■□■□	■■□■
S	■□■□	■■□□
T	■□■□	■□■■
U	■□■□	■□■□
V	■□■□	■□□■
W	■□■□	■□□□
X	■□■□	□■■■
Y	■□■□	□■■□
Z	■□■□	□■□■

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Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)	
MS-PS4-3	Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. [Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in WiFi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [Assessment Boundary: Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.]
A note from the authors: While students are working toward an understanding of the reliability of digital signals over analog signals, it is compelling for students to be able to speak to the fundamental differences between the two types of signals. The addition of the basics of binary terminology and quantitative differences between the two types of signals is above the assessment boundary for this Performance Expectation but does not go beyond observations and basic encoding for students. The mechanism for the encoding and retrieving is not discussed as it is more appropriate for a high school level. Students will revisit their claim chart poster at the end of the lesson to consider if tagging technologies gives further evidence and reasons to support whether there are more, less, or the same number of shark encounters now as compared to the past.	

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)

Asking Questions and Defining Problems

- Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

Analyzing and Interpreting Data

- Consider limitations of data analysis (e.g. measurement error) and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).
- Analyze and interpret data to determine similarities and differences in findings.

Planning and Carrying Out Investigations

- Plan an investigation ~~individually and~~ collaboratively, and in the design: identify independent and dependent variables and controls, ~~what tools are needed to do the gathering~~, how measurements will be recorded, ~~and how many data are needed to support a claim.~~

Appendix 8.7

DISCIPLINARY CORE IDEAS (DCI)
PS4.C: Information Technologies and Instrumentation
• Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.

CROSSCUTTING CONCEPTS (CCC)
Cause and Effect
• Cause and effect relationships may be used to predict phenomena in ~~natural or~~ designed systems.
Systems and System Models
• Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. • Models can be used to represent systems and their interactions— such as inputs, processes and outputs~~—and energy, matter~~, and information flows within systems.

Common Core State Standards (CCSS)

CCSS ELA SCIENCE & TECHNICAL SUBJECTS
CCSS.ELA-Literacy.RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
CCSS.ELA-Literacy.RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
CCSS ELA WRITING
CCSS.ELA-LITERACY.WHST.6-8.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

Appendix 8.7

California English Language Development (ELD) Standards

CA ELD		
Part 1.8.5 Listening actively to spoken English in a range of social and academic contexts		
EMERGING	**EXPANDING**	**BRIDGING**
P1.8.5 Demonstrate active listening in oral presentation activities by asking and answering basic questions with prompting and substantial support.	**P1.8.5** Demonstrate active listening in oral presentation activities by asking and answering detailed questions with occasional prompting and moderate support.	**P1.8.5** Demonstrate active listening in oral presentation activities by asking and answering detailed questions with minimal prompting and support.

In addition to the standard above, you may find that you touch on the following standards in this lesson as well:

P1.8.1: Exchanging information and ideas with others through oral collaborative discussions on a range of social and academic topics

P1.8.2: Interacting with others in written English in various communicative forms (print, communicative technology and multimedia)

P1.8.3: Offering and justifying opinions, negotiating with and persuading others in communicative exchanges

P2.8.5: Modifying to add details

P2.8.6: Connecting ideas