Tags and Waves

8.6

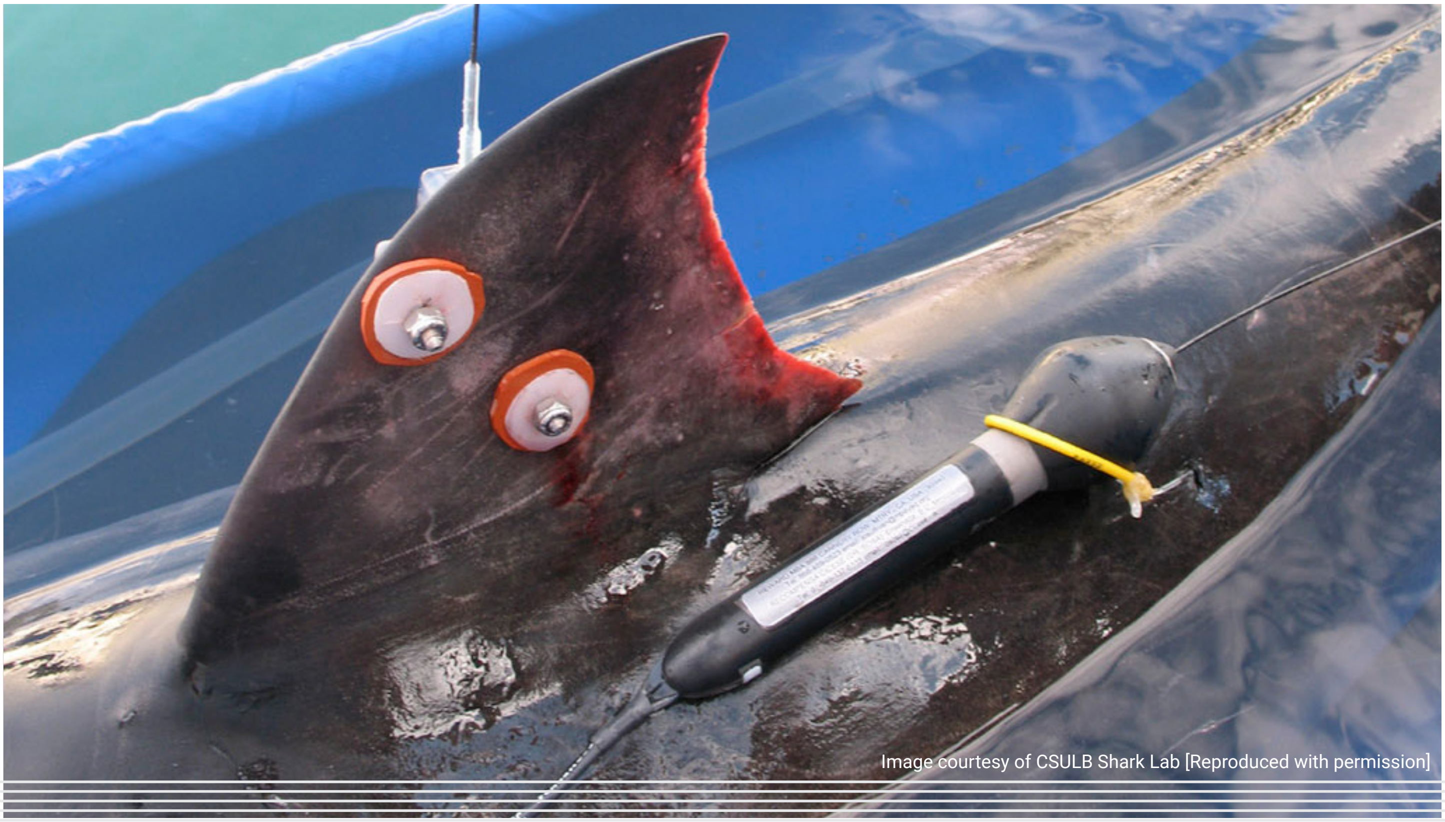

Image courtesy of CSULB Shark Lab [Reproduced with permission]

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

Develop and use a model to show how device function is influenced by the properties of waves.

Investigative Phenomenon

Devices that emit different types of waves will perform differently in air, without air, and when submerged in water.

Standards

Refer to Appendix 8.6 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

Prior to this, students applied understanding of how sharks have electrosensitivity to components of tracking devices. In learning this, students explored magnetic fields, currents, and the relationship between the two.

This lesson provides students the opportunity to conduct an investigation to learn more about the various types of devices used to track white sharks (those that transmit and those that receive information/data) and the influence of different mediums on the performance of the wave used by those devices. Students build iterations of a model, based on evidence, to show their understanding of both observable and unobservable phenomena and how differences in a system impact the phenomena. They use this model to show complex and microscopic structures and systems and visualize how their functions depend on the composition and relationship among parts and properties of different materials. The purpose of this lesson is to introduce waves in a context that is motivating for students, giving them partial understanding of PS4.A (a sound wave needs a medium through which it is transmitted). Ideally, students would enter this learning sequence having a foundation in wave properties as they will be able to apply that knowledge to find deeper understanding here.

In the next lesson, students will explore the concept that digital signals are more reliable than analog and thus used in tracking devices.

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

Time

135 minutes

Part I	45 minutes	Engage
Part II	70 minutes	Explore
Part III	20 minutes	Explain

Materials

Whole Class

- ❑ *REMUS Shark Cam: The Hunter and the Hunted* video, https://vimeo.com/101165012
- ❑ *Shark sightings in shallow water have experts racing to learn why* video, https://www.nbcnews.com/video/shark-sightings-in-shallow-water-have-experts-racing-to-learn-why-947022915732
- ❑ *Bell in a Bell Jar* video, https://www.youtube.com/watch?v=ce7AMJdq0Gw
- ❑ *NGSS Learning Sequence: Jawsome* video, https://www.youtube.com/watch?v=CajgBDBOkLk&feature=youtu.be

- Ruler
- Hand-held radio (small, battery-powered, and AM/FM radio – emergency radios work well for this)
- Audible timer (separate object, this should not be a part of the same object as the radio)
- Extra large zip-top bags
- Two large transparent tubs or fish tanks, about 10–20 gallons each (If possible, set up more than one pair of these in the classroom for easier student access.)
- Salt
- Long spoon
- Pitcher (to make salt water and transfer to tub/tank)
- Access to 20–40 gallons of water (more if replicating tub set up)
- Object that uses waves that students might think of to test (flashlight, old cell phone, etc.)
- Vacuum demonstration materials: bell jar, vacuum base plate, buzzer, hoses, and pump (If you do not have access to these materials, you might try asking the local high school or college if they have equipment you can borrow. Alternatively, a video can be used in its place; link in the lesson below.)

Per Group of 4

- Two metal spoons
- Internet-enabled devices
- Large white boards (chart/butcher paper can be substituted)
- White board markers and eraser
- Yellow, orange, and blue sticky notes (These colors aren't critical, although three different colors are needed.)
- Rag (to dry spills)

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)
- 8.6.H1: Final Wave Model and Explanation Rubric

Teacher

- 8.6.R1: Shark Lab Tracking Devices
- 8.6.R2: Shark Lab Model

Advance Preparation

1. Fill one of the tubs/tanks with fresh water.
2. Prepare salt water for the other tub/tank. No need for precision with respect to concentration; the water just needs to be salty. (If you want to match ocean salinity, your target is 35 parts per thousand, but the activity works better if salinity is higher. To see whether the salinity is adequate, seal the AM/FM radio in a zip-top bag and submerge in the center of the tub/tank surrounded by several inches of salt water. If adequate, the signal should be blocked.) Make sure you dissolve the salt fully in the tank of water the night before the activity to get noticeable differences when comparing energy transmission through fresh water and salt water.
3. Prepare the vacuum demonstration if you have access to materials. If you do not have access, you might try asking the local high school or college if they have equipment you can borrow. (Step 11 of Procedure)
4. Duplicate **8.6.H1: Final Wave Model and Explanation Rubric** for each student. (Step 13 of Procedure)
5. Review videos prior to working with students. Be sure you are able to project video from the internet. (Steps 10, 11, and 14 of Procedure)
6. Review **8.6.R1: Shark Lab Tracking Devices**.
7. Review **8.6.R2: Shark Lab Model**.

Procedure

Part I

Engage (45 minutes)

Develop and use a model to show how energy is transmitted through different mediums.

1. Begin by asking students to discuss in groups how they think trackers like REMUS have the potential to provide "hype-free" information on sharks (potentially addressing both parts of the anchoring phenomenon).

2. Ask students how they think trackers like REMUS home in on a tag on a shark and communicate with scientists on a boat. Give students time to discuss and record ideas in their Science Notebook. If students are struggling, replay the beginning of the *REMUS SharkCam: The Hunter and the Hunted* video and pause where it mentions the use of acoustic technology. Engage students in a discussion of what they think *acoustic technology* means and how it might be used as a tracking tool.

3. Ask students if they have any experience with sound traveling in the air and briefly discuss. (Students might relate to shouting from across a room, how a car sounds if it speeds by, etc.) To help give all students the same reference point, ask students to take two spoons, tap them together once, and ask students to describe what is happening. (Let students know they may try this again if needed.) Continue to ask, "what else" until students describe that their ear picks up a sound that began at the spoon and that the spoons vibrate.

    a. ▶ If students don't mention vibration (drawing on prior knowledge from elementary grades), take a plastic ruler, suspend half off the edge of a table, and "pluck" the ruler. Students should observe hearing a sound and seeing the ruler vibrate.

    b. ▶ If students don't mention their ear picking up the sound, ask more probing questions to get at the idea that the vibration would continue through the air and within components of the ear (cilia, bones); these components vibrate and register as a sound with the brain.

    c. Have students recall their ideas about models and how they communicate scientific understanding, and that models need to include enough detail that an outside observer could infer relationships between parts.

    d. Ask students to draw a quick model in their Science Notebook showing how the sound was generated by the spoons (vibrating source), how it moved in the air (medium), and how the ear was able to detect it (receiver). How does the energy flow from spoon to ear? What are important features about the structure of the ear that make hearing possible? What parts are necessary for hearing? How can we know? Before students begin their model, ask for their ideas of features needed for a model to convey understanding to themselves as well as other people.

e. Ask students to draw a rough model in their Science Notebook of how they think an ear is able to hear sound from two spoons that hit.

   › Ask students to swap notebooks with a partner, review, and have a brief discussion of the model and what was clear/not clear. Encourage students to make a revision that would improve the clarity of their model.

TEACHER NOTE

By the end of 8th grade, models should include particles (in this case, air particles). ▶ If you notice only a few models that include air particles, have students share models with peers and encourage another revision. If this doesn't self-correct student models, ask the class to direct you (at a white board in the front of the room) how to model the phenomenon. Only draw/label what students direct you to; ask questions about what they are asking you to do and why. If no one mentions air, ask what is in between the spoon and the ear and how it can be represented in the model. The class should come to an agreement of how to show air particles (usually small circles, O) and how they should be spaced since air is a gas. If the idea of vibration has emerged, ask what that vibration would do to the air particles and how that could be shown in the model. (Many students will agree that a vibrating particle can be drawn as "O", as opposed to non-vibrating, O.) This particle idea is important to understand moving on to the idea of sound moving under water. The idea of energy should also emerge as students have previously built this idea in prior grades. Many students tend to agree to show energy moving as a directional arrow.

4. Ask students what happens with sound underwater. Ask students if they have any experience with sound traveling under water (maybe a time they decided to have an underwater "tea party" or spoke to someone or themselves while submerged in a pool or bathtub) and discuss as a whole class.

5. Ask students to gather around the tank filled with salt water and ask for a volunteer to place their ear up against the side. Take two metal spoons and tap them together, submerged in the center of the tank. Ask the student to describe to the class what s/he notices. Repeat tapping the spoons together in the water and discuss differences students notice between the air and water. Invite groups to try this themselves.

   a. Ask students to return to their seats and think of how they could model this. Before students begin their model, ask for their ideas of how the model will change. (How will they represent air in their model? How will they represent water?)

b. Ask students to individually draw a new rough model in their Science Notebook showing how sound was generated by the spoons (vibrating source), how it traveled through the different mediums (air vs. water—how are the two different?), and how the ear was able to detect it (receiver). How does the energy flow, from spoon to ear?

TEACHER NOTE

This note is intended to help facilitate student sensemaking of phenomena. Once students are describing the role of the spoons and noticing the vibration, then it's appropriate to encourage students to use the phrase, vibrating source. The same is true for their ears; once they realize the ear has a role in detecting the vibration, then it's appropriate to encourage use of the word receiver. If students have a hard time internalizing that the spoons vibrate, model the same phenomenon with a ruler on the edge of the desk that gets tapped; kids will readily notice the vibration and can apply that understanding to the spoons. Showing a video clip of a guitar string can also help illustrate the concept (things that make sound vibrate). In addition, students may forget the importance of particles in their model. ▶ If you don't see students representing air or water in their models, ask them to recall what air is made of and what water is made of and how they could show that in their model. Then ask how they think the energy from the vibration gets from the source to the receiver. A simple example of having students line up, shoulder-to-shoulder, feet "glued" into place, and gently pushing on the outside shoulder of student #1 (towards the shoulders of other students) would demonstrate how energy from one end would go through particles (students) to the other end, showing the particles moving but not dislocated from their position.

Additionally, when students are diagramming their models of the spoons tapping in the water, it is useful for this model—and for other models within future lessons—to have the class come to consensus about what symbols can represent the "unobservable mechanisms" involved for both matter and energy. For example, students may agree that air and water particles are drawn as circles (perhaps color coded differently) and sound waves are drawn as half circle lines. A consensus on these symbols help students understand the ideas being expressed in a model diagram when groups are sharing their thoughts with others. If different groups use a variety of different icons/symbols to express their thinking, their ideas are more likely to get lost in translation.

Caution about sound: The intent of considering sound (acoustic) wave use in tracking devices here is to help explain why scientists use different types of waves in tracking devices. Students will eventually be able to conclude that sound needs a medium to travel, but differences between salt water and fresh water will only be explained by ideas around it being harder to move in salt water than fresh water; a more complete explanation involving speed of the wave is reserved for high school.

6. Monitor work and select a few students to share their model with the class. Encourage students to edit their models if they feel that something they saw would help make their model clearer in showing what they are understanding right now. Verify with the class that what their model shows is sound waves being *transmitted* through particles of water and air (all of which is directly un-observable) and ask students to include a description that uses the word *transmitted*.

As students share and discuss as a class, encourage them to use discussion norms such as wait time, encouraging others to say more, asking for evidence, paraphrasing or repeating, adding on, etc.

7. Ask students to share their individual models as a group and discuss. Remind students that they can use **8.1.H2: Scientist Communication Survival Kit** (from Lesson 1: Shark Encounters) to help with collaborative communication. After everyone has had a chance to share within the group, ask the group to discuss the following and revise:

   - What is something all of the models have in common?
   - What is something unique that the person to the left of you included in their model that adds useful meaning to the model?
   - What is something you didn't originally think of or see in any of the models, but now you think might be important to include?

8. When groups are finished discussing, ask each to create a group consensus model on a group whiteboard *but this time, instead of spoons and ears*, let students know they will now begin to tackle some of their questions from Lesson 4: REMUS about how REMUS works. Ask students to consider how REMUS works in a similar way as the spoons:

   How does a tracking device like REMUS use sound energy, specifically, to locate and gather information from a tag on a shark?

   a. The introduction of energy at this point will help with later conceptual understanding of transmission and absorption. Before students begin their group consensus model, pose the question, "How does a tracking device like REMUS use sound energy, specifically, to locate and gather information from a tag on a shark?" Ask students to discuss why energy is introduced at this point and what they know about energy. All students know something about energy—even if they don't think they do. Ask the class what they remember about energy. (▶ If they are stumped, focus them on sound energy. This is a common example of energy that younger students learn about; this is a specific 4th grade DCI.)

      Responses could include the following:

      - *Moving objects, light, heat and sound have energy.*
      - *Energy can move from place to place.*
      - *Energy can change the motion of objects.*
      - *Energy can move in the form of a wave and a wave is a regular pattern of motion.*
      - *Energy can be tracked through physical and chemical interactions.*
      - *Temperature is a measure of total energy of a system.*

- *Burning can release energy.*

b. Since a tracking device uses sound (acoustic), and sound is a form of energy, ask students how they will represent what happens to the energy in the water, and the sorts of things the energy might interact with. (Many students will identify "seen" objects like fish, so encourage them to identify things that are unobservable, like water molecules, other dissolved compounds like salts, and energy.) Use questions to attempt to get students to think of what these objects are rather than telling them. Examples:

- "What are all of the things you can think of that make up ocean water?"
- "What else besides H_2O is in the water?"
- "If you look at a bottle of soda, we know that there is soda in there, but what else? (What makes it fizzy?)"
- "What is dissolved in the water or soda?"

c. Give groups time to construct their model following the discussion. Once students begin modeling how a tracking device uses sound to locate a shark, ask them to expand their model to predict how researchers (via the tracker) would get information from the tag. Here are some guiding questions to help students:

- What is REMUS homing in on?
- How are you showing energy from REMUS reaching the shark?
- How will a scientist retrieve information from the tag?

▶ For students struggling with the modeling process, suggest they add a story of what is happening to accompany the work they are able to do (like a narrative). If able, encourage them to use this story to inspire ideas of things they can add to the model and vice versa.

Procedure

Part II

Explore (70 minutes)

Develop and use a model to show differences in how energy is transmitted through different mediums.

9. Ask groups to think of the types of data a tag might gather that would be of interest to a shark researcher. (If they refer back to what they learned about REMUS, they may think of data such as temperature, salinity, etc.) As it turns out, REMUS is a unique device; most trackers don't use a video/audio feed with a research team anxiously waiting to retrieve their robot to check out the footage! REMUS only allows scientists to study one tagged shark at a time (per tracker). Ask students to consider some other things that tags might be able to do if a team needed to gather information on more sharks (and by *do*, we mean *measure*).

10. To give students a context beyond REMUS, show students the video, *Shark sightings in shallow water have experts racing to learn why*.

    Ask students to record questions they have during the video about how the tag is working. Next, ask, "If a shark has a device like a fitness tracker and camera, how do researchers get the video feed and the information (data) from this tag or one like REMUS?" Discussion should involve recognizing this data needing to move through salt water, between tag and receiver. Ask, "How does the transmission of that informational data (energy) change when it's moving in the water vs. the air?" and discuss.

11. Mention that sometimes interesting things can happen to different types of waves under different circumstances. Ask students to work in groups to figure out what happens to radio waves and sound waves under different conditions. (These are the two most common waves used in tracking devices; *conditions* refers to the medium of air, water, and saltwater.) Groups think of different scenarios and test them.

    a. Ask what is needed for a fair test and discuss. (Students should communicate the idea that we should test the same wave-making device in all three conditions.)

    b. Brainstorm with the class to think of objects in the classroom that use radio waves (many students will have radio wave devices on them—cell phones, bluetooth speakers, wireless computer mouse) and those that use sound waves. Objects will need to fit inside sealed extra large zip-top bags (double bag if concerned). Many students will confuse radio with sound, so having an object that makes sound, like a timer buzzer, that isn't a radio will be important. To help students develop the idea that the *medium* a wave travels through is important, have at least one tank of salt water and one of fresh water available, and vacuum set-up if you have access to one. (If not, have video in Step 11d below, ready to show.)

TEACHER NOTE

This is intended to be a faster investigation (Explore) for students and thus, how students plan their investigation has simple requirements to expedite the work. Thinking of the spoons or a device like a timer/buzzer that emits sound, the sound should be somewhat harder to hear when the device is submerged in fresh water or salt water, but still audible. Radio waves, however, are disrupted by the ions in salt water. A radio submerged in salt water won't be able to receive the radio signal (signal will be "cut" when surrounded by at least a foot of salt water on all sides), and therefore students won't be able to hear the radio. Making sure students have access to a device that makes sound but doesn't use radio waves will help avoid confusion about the radio receiving a signal vs. producing sound. Quality zip-top bags are needed to seal devices and protect them from water damage.

c. Direct students to begin by developing a plan for their test(s) in their Science Notebook. In order to test something, each member of the group needs to record simple procedures (simple is ok, this is supposed to be quick):

- Describe what you will do.
- Predict what the effect will be.
- Record results (qualitative and quantitative encouraged).
- Small models are encouraged.
- Give a brief explanation (identify what you think is going on).

After a group can verify that all group members are ready (each has a description and prediction), students from the group may begin testing and recording results, small models, and explanations.

d. Encourage students to conduct at least two different tests using radio waves and two different tests using sound waves (more if time allows). During the testing, occasionally pose the question, “I wonder if this works without the air, like if it was above the atmosphere or in outer space?” Groups may ask how sound travels if there is no medium or if the molecules within that medium are spaced very far apart (far enough as to not be able to interact with each other, e.g., above atmosphere or in outer space). At this point, either do the vacuum demonstration (object emitting sound, sound is no longer heard as air is removed from the system) or, if equipment is not available, show the video, *Bell in a Bell Jar*.

e. Ask students to document in their Science Notebook any differences in how radio waves and sound waves transmit energy through salt water, fresh water, and the air (change in variables). Encourage use of the words *transmitted* (if students describe energy moving from place to place) and *absorbed* (if students describe energy changing from one form to another).

f. Have a class discussion about what groups observed (applying vocabulary). Ask students the following questions:

- “Do radio waves and sound waves work the same in air, without air, in fresh water, and in salt water? What cause and effect relationship could explain the phenomena?”
- “How are air, fresh water, and salt water different?”
- “Why would two different waves behave differently in salt water? How do you think the ability of the wave to transmit energy is impacted by the salt water?”

Throughout this process, encourage use of the **8.1.H2: Scientist Communication Survival Kit** (from Lesson 8.1: Shark Encounters) as this helps to ensure equitable conversations and contributions from students. Consider providing sentence frames for students who need literacy support, or allowing these students to work in pairs writing portions together; later you can make a copy of the work completed for the other student to put into their Science Notebook. Alternatively, allow students to do this work in their native language.

TEACHER NOTE

Radio waves aren't a specific feature of the DCI being addressed, but do belong to the same type of energy as light. In this case, however, radio waves are different waves than light waves (they have a longer wavelength) but they behave in the exact same manner (perpendicular motion of particles but the energy has an overall forward movement). It may be useful to let students know they are the same type of wave and to consider how the structure of the wave impacts its function. (If students ask, let them test light sources in the water tanks and compare them to the AM/FM radio.) In both cases, radio/light and sound, energy of the wave moves forward in a repeating pattern that is predictable and has a different impact on the particles in the medium it moves through:

- Radio and light—the particles move up and down
- Sound—the particles move left and right

To help students understand the differences, once again, have a few students stand in a "home" position: standing in a line, shoulder to shoulder, arms locked at elbow, feet "glued" into place. Gently push on the outside shoulder of student number 1 (towards the shoulders of other students) to demonstrate sound (movement going left and right through "particles" to the other end, showing the particles moving but not dislocated from their position). In the case of radio and light, have students stand in the home position again, but this time have student number 1 bend over and stand back up, this pulls student number 2 (and onward) down and up simulating the movement of particles going up and down.

Then ask how they think the energy from the vibration gets from the source to the receiver. A simple example of having students line up, shoulder-to-shoulder, feet "glued" into place, and gently pushing on the outside shoulder of student number 1 (towards the shoulders of other students) would demonstrate how energy from one end would go through particles (students) to the other end, showing the particles moving but not dislocated from their position.

It is expected that students would engage in a previous learning sequence prior to this one where they develop understanding of this aspect of PS4.A—a simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude—in more depth through the SEP of mathematical and computational thinking (although some teachers may choose to spend that time now). This lesson will provide opportunities for students to apply that knowledge (although we have left out the terms wavelength, frequency, and amplitude to allow flexibility for teachers who may wish to address it later). As an aside, students do begin exploring a related DCI in 4th grade and may recall some of that information.

g. If time permits, allow motivated students and/or those already showing clear understanding of the DCI to test anything that generates a wave in the tank. Encourage them to draw a Venn diagram to compare and contrast mechanical waves (sound) with electromagnetic waves (light and radio).

12. Inform students that REMUS and the tag placed on white sharks are just one type of device that scientists use. Partner students with those who have a mobile device (or get access to Internet-enabled laptops/tablets) and ask students to research SPOT and PAT tags (two of the most commonly used tags on white sharks). Ask students to use their research to both clarify their ideas about how radio and sound waves work and add to their list of things that the tags can measure and record this thinking in their Science Notebook. (▶ If you need to differentiate for students, assign only one type of tag to students needing more support; SPOT tags involve a simpler process of transmission and may be easier to compare to the models already generated by students, whereas students able to negotiate more complexity of steps can work with PAT tags. If splitting up the research, be sure to give opportunity for the two to share what they researched to help all students build complete understanding of the need for both tags.)

13. Once students have had adequate time to research and synthesize the new information, ask them to revise their group consensus models to accomplish the following:

    a. Show how two types of waves, sound and radio waves, allow trackers and tags to communicate.

    b. Include evidence for components of the model. (What this looks like is a model diagram with an accompanying explanation using the claim, evidence, reasoning format to justify their thinking on their model.)

    c. Describe or show the path of energy flowing through the system.

    To help guide students in creating grade level appropriate models, give students the rubric to help guide work, **8.6.H1: Final Wave Model and Explanation Rubric**. Once again, for those needing support, allow for stories/narrative to be used.

14. Inform students that they now have a body of evidence to explain what happens to various waves in various mediums. They now get to see if information from scientists verifies and supports their work, and have an opportunity to have some student questions answered by scientists. Let them know that a group of students doing the same work had the chance to do this. Show the video, *NGSS Learning Sequence: Jawsome*, from the CSULB Shark Lab (explaining how they use tracking devices to study sharks) and ask students to consider where their own findings (which they have modeled) are in agreement with the Shark Labbers (the “affectionate” term they use to describe scientists in the lab). Point out that this “consensus” reinforces their work. Have students note anything from the video that

confirms their model. In addition, what new information learned from the video might further inform their model? As students watch the video, ask them to record the following in their Science Notebook:

a. Identify any details/evidence about the differences in *waves* that better help you understand the function of respective components of tracking devices. (Connect to prior understanding of wave properties learned in the unit previous to this.)

b. Identify any details/evidence about the differences of the *medium* that better help you understand the function of respective tracking devices.

c. Identify any details/evidence about the tools—tags, trackers, and receivers—that help you better understand how scientists can use these devices to study white sharks.

d. Identify common thinking between you and the Shark Labbers.

e. Note any *aha*'s you have!

f. What are you still wondering about waves and tools?

TEACHER NOTE

8.6.R1: Shark Lab Tracking Devices and **8.6.R2: Shark Lab Model** are for your reference. **8.6.R2: Shark Lab Model,** in particular, is **NOT** intended for students to copy, but provided in case it would benefit your discussions with students.

Ask students to collaborate as a group to update their group consensus model to show new understanding. If time warrants (▶ and especially if models could benefit from some editing or clarification), ask groups to move around the room to review the models of two other groups and provide sticky-note feedback to each group's consensus model:

- Yellow sticky notes: Ask for clarification of ideas
  - What do you mean ______?
  - Can you elaborate on how ______ is evidence for the model?
  - We respectfully disagree with ______ because ______.
- Blue sticky notes: Build on or add to ideas
  - We can add to your idea of ______ by suggesting you include ______.
- Orange sticky notes: Agree with and praise ideas
  - We agree with your thinking on ______.

Students returning to their group are asked to make at least two changes to their group consensus model based on peer feedback.

Procedure

Part III

Explain (20 minutes)

Develop and use a model to show differences in how energy is transmitted through different mediums.

Develop and use a model to show how device function is influenced by the properties of waves.

15. Ask students to draw their own individual model in their Science Notebook to show their current understanding of how sound and radio waves are used in tracking devices and how scientists might get information from a tag on a white shark. Remind students that models communicate scientific understanding; models need to include enough detail that an outside observer could infer cause and effect relationships. (To probe thinking, ask how a change in medium, salt water vs. air, has an effect on waves.) This final model must also include an explanation for wave behavior in its particular medium. (Explanations include evidence that supports a claim and scientific reasoning. See **8.6.H1: Final Wave Model and Explanation Rubric**.)

16. As groups finish, ask them to revisit **8.1.H3: My Shark Encounter Claim Chart** from Lessons 8.1–8.5 and add any new information that could be used to support any of the claims and subsequent evidence and reasoning.

TEACHER NOTE

The activity in Step 15 is intentionally open-ended to allow for students to freely show knowledge. For students that need more direction, consider adding more specificity such as: How do researchers on shore or on a boat get informational data (energy) from a tag or tracking device that is under the surface of the ocean, and what is this informational data (energy)?, or What types of informational data can be collected?, or Imagine two different receivers are being used, one below the surface of the ocean and one above; what type of wave/energy is most advantageous for each circumstance and why? For students that are highly motivated, ask them to extend their model to compare how the human ear detects sound to how a white shark uses their ampullae of Lorenzini to detect electric fields. How might pressure and/or temperature changes in the water affect the detection process? How do the ampullae of Lorenzini compare to the tympanic membrane in the human ear? How do pressure and temperature affect how humans detect sound?

Accommodations

For classes where students will struggle with searching for information on SPOT and PAT tags, consider archiving a few good resources in a shareable document for students to quickly link to. If students tend to disengage easily, have at least four resources ready and jigsaw the task as a group where students know they will be responsible for teaching the other members of their group about their research.

When showing short videos, it's often helpful to students to watch the video once to get a sense of the purpose. Showing the video a second (and sometimes third time) allows students to focus on important details that can be recorded in their Science Notebooks and discussed.

During the investigation with the salt water tank, allow each group the chance to use the salt water tank once they have completed their Science Notebook work. (Avoid doing this as a class demo.) This will motivate students to complete their work.

By seating students in groups (groups of 4 work well) and encouraging regular conversation, students have time to interact more with content and naturally help those that need more support. Use of **8.1.H2: Scientist Communication Survival Kit** helps with making sure that students who don't feel comfortable with sharing (often because of language, literacy level, uncertainty of content knowledge, etc.) are prompted to do so in a supportive way.

Use of a sense-making Science Notebook supports student language development, conceptual development, and metacognition. Students should be prompted to use their Science Notebook for

- ❑ prior knowledge of phenomena,
- ❑ exploration of phenomena and data collection,
- ❑ making sense of phenomena, and
- ❑ metacognition.

In this lesson, students are asked to create a plan for testing in their Science Notebook. Students often come up with really great ideas for organizing; however, some can struggle. Keeping a "teacher notebook" that provides an example for how to organize information can help. Make the teacher notebook available for any student who is apprehensive about organizing their own. This can encourage independence without over scaffolding.

Consider providing sentence frames for low literacy and second language learners. The use of graphic organizers can help struggling students manage Science Notebook work.

References

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

NBC News/Today (2017, May 18). *Shark sightings in shallow water have experts racing to learn why.* Retrieved from https://www.nbcnews.com/video/shark-sightings-in-shallow-water-have-experts-racing-to-learn-why-947022915732

QuantumBoffin (2010, February 1). *Bell in a Bell Jar.* Retrieved from https://www.youtube.com/watch?v=ce7AMJdq0Gw

Woods Hole Oceanographic Inst. (2014, July 19). *REMUS SharkCam: The Hunter and the Hunted*. Vimeo, Retrieved from https://vimeo.com/101165012

Toolbox Table of Contents

Final Wave Model and Explanation Rubric

Rubric for **constructing explanations** as a primary practice and **developing and using models** as a secondary practice.

4	3	2	1
Model(s) in the response portray components accurately in a picture or diagram that relates to the claim in the explanation. Components are accurately labeled in the explanation.	Model(s) in the response portray components in a picture or diagram that relates to the claim in the explanation. Components are mostly labeled and accurate.	Model is incomplete (missing some components) or contains **minor** errors.	Model is missing, unclear, or contains major errors.
Relationships among those components are shown in the model AND described in the explanation.	Relationships among those components are shown in the model OR described in the explanation.	At least one relationship among those components is shown OR described.	No correct relationship(s) are identified.
The model can be used to provide an explanation AND a prediction related to the claim given that is grounded in science and includes meaningful limitations of the model.	The model can be used to provide an explanation OR a prediction related to the claim given that is grounded in science and includes meaningful limitations of the model.	The model can be used to provide an explanation and/or a prediction that demonstrates partial understanding of the science.	The model cannot be used to provide an explanation or a prediction.
The scientific reasoning **explicitly** uses the crosscutting concept of *cause and effect* as a **central frame** for the explanation.	The scientific reasoning **explicitly** uses the crosscutting concept of *cause and effect* in the explanation.	Appropriate crosscutting concept of *cause and effect* is **identified** in the explanation.	An appropriate crosscutting concept is not identified in the explanation.
The scientific reasoning is accurate, linking multiple lines of evidence to the foundational ideas in the science discipline(s).	The scientific reasoning is accurate, linking a few lines of evidence to the foundational ideas in the science discipline(s).	The scientific reasoning has minor errors. May or may not link the evidence to the foundational ideas in the science discipline(s).	The scientific reasoning has major errors or is missing.

Note: Final Wave Model and Explanation Rubric from NGSS Rollout #3. CA NGSS Collaborative, 2016. Adapted with permission.

Shark Lab Tracking Devices

Acoustic and radio transmitters utilized by the CSULB Shark Lab as seen in CSULB Shark Lab (2017, July 18). *NGSS Learning Sequence: Jawsome*. Retrieved from https://youtu.be/CajgBDBOkLk

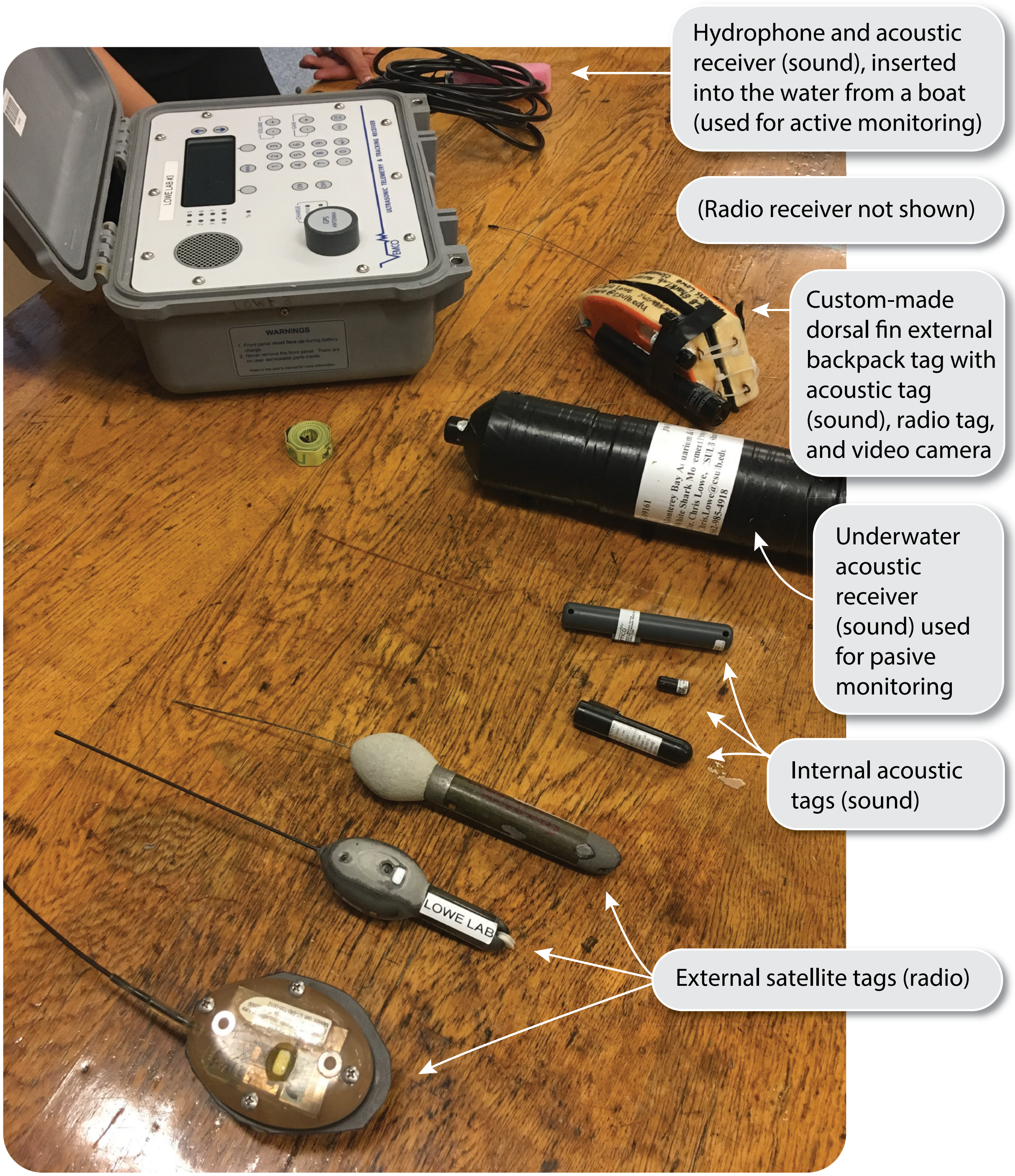

Image courtesy of CSULB Shark Lab [Reproduced with permission]

Shark Lab Tracking Devices (continued)

Custom Dorsal Fin "Backpack"

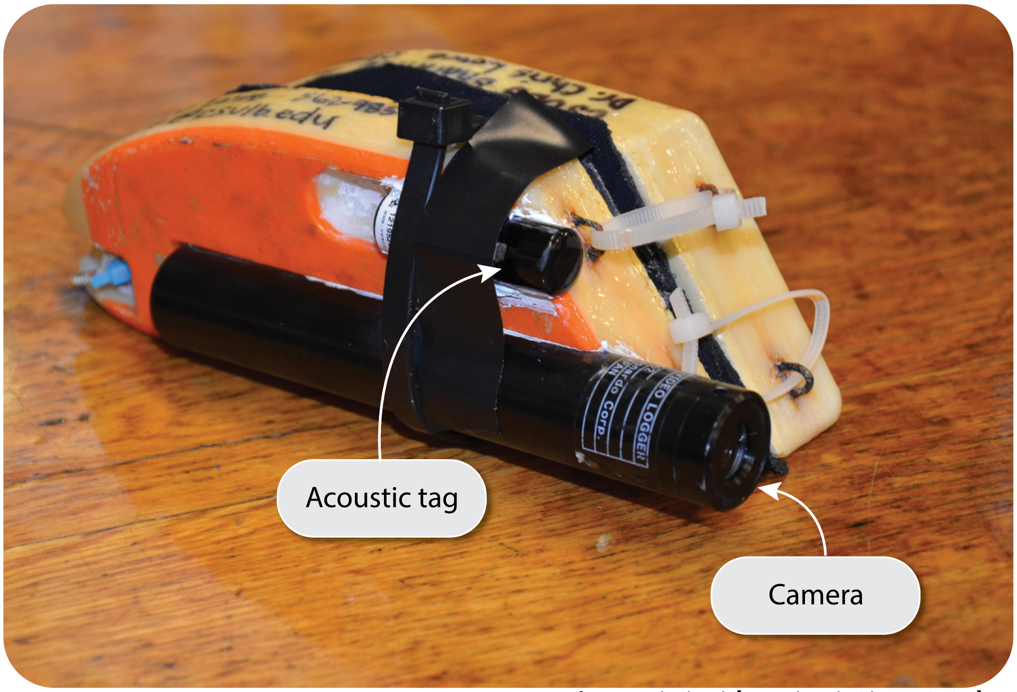

Image courtesy of CSULB Shark Lab [Reproduced with permission]

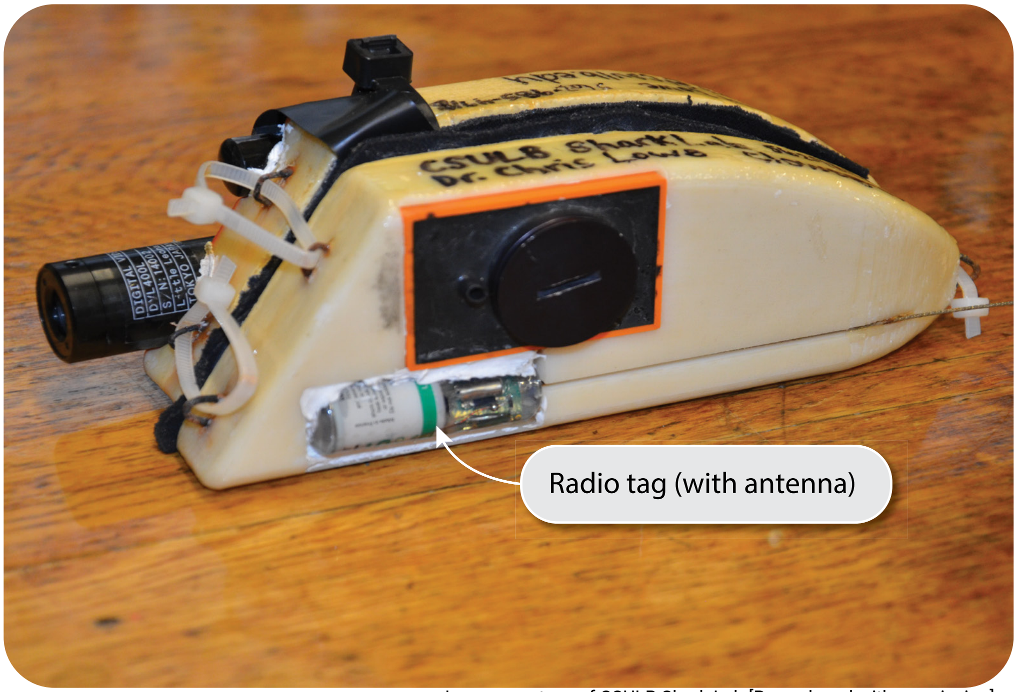

Image courtesy of CSULB Shark Lab [Reproduced with permission]

Shark Lab Model

Model of various tracking devices and transmission in water vs. air, made by Shark Lab researchers/students as seen in CSULB Shark Lab (2017, July 18). *NGSS Learning Sequence: Jawsome.* Retrieved from https://youtu.be/CajgBDBOkLk

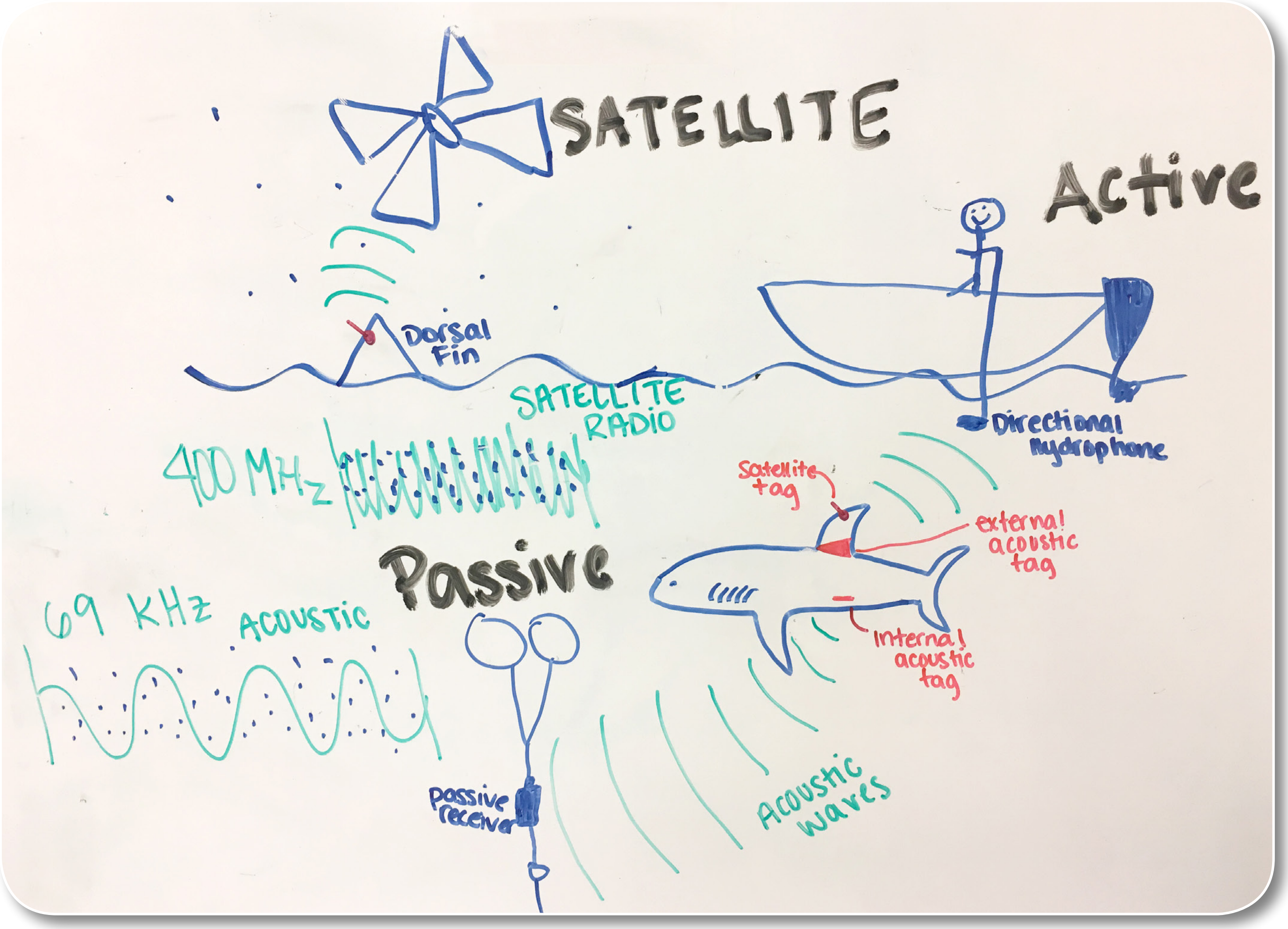

Image courtesy of CSULB Shark Lab [Reproduced with permission]

Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)	
MS-PS4-2	Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]
A note from the authors: Students build understanding of only one aspect of this Performance Expectation in this lesson (specifically, that waves move differently through various materials) and will not build a stronger understanding until the next lesson in this sequence Lesson 8.7: Digitized Signals. Be aware that in helping students develop models of wave behavior, this lesson goes beyond the assessment boundary of MS-PS4-2, which states that wave behavior will only be addressed for light and mechanical waves; introducing the electromagnetic spectrum is beyond the middle school level. However, because this phenomenon is compelling and includes many important aspects of the Evidence Statements for MS-PS4-2, it is useful to build student understanding. Note that the lesson specifically avoids discussion of the electromagnetic spectrum, as that is more appropriate for high school.	

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

SCIENCE AND ENGINEERING PRACTICES (SEP)

Developing and Using Models

- Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed.
- Develop and/or use a model to predict and/or describe phenomena.
- Develop a model to predict and/or describe unobservable mechanisms.

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 the claim~~.

DISCIPLINARY CORE IDEAS (DCI)

PS4.A: Wave Properties

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1) *only wavelength is explored
- A sound wave needs a medium through which it is transmitted. (MS-PS4-2)

Appendix 8.6

CROSSCUTTING CONCEPTS (CCC)
Cause and Effect
• Cause and effect relationships may be used to predict phenomena in natural or designed systems.
Energy and Matter
• Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). • The transfer of energy can be tracked as energy flows through a designed or natural system.
Structure and Function
• Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the ~~shapes~~, composition, and relationships among its parts. • Structures can be designed to serve particular functions by taking into account properties of different materials, ~~and how materials can be shaped and used.~~

Common Core State Standards (CCSS)

CCSS ELA SPEAKING & LISTENING
CCSS.ELA-LITERACY.SL.8.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.
CCSS.ELA-LITERACY.SL.8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.
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 8.6

California English Language Development (ELD) Standards

CA ELD		
Part 1.8.2 Interacting with others in written English in various communicative forms (print, communicative technology and multimedia)		
EMERGING	EXPANDING	BRIDGING
P1.8.2 Engage in short written exchanges with peers and collaborate on simple written texts on familiar topics, using technology when appropriate.	**P1.8.2** Engage in longer written exchanges with peers and collaborate on more detailed written texts on a variety of topics, using technology when appropriate.	**P1.8.2** Engage in extended written exchanges with peers and collaborate on complex written texts on a variety of topics, using technology when appropriate.
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 P1.8.3: Offering and justifying opinions, negotiating with and persuading others in communicative exchanges P1.8.5: Listening actively to spoken English in a range of social and academic contexts P1.8.6: Reading closely literary and informational texts and viewing multimedia to determine how meaning is conveyed explicitly and implicitly through language P1.8.8: Analyzing how writers and speakers use vocabulary and other language resources for specific purposes (to explain, persuade, entertain, etc.) depending on modality, text type, purpose, audience, topic, and content area P1.8.11: Justifying own arguments and evaluating others' arguments in writing P1.8.12: Selecting and applying varied and precise vocabulary and other language resources to effectively convey ideas P2.8.5: Modifying to add details P2.8.6: Connecting ideas		