How Can We Hear So Many Different Sounds From Across The Room?

1.0 pilot version - Jan. 2017

Teacher Guide

NGSS Middle School Storyline

Synopsis: *In this unit, students start by observing a perplexing phenomena. When a sewing needle taped to a cone, is dragged over the surface of a plastic disc spun under it, voices and musical notes are heard coming from it. This leads students to start noticing and wondering about other sound related phenomena, which in turn leads to wealth of new questions about ..*

- *What causes different sounds?*
- *What is traveling from a sound source to my ear?*
- *Why does the same thing sound different for people in different locations?*

What students figure out: *By the end of the unit, students develop powerful ideas about the nature of matter, energy, and waves to account for a variety of phenomena. These ideas include:*

- *The way that matter vibrates is related to the type of sound it produces (in terms of volume and pitch).*
- *Collisions & vibrations between the particles that make up matter can transfer energy through that matter.*
- *Sound is a pressure wave in air or any other material medium.*
- *Sound can make matter vibrate; different structures in our ear respond differently to different sounds.*
- *When a wave meets a surface between two different materials or conditions, part of the wave is reflected at that surface and another part continues on.*

NGSS PERFORMANCE EXPECTATIONS BUNDLE

MS. Waves and Electromagnetic Radiation

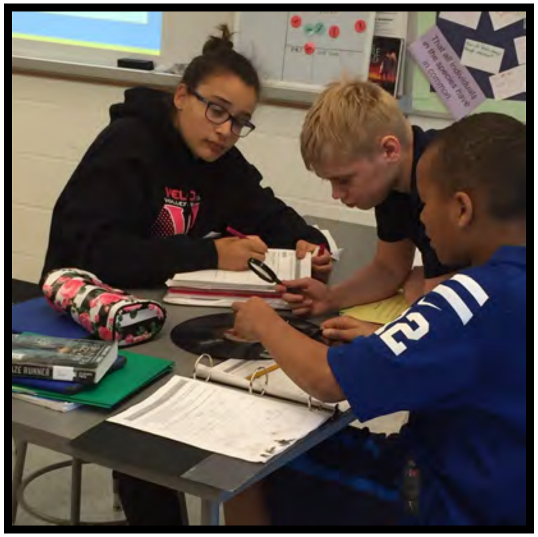
MS-PS4-1	MS-PS4-2	MS-PS4-3

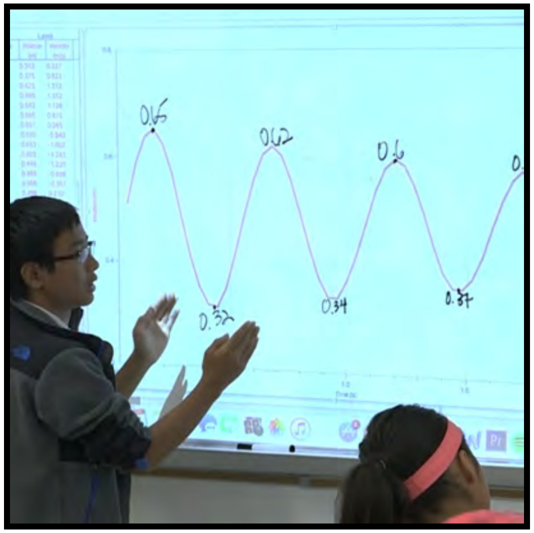
4. Waves: 4-PS4-1

1. Waves: Light & Sound: 1-PS4-1

MS. Energy: MS-LS1-8 (partial)

MS. Structure, Function & Info. Processing: MS-PS3-5 (partial)





These materials were developed through with support from the Gordon and Betty Moore Foundation to Northwestern University and support from the NGSX Project at Clark University, Tidemark Institute, and Northwestern University.

Targeted NGSS Performance Expectation(s):
1-PS4-1. Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate. [Clarification Statement: Examples of vibrating materials that make sound could include tuning forks and plucking a stretched string. Examples of how sound can make matter vibrate could include holding a piece of paper near a speaker making sound and holding an object near a vibrating tuning fork.] **4-PS4-1.** Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move. [Clarification Statement: Examples of models could include diagrams, analogies, and physical models using wire to illustrate wavelength and amplitude of waves.] **MS-PS4-1.** Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. [Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] **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.] **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.] **MS-LS1-8. (Partial)** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories. [Assessment Boundary: Assessment does not include mechanisms for the transmission of this information.] **MS-PS3-5. (Partial)** Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.]

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Science & Engineering Practice(s)	Disciplinary Core Ideas - DCI(s)	Cross-Cutting Concept(s) - CCC(s)
Developing and Using Models • Develop and use a model to describe phenomena. (MS-PS4-2) **Using Mathematics and Computational Thinking** • Use mathematical representations to describe and/or support scientific conclusions and design solutions. (MS-PS4-1) **Obtaining, Evaluating, and Communicating Information** • Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings. (MS-PS4-3) • Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. (MS-LS1-8) ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS4-1)	**PS4.A: Wave Properties** • Sound can make matter vibrate, and vibrating matter can make sound. (1-PS-4-1) • Waves of the same type can differ in amplitude and wavelength. (4-PS4-1) • A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1) • A sound wave needs a medium through which it is transmitted. (MS-PS4-2) **PS1.A: Structure and Properties of Matter** • Matter of any type can be subdivided into particles that are too small to be seen...(5-PS1-1) **PS3.B: Conservation of Energy and Energy Transfer** • When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5) **PS4.B: Electromagnetic Radiation** • However, because light can travel through space, it cannot be a matter wave, like sound or water waves. (MS-PS4-2) **PS4.C: Information Technologies and Instrumentation** • Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (MS-PS4-3) **LS1.D: Information Processing** • Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories. (MS-LS1-8) **Connections to the Preamble for PS4.A** • Sound is a pressure wave in air or any other material medium. • The human ear and brain working together are very good at detecting and decoding patterns of information in sound (e.g., speech and music) and distinguishing them from random noise. • When a wave meets the surface between two different materials or conditions (e.g., air to water), part of the wave is reflected at that surface and another part continues on.	**Patterns** • Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena. (4-PS-1) • Graphs and charts can be used to identify patterns in data. (MS-PS4-1) **Structure and Function** • Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS4-2) • Structures can be designed to serve particular functions. (MS-PS4-3) **Energy and Matter** • Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). (MS-PS3-5) **Connections to Engineering, Technology, and Applications of Science** • Influence of Science, Engineering, and Technology on Society and the Natural World Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. (MS-PS4-3) **Connections to Nature of Science Science is a Human Endeavor** • Advances in technology influence the progress of science and science has influenced advances in technology. (MS-PS4-3)

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Development History:

- Design team starts work on Alpha version of storyline in Fall of 2015.
- Alpha version of storyline piloted by Lisa Brody and Keetra Tipton in Spring 2016.
- Design team expanded.
- Beta version of storyline developed in fall 2016.
- Beta pilot planned for fall/winter of 2016.
- 1.0 field trials MI planned for spring of 2017.

Key to storyline columns:

Lesson Question (time) *Building toward* ⬇ *NGSS PEs:*	**Phenomena**	**Lesson Performance Expectation(s):**	**What We Figure Out** (CCCs & DCIs), *New Questions* and **Next Steps**
		• **Blue bold font: Science and Engineering Practice** • Regular font: Quoted from Appendix F Practices Matrix • *Italicized font: Specific storyline context (phenomena / question)* • Green font: Cross-cutting concept(s) • Orange font: Disciplinary Core Ideas (or pieces of these DCIs)	• Green font: Cross-cutting concept(s) • Orange font: Disciplinary Core Ideas (or pieces of these DCIs) • *Purple italicized font: New questions that we now have* • **Purple bold font: Our ideas for the next (or future) steps to pursue.**

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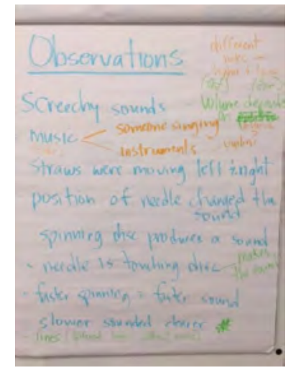
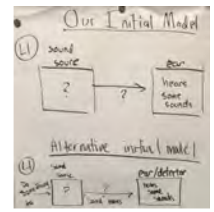
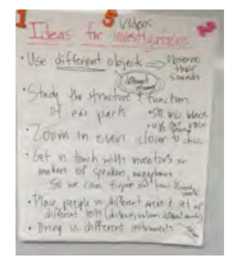
This Lesson....What we are doing now: This is the first lesson in the series. Students will observe a perplexing anchoring event: when a sewing needle taped to a cone, is dragged over the surface of a plastic disc spun under it, voices and musical notes are heard coming from it. You will help student use the observations from this phenomena to think about other sound related phenomena, which in turn will lead them to form a broader set of questions about sound to form a driving question board. Then you will help students brainstorm ways for the class to investigate these questions. These questions and ideas for investigations will motivate and guide the direction of many future lessons throughout the unit.

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L1: How can we hear so many different voices and sounds from across the room when we spin the record? 3 periods: 40 min. each *Building toward* *NGSS PEs:* *1-PS4-1, 4-PS4-1, MS-PS4-1, MS-PS4-2, MS-PS4-3 MS-LS1-8, MS-PS3-5.*	When a sewing needle taped to a cone, is dragged over the surface of a plastic disc spun under it, voices and musical notes are heard coming from it.  Other phenomena we recall about sounds we have or haven't heard from a distance.	**Develop an initial model** to describe unobservable mechanisms (causes) *that help explain "how you can hear so many different voices and sounds (effect) from across the room when we spin the record?"* **Ask questions** that arise from careful observation of this phenomenon, from patterns in other *sound related* phenomena, *or from gaps in our current* models, to clarify *what it is we want* to seek additional information *about and to start identifying ways to* investigate these within the scope of the classroom.	From spinning the record we noticed that: • We could hear voices, words, and instruments playing songs coming from the cone/record/needle apparatus. • The closer we were to the record the louder the sound was. • How fast you spin the record affects some aspects of the sounds we heard.   We made some initial models. After comparing initial models we noticed some differences in how we represented what is happening at the sound source and in the space between the sound source and our ear. But we also saw common elements such as: • a sound source • an ear (or other detector). • sound traveling from the sound source to our ear.  *We brainstormed some other phenomena we experienced at times where we either could or couldn't hear different sounds coming from different sound sources. These phenomena raised lots of questions.* *We organized our questions into these categories:* • *Q1: What causes different sounds?* • *Q2: How do sounds move from a sound source to my ear?* • *Q3: Why does the same thing sound different for people in different locations?*  **And now that we have a broad set of questions we want to be able to answer, we thought of possible ideas for investigations to help us make progress on some of our questions. One idea we had was related to the needle and its interaction with the moving record. We want to see the needle and the record up close where they are touching as it is making sounds.**

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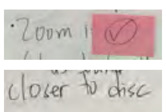
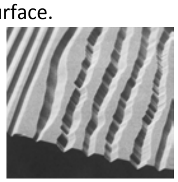
This Lesson....What we are doing now: Since students will have suggested that we need to zoom in and get closer to the needle and the record to see what is going on, that is what you provide them today, through a series of progressively more detailed inspections of the surface of record and the needle interacting with it. You help students argue from evidence that the grooves on the record are causing the needle to wobble back and forth in different patterns as it spun.

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L2: What does the record look like up close? 2 Periods: 40 min each  *Building toward* *NGSS PEs:* *1-PS4-1, 4-PS4-1*	A video of a record playing a longer song shows patterns in the motion of the needle across the record surface. A magnifying glass and a piece of a record reveals some patterns in the record structure Looking at pictures of the record surface under the microscope reveals patterns in the structures on its surface.  Watching an electron microscope video of needle on a record player reveals patterns in how the needle moves in relation to the structure of the groves.	**Analyze data and interpret data** *[from feeling the surface of the record, looking at it with a magnifying glass, and observing a microscopic view of the record and needle interacting]* to provide evidence for *how the structure of the record causes the needle to move back and forth (function/effect) in different patterns and we heard different sounds being produced.*	After looking at a piece of the record up close (with a magnifying glass), we noticed some patterns in its structure: • The record appears to have lines that make circles around it • When the record plays a song the needle appears to move from one line to the next.  This led us to argue that: • The needle follows these lines in a spiral around the record and different lines make different parts of the song (or different songs) play, when the record is spun. *We brainstormed and generated a new idea and a new question:* • *Maybe there is something different about the structure of lines that would explain why the record sounds different in one groove (or one part of it)?* This led us to argue that we needed to zoom in closer to look for any visible structural differences in the lines. From the electron microscope images, we notice some interesting patterns: • We notice that the lines on the record are actually grooves. • The grooves have a wavy structure along the edge of them. • The pattern of the wavy structure varies along a groove and between grooves. • The needle moves back and forth as it moves across the grooves. This led us to propose a structure / function relationship connected to a cause and effect: • The structure of the groves causes a push on the needle in different directions as the record spins. • This generates an effect: the needle is moved back and forth in different patterns. **Next steps: We have some questions we want to investigate.** *Can moving the needle back & forth in different patterns be causing it to make different sounds? What other things make sound? What are other objects doing when they are making sounds?*

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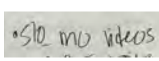
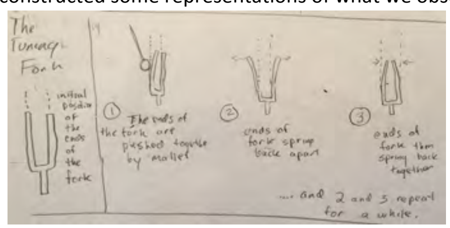
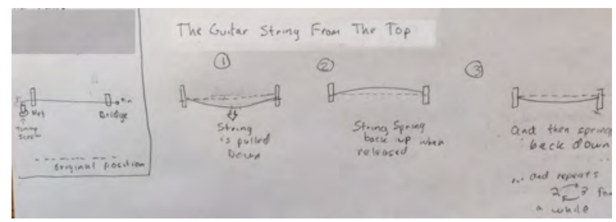
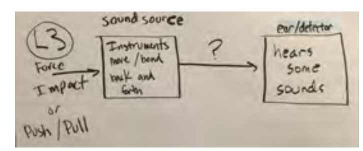
This Lesson....What we are doing now: You will pick up on a question that students were curious about from last time, related to whether other objects, were moving back and forth when they make sounds. Students will feel the surface of various instruments after another person strikes/plucks them and connect what they feel to what they observe when they analyze slow motion videos of those objects. You will co-construct a way to represent the shape changes observed in these objects over time, and students will apply this type of representation to the shape changes they observed in another instrument.

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L3: What are other objects doing when they are making sounds? 1.5 Periods: Day 1: 40 min Day 2: 20 min   *Building toward* *NGSS PEs:* *1-PS4-1,* *4-PS4-1*	Various musical instruments (drums, stringed instruments, & xylophones) that we pluck or strike make a sound and we can feel a type of motion on them. Slow motion video of these after they are struck reveals patterns in their motion. ● Snare Drum ● Cymbal ● Guitar ● Tuning Fork	**Analyze data interpret data** to provide evidence for phenomena *related to the* patterns *between what we feel on the surface of an instrument after it is struck and the* motion *of various musical instruments* after they are struck*, from a slow motion video.* **Develop and use a model** to describe (phenomena) *how the shape* (structure) *of an instrument changes after being struck (deforming above and below its initial position =* vibrating*); use the model to argue whether the* structure *of other solid objects also changes like this* (cause) *when they* produce sounds (function/effect)*.*	From touching various objects that we plucked or struck to make a sound we noticed a pattern ● Sound sources feel like they are moving very slightly (back and forth) when they are making a sound (after striking or plucking them) From watching slow motion videos of similar objects we noticed a pattern: ● We could see the objects (sound sources) changing shape back and forth after being struck or plucked We constructed some representations of what we observed as a class:  We developed an initial explanation together, as a class, for why the instruments change shape back and forth after being struck. ● Striking or plucking these objects, applies a force to that object (a push or pull on it). ● This force temporarily bends (deforms) the object. ● When the force is removed, the springiness of the object (its elasticity) causes it to try to return to its original shape. ● And this leads it to repeatedly bend back and forth for a while. We updated our model to reflect what we figured out. Then when we start using the model to try to determine how generalizable it is (e.g. when we cover up up the word "instruments" on our model), this made us wonder, *does our model apply to other things? If instruments move back and forth when they make sounds, do all things move back and forth when they make a sound?*  Some of us thought yes, but others thought no. For the later, the example of really solid objects (like the table or ground) were brought up as things that do not vibrate back and forth after being struck, because they aren't springy like instruments. **Next steps: We wanted to investigate this controversy and question more next time.**

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How Can We Hear So Many Different Sounds From Across The Room?

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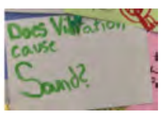
This Lesson....What we are doing now: You will pick up on a disagreement about whether all objects vibrate when they are making a sound that students articulated from the last lesson. You will introduce how a new type of detector works, (a laser that shines on a small mirror laid on the surface of another object) to make predictions about what we could see the laser dot on the wall do, when striking a drum face vs. the table. The results of this test will provide evidence that all objects are springy (elastic) up to a point and that all objects vibrate when they make sound. You will help students apply this new idea back to the needle and record it in order to partially answer the question, "How do the interactions between the needle and the record produce sounds?"

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L4: Do all objects vibrate when they are making sounds? 1 period: 40 min.  *Building toward* ↓ *NGSS PEs:* *1-PS4-1,* *4-PS4-1*	A mallet striking a drum head with a mirror on it and a laser bouncing off the mirror shows a blurred image in the reflected dot for a short duration. A rock dropped on a table with a laser and a mirror provides similar patterns.	**Engage in argument** from evidence to support or refutes claims about whether, "all objects vibrate (cause) back and forth when they are making sound (effect)?" by providing and receive critiques about one's explanations, procedures, and models and posing and responding to questions that elicit pertinent elaboration and detail to help determine ways we could gather evidence to answer this question. **Construct an explanation** based on evidence obtained from previous class investigations and scientific principles to construct an explanation (as a class) of how the structure of the record causes vibrations in the needle that lead it to produce sound (effect)as the record is spun.	 We conducted an investigation with a mirror, laser pointer, table, drum/xylophone bar, a mallet, and rock and noticed a pattern: • When we strike a wooden xylophone bar or drum, with a laser beam (dot) bouncing off of a mirror on it, the dot that shows up on the wall/ceiling moves and shakes above and below the point which it started. • When we drop a rock onto the table with a laser beam (dot) bouncing off of a mirror on it, the dot that shows up on the wall/ceiling moves and shakes above and below the point which it started. • The harder we strike either surface, the louder the sound and more the dot shakes back & forth (distance & duration). The results of the experiment provided us evidence to develop some general principles: • All objects are elastic up to a point; they can bend and spring back from applying an external force to them from a collision, striking them, or plucking them. • Objects bend/ bounce back and forth around their initial position or shape as they try to return to their original position or shape after being deformed. • This type of repeated change in an object's structure or motion is called a vibration • **Vibrating objects make sound. (1-PS-4-1)** We connected these principles to our anchoring phenomena by developing a class constructed - outline for an explanation to answer the question "How do the interaction between the needle and the record produce sounds?" 1. The needle is springy (it is elastic up to a point) 2. As the record spins, wavy grooves in the plastic record move under the needle. 3. The needle is pushed back and forth by the record as it dragged through these grooves. 4. When the needle is pushed to one side by the grooves in the record it elastically deforms. 5. When the push is removed the the needle springs back, it vibrates. 6. Since all vibrating things make sounds, and the needle is vibrating, it makes a sound. *Developing this explanation led to some new questions: Was the difference in the pattern in the groves somehow responsible for all the different sounds we heard? What was different about the vibrations of all these other objects we observed, when they produced different sounds? What would be different about the vibration from the table, that would make a bigger blur (in the reflected laser dot) when I hit it harder to make a louder sound?* **Next steps: We wanted to study the vibrations from things making different kinds of sounds, starting with louder vs. softer sounds (striking instruments harder or softer . We just will need a way to detect, look closely, or zoom into the sound source to see how the vibrations of it (the sound source) compare in these different conditions.**

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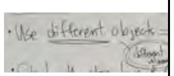
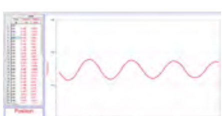
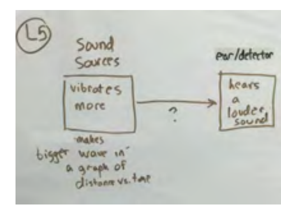
This Lesson....What we are doing now: Students will use experiences from earlier lessons to argue that hitting, plucking, or striking an object harder, is what causes it to produce a louder sound. They will argue that a wooden stick could be used to simulate the type of shape changes we saw (vibrations) in all the previous sound sources. You will demonstrate how a new device (a motion detector) works. Students will make predictions about how a graph of distance vs. time for the end of the wooden stick would look for louder vs. softer sounds. You will collect data and students will notice patterns that start to introduce some important wave like characteristics in the motion of matter that is vibrating.

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L5: How do the vibrations of the sound source compare for louder and softer sounds? 1 period (40 min)  *Building toward* ↓ *NGSS PEs:* *1-PS4-1,* *4-PS4-1,* *MS-PS4-1,* *MS-PS4-2,* *MS-LS1-8*	Previous phenomena related to the deformation and vibration of the table, guitar string, drum face, and tuning fork when struck We see patterns in the effects on a long thin wooden stick that we clamp down and strike and measure the position of the end of, using a motion detector.  	**Use mathematical and computational thinking** using digital tools to analyze patterns and trends in the graphs of position vs. time data for a large vibrating object to provide evidence for how the y-values (e.g distance between a peak and valley) and x-values on the graph (e.g. time between a peak and a valley) for deforming it different amounts (simulating a loud vs. soft sounds). 	We noticed patterns between the behavior of the long wooden stick similar to our instrument we modeled. ● Both objects vibrate by changing shape/bending back and forth. ● The wooden stick vibrates much slower than the instruments. *We think we could we use the long wooden stick, to see how the vibrations of the sound source change when it is struck or plucked to make a louder vs. softer sound, since it's vibrations are easier to observe (they are slower).* We noticed patterns in the graphs of distance vs. time for the end of the vibrating wooden stick: ● The distance of the end of the rod from the detector over time goes up and down and makes a wave shape (S turned sideways). ● The wave pattern repeats. We decide to refer to each repetition as a single wave. ● The high points (peaks) become less high and the low points (valleys) become higher (not as low) as additional waves are produced. ● The harder struck trial, resulted in the peaks getting higher and and valleys getting lower on the wave. This corresponds to the rod moving back and forth a smaller and smaller distance. ● The harder struck trial, doesn't seem to affect the number of waves that repeat in a certain amount of time (or the time from a peak to a valley) We update our model to represent what we figured out now that we know that a loud sound makes a bigger wave on our graph and a soft sound makes a smaller wave on our graph, we started wondering and predicting what would the shape of the graph look like if we make a different pitch sound?  **Next steps: We start brainstorming how we might investigate our new question and have predictions of what those vibrations might look like. And we want to collect more data on the vibrations from sound sources making different pitched notes next time.**

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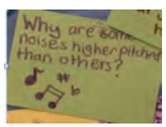
This Lesson....What we are doing now: Students will draw on experiences from an earlier lesson and connect those ideas to what they notice in playing a song from small transparent music boxes. Their observations will lead them to suggest that changing the length of the wooden stick would allow us collect useful data on any changes in the vibrations at the sound source due to changes in pitch. Collecting data with the motion sensor, together as a class, and comparing it to the graphs from the last lesson, will allow students to notice new patterns of change related to the amount of time a wave takes. You will help students argue that we need different ways to describe these two types of "size" changes on the graph. This motivate the introduction of amplitude and frequency as ways to keep track of two different features of the wave in the graph of distance vs. time . After applying these ideas to update the class consensus model for how we hear different sounds, you will help students recognize a gap remaining in the model, in relation to the question "what actually is in the air when a sound goes to your ear?"

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L6: How do the vibrations of the sound source compare for higher vs. lower pitch notes? 2 periods (2 x 40 min)  *Building toward* ↓ *NGSS PEs:* *1-PS4-1,* *4-PS4-1,* *MS-PS4-1,* *MS-PS4-2,*	A guitar string plucked with a finger pressing on the string at different locations, Xylophone bars of different lengths hit with a mallet, and Music box that we wind and play in our hands show patterns in the pitch of the note vs. the length of the object that struck or plucked" We see patterns in the effects on a long thin wooden stick that we clamp down and strike and measure the position of the end of, using a motion detector	**Analyze data and interpret data** to determine a causal relationship between the *length of tine/bar and the pitch of note produced (effect) by a music box or xylophone.* **Use mathematical and computational thinking** using digital tools to analyze patterns and trends in the graphs of position vs. time data for a for a vibrating objects of different lengths to provide evidence for how the y-values (e.g distance between a peak and valley) and x-values on the graph (e.g. time between a peak and a valley) compares for different pitch sounds. **Develop a model:** Modify our consensus model—based on evidence – to match what happens if a	Last time we were wondering, *what would the shape of the graph look like if we make a different pitch sound?*  We investigated various musical instruments and noticed patterns in the notes produced by the structures in various instruments (xylophone & music boxes): ● Shorter tines, strings, bars, create higher notes when struck or plucked. ● Something looked different about how the tines were vibrating. This led us to come up with an idea for how we could reuse the wooden stick device from last time and the motion detector to investigate what is happening at the sound source when higher or lower notes are produced. We decided we simply have to shorten the stick to make a scaled up version of a shorter "tine" (which was what was making a higher pitched note) and compare its vibrations to those that the stick made when it was a longer tine (a lower note). We reduced the length of wooden rod by a foot made some predictions to our original question, *what would the shape of the graph look like if we make a different pitch sound?* We used the motion detector and collected data from the different length wooden rods and noticed patterns : ● How far it moves back and forth gets progressively smaller after the initial force is removed. ● The same number of waves (A single wobble back & forth) takes the same amount of time from a single rod, no matter how hard you hit it (ie. 3 waves pass in 2 seconds regardless of loudness). ● The amount of time it takes for one wave is smaller for shorter rods. ● We can see more waves across the same unit of time for shorter rods (ie 5 waves pass in 2 seconds, compared to 3 waves in 2 seconds for a longer rod) In discussing various features in the graphs, we argued we needed a way to refer to two features we are seeing important patterns in across all the graphs: ● We argued we needed a way to refer to the distance between a high point and the next low point, since that was sometimes changing and sometimes staying relatively constant. We agree to refer to this characteristic as the amplitude of the wave. ● We decided we needed a way to refer to how often the waves are repeating, since that was sometimes changing and sometimes staying relatively constant. We agreed to refer to this characteristic as the frequency of the wave (more frequent waves are ones that occur more often, less frequent ones occur less often)

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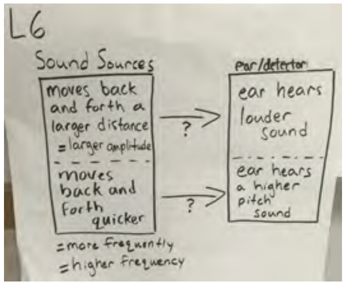
MS-LS1-8		variable or component of a system is changed, showing *how causing a sound source to vibrate with greater amplitude produces a louder sound (effect), and how causing a sound source to vibrate at an increased frequency produces a higher pitch sound (effect)*	We used the graphs of the wooden rod motion as evidence from both lessons to argue that: ● The surface of vibrating object, makes a repeating wave pattern (for distance vs. time). ● The amplitude of the vibration cycle/wave increases as the sound gets louder. (**DCI: Waves of the same type can differ in amplitude (height of the wave) (4-PS4-1)**) ● The frequency of the vibrations don't change as loudness changes.(**DCI: A simple wave has a repeating pattern with a specific frequency..... (MS-PS4-1)** ● The frequency of the vibrations change as pitch changes. Higher pitch sounds come from sound sources that are vibrating more quickly (**DCI: A simple wave has a repeating pattern with a specific frequency..... (MS-PS4-1)**  We update our model (see diagram to the right) to show some important cause and effect relationships As we took stock of our updated model, we realized that though we feel we have figured out some of the answers to some of our questions about *how different sounds are produced (different sounds are produced from differences in the in the way the sound source vibrates), we haven't agreed on a way to explain how the sound gets from a sound source to my ear.* **Next Steps: We think we can apply what we know to any new phenomena where sound is being produced, to explain what is happening at the sound source for different kinds of sounds, and we agree to self-assess our understanding with a new phenomena in our next lesson.**

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This Lesson....What we are doing now: You will assess student understanding of vibrations and properties of waves through the introduction of a new phenomena - music coming from a speaker in a truck stereo. Students will apply what they know to explain this new phenomena. This phenomena will be extended in later lessons to motivate looking more closely at a stereo speaker to gather evidence for whether it is doing what we think it is doing.

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L7: What can we explain and what new patterns do we notice in another phenomena? (Embedded Assessment #1:) 1/2 period: (25 min) *Building toward* *NGSS PEs: 1-PS4-1, 4-PS4-1*	A video clip of blasting music in a truck provides evidence of changes in the loudness and pitch of sounds coming from the sound source over time.	**Construct an explanation** that includes qualitative or relationships *(patterns)* between variables that predicts *how the* vibrations of the sound source *in the truck that producing music would compare for different types of sounds heard coming from it.*	We started our lesson, looking forward to self assessing and applying our understanding to the context of a new phenomena. We analyzed the first few seconds of a video clip of music blasting from the stereo of a car/truck with some people in it. In class assessment portion of this activity: Each of individually used what we figure out in previous lessons about vibrations at the sound source to predict and explain the first 3 minutes of a video clip, including answering questions the phenomena related tot: • *Where is the sound coming from?* ○ There must be a sound source. It is probably from something in the car/ truck's (e.g. speakers in the (stereo, radio). • *If you could zoom into the sound source, what do would you expect to see it doing anytime it produced a sound?* ○ The speaker would be vibrating back and forth. • *If you could zoom into the sound source, what would you see it doing differently when it produced louder sounds?* ○ The louder the sound it produces, the further the movement would be back and forth (or more amplitude). • *What would you see the sound source doing as it produced higher pitched sounds/notes* ○ The speaker would be vibrating more quickly/frequently when a higher pitched note was playing (higher frequency) • *What would you see the sound source doing as it played a lower pitched note?* ○ The speaker would be vibrating more slowly/less frequently when a lower pitched note was playing (lower frequency) **Next Steps: We want to check in on our assessment to see if we are in agreement on what is happening at the sound source for this phenomena.**

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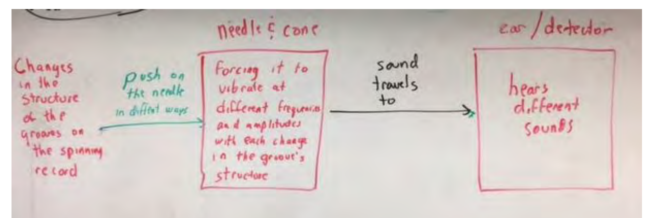
This Lesson....What we are doing now: You will help students look into the speaker more closely by disassembling a speaker together. In doing this you have students inspect (touch with an insulated straw) and watch the motion of a cone inside a large amplified speaker as it plays music, while it is hooked up to a computer (or watch a video of this).

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L8(a): Can a single object, like a stereo speaker or a needle, really be forced to make all these different sounds? (⅓ period) 20-25 min *Building toward* *NGSS PEs:* *1-PS4-1,* *4-PS4-1,* *MS-PS4-3*	Speaker deconstruction (optional: and homemade speaker reconstruction and testing). Two video clips 1 and 2: provide evidence of the type of changes in the vibrations that can be observed in a speaker cone when it plays sounds of different loudness and sounds of different frequencies.	**Conduct an investigation** to produce data to serve as the basis for evidence to answer scientific questions *raised in our last lesson about the predicted patterns we expect to find between the amplitude and frequency of vibrations of the stereo speaker and the type of sounds it produced in terms of loudness and pitch.*	We wanted to check in on our assessment and we all agree what should be happening at the speaker in the car. But when asked if we all really have seen or felt a speaker do this, some of us claim that haven't seen a speaker do this and want to confirm some our predictions. So we decided to look closely at a speaker as it was making sounds. We took off the grill of a speaker and noticed patterns in the motion of the cone (or saw it through two video clips: 1 and 2: ● It vibrated when it made sounds ● The amplitude was bigger for louder sounds ● The how fast the speaker moved back and forth also appeared to change for different notes produced. We argued from evidence that the speaker is being forced to vibrate back and forth lots of different ways, based on the signal (which we think might be electrical) coming through the wire from the electronic device it is hooked up to. And we used the wooden stick to visualize how the needle on the record might also being forced to vibrate in different patterns (at different amplitudes and frequencies over time) We revised our model to include a new idea:. ● You can force an object to vibrate different ways by pulling and pushing in different patterns to make lots of different sounds. ● This means that when the 'bumps' in the record were pushing and pulling the needle, they were FORCING it to move and vibrate in many different ways, which forced it to produce all sorts of different sounds (of different pitches and different loudness)  The speaker phenomena also raised more questions: ● *How is the cord going from the ipod/computer/phone to the speaker getting it to move.* ● *Is there something in the cord that is making it do that (a signal, electricity)?* ● *What is inside the ipod/computer/phone that knows how to make the music?* ● *How do these electronic devices record and playback things like sounds anyway?*

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			Next Steps: At some point, we want to take apart a speaker and see how it works and we want to figure out how these electronic devices work too. Note: Lesson 8b helps address and follow-up on this line of questioning. There may be advantages to conducting lesson 8b next. There may be advantages to waiting to conduct lesson 8b until the very end of the unit.

This Lesson....What we are doing now: You will help students look into the speaker more closely by disassembling a speaker together. In doing this you will identify three essential parts of the speaker. You will provide a video for student to use as a reference for how to rebuild a speaker out of these three parts. Students will assemble and test this assembled system of parts and find that it plays music from various electronic music players. You will help students transfer the explanation for how the speaker can be forced to vibrate in many different ways to explain how the needle on the record can also be forced to vibrate many different ways, by variations in the structure of the grooves on the record, to cause it to produce many different kinds of sounds.

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L8(b): How does a stereo speaker make all these different sounds anyway? Option A: 20 min. Option B: 60 min. *Building toward* ⬇ *NGSS PEs:* *1-PS4-1,* *4-PS4-1,* *MS-PS4-3*	Speaker deconstruction (optional and homemade speaker reconstruction and testing).	**Conduct an investigation** to produce data to serve as the basis for evidence to answer scientific questions *raised in our last lesson about three structures (a cone, a coil of wire, and a magnet) interact together (when plugged into an electronic music device), to play back music stored on the device (function).*	We decided to take apart the speaker and see (virtually via video or as a demo or if we have extra speakers from the thrift store - ourselves). We noticed patterns in the type of structures we found: • There was a cone, a coil of wire, and a permanent magnet This raised a new line of questions • *Wait that's all there is to a speaker, there's no way that hooking those three things up to my iphone would turn it into a speaker system would it?* • *Could we put those three structures together and rebuild a working speaker?* We wanted to see if that was possible. We watched the video/instructions on how to build a homemade speaker, out of paper plates, a stack of magnets, and a coil of insulated wire. And we saw evidence that it worked in the video Option B: This looked too cool and kind of hard to believe. We wanted to try to build this device ourselves and test it out ourselves. We followed the directions on how to build it and how to hook it up (we striped some aux cords and plug them into our ipads/computer/iphones and alligator clip them to the end of device we built out of these materials). We notice some patterns in a new phenomena: • We hear the entire song coming from the paper plate! • The song is really quiet compared to what we hear from from our headphones or larger speakers. We argued from evidence that: • Speakers use magnets and a electricity in coil of wire to somehow to make the cone vibrate to make all kinds of different sounds. • There must be some kind of information stored in the electronic device that is used produce the right signal in the wire that moves the magnets a certain way.

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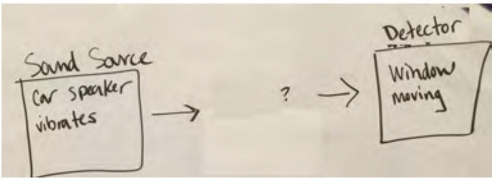
			Next Steps: At some point want to figure out more about these sorts of electronic devices store, transmit, playback and amplify these songs too. Note: Lesson 8c helps address and follow-up on this line of questioning. It is strongly recommended that Lesson 8c come at the end of the storyline, as it builds on some other ideas developed throughout the unit.

This Lesson....What we are doing now: Students will revisit the video of the stereo playing in the truck, but this time will watch what happens next, discovering that the stereo is causing a window in a building across the parking lot to move. They will attempt to model how this could be happening, by showing what is happening in the space between the sound source and the window. You will use the differences in these models to motivate needing to investigate this aspect of the model further, related to what actually is traveling across that space?

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L9: How does a vibration at the sound source make something move that is far away? 1.5 periods (60 min) *Building toward* *NGSS PEs:* *1-PS4-1,* *4-PS4-1,* *MS-PS4-1,* *MS-PS4-2*	We see additional patterns as we play the 2nd half of the full video of music in the truck, related to apparent effects in the motion of a window in a building across the parking lot from the truck.	**Develop and use a model** to describe unobservable mechanisms *at work in the space between a sound source playing (a stereo speaker in truck) and another object at a distance (a window in a building across the parking lot) that help explain what is causing it to move (effect).*	We revisited the blastic music in the truck video, of two guys sitting in a car playing music on their radio, but this video clip continued longer than before, and as the camera panned out, we noticed some interesting patterns: • Parts of the car and a window in a building across from the car appear to move when parts of the music are played • Some parts of the song appear to make these things move more than others. The led us to realize that there was something we haven't explained in our model yet: • *What does this exactly mean when we say sound travels from the source to the detector?* • *What is it that traveling from here to here?* • *When we say the vibrating object produces sound, what does that mean? How does a vibrating object produce a thing that travels?*  We wondered: *What is going on in between the sound source and the window that can help explain, How is it possible that a wiggle/vibration at the sound source could cause something (the window) far away to do move this way?* We individually create models to try to explain this question. We shared out our models, comparing what was similar and different across our models, that try to account for "HOW does a vibration actually make something far away move?" All of the differences we saw in the models raised more questions. • *Is sound is it's own essence and that maybe air carries it across?* • *Is the air being pushed to the window?* • *Is the air moving at all?*

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			We brainstormed ways to test what is happening to the air in between the sound source and the window. We shared out some of our ideas. One idea was to explore what happens if we take away the air? We think that would help us figure out if the air is the thing actually moving the window. We had different predictions about what would happen. This led us to wonder if anything would be different about the sound we heard too, if we trapped the air between the sound source and our air,, since if sound is moving through the air, this would tell us what, if any role the air plays in helping sound move. **Next steps: we want to block the air from between a sound source and another thing (e.g. our ears) and see what happens. Would we still hear a sound?**

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This Lesson....What we are doing now: You will help students test the idea that the air from the sound source is traveling to the window or the ear. The results from these investigations will provide evidence that the air is not moving all the way from one location to another. This will help motivate the question of whether you need air at all in order to hear a sound.

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L10: Is the air being moved all the way from the sound source to my ear, when I hear the sound or when the window moves? 1 period (40 min) S *Building toward*	When a cell phone in an airtight container (tupperware) filled only with air placed on a scale, the scale shows no change in mass, between before and after the phone is called and it made ringing sounds that we could hear outside of the container.	**Design and conduct an investigation** identifying what tools are needed to do the gathering and what data are needed to support a claim; *collect data to serve as the basis for evidence to support the claim, "The air is not being moved (cause) all the way from the sound source to my ear, when I hear the sound or when the window moves? (effect)"*	We had some ideas for testing whether the air was moving from the sound source to the window (or our ear). These ideas all included some way of blocking the air. So we put it in a container (a ziplock bag or airtight tupperware) and we played music and it seemed like we could still hear it. We started to argue that this shows that air isn't moving from the sound source to our ear when we hear it, but that seemed weird. *How were we able to hear it then?* Some of us raise the question, *Are we sure no air came out? How do we really know that no air or stuff came in or out?* Maybe there was a small leak. That raised an interesting issue, how do we know that a container hasn't leaked any air from it. We thought of some possible ways to test that. We learned from **….. Grade band DCI** that all matter has weight, so we could weigh it. Not all of us are convinced that air has weight, so we do a quick investigation of putting a basketball on a scale weighing it - taking air out - would that change the weight? We make hypotheses - it does change the weight! Cool - so air has mass. One kind of idea that we came up with was to build a closed system with a sound source in it to test whether the air near the sound source is being pushed to our ear. We thought that could be one way to see if air moved out of the bag (by massing it before and after it makes a sound). So we decided to test that. We noticed patterns: ● The mass of the bag and cell phone didn't change as it made a sound ● No air appeared to escape from the bag, but we still could hear a sound.

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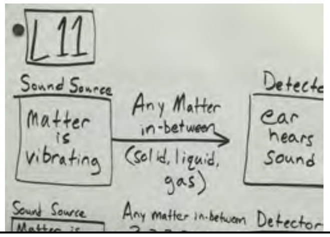
↓ NGSS PEs: *MS-PS4-1, MS-PS4-2*			We update our model to show that no air is moving out of the container. As we looked at the model further, we wondered if the air was even needed in it, since the sound is moving, but the air isnt;. This led to an argument around a new question, *do we even need air to hear a sound?* We all had different predictions. **Next steps: Now we wondered how we could test that, so we brainstormed some possibilities.**

This Lesson....What we are doing now: You will help students test whether air is even needed to hear a sound. One investigation will provide evidence that sound will move through any type of matter, while the other investigation will provide evidence that it can't move a space that has no matter in it (a vacuum). These finding will motivate the questions why removing the air prevents sound traveling. idea that the air from the sound source is traveling to the window or the ear. The results from these investigations will help students realize that maybe there is something in common about solids, liquids, and gases that allows sound to move through them.

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L11: Do we even need the air to hear the sound from the source? 1 period (40 min) *Building toward* ↓ NGSS PEs: *MS-PS4-1, MS-PS4-2*	A cell phone which is playing music is hung on a string inside an airtight container (bell jar) so it is touching nothing (except the surrounding air and string). When a vacuum pump is hooked to the container and turned on, no sound is heard after about 30 seconds. When we release the valve to let the air back in, we hear the sound come back.	**Design and conduct an investigation** identifying what tools are needed to do the gathering and what data are needed to support a claim; *collect data to serve as the basis for evidence to answer "no, air specifically is not needed, but matter of some sort is needed ()" in answer to the question, "Do we even need the air to hear the sound from the source?" (setting the groundwork for matter vs. energy)*	**We had two sets ideas for investigations that could help answer our question. One kind of idea that we came up with was to use something to take all the air out of the container (suck it all out). The other idea was that we could fill the container that the sound source was in with something other than air (like water).** For the first idea, we realized we needed some kind of special pump or something to make sure we got all the air out. So we wanted to see what would happen if we used something like this when you put the cell phone in a container and pumped out all the air and called the phone. For the second idea, we realized we could put the sound source in a container of water. But even though some of us had waterproof phones, we thought might work to use, we didn't want to risk damaging the phone, so we decided to collide to objects together in a container filled with water (e.g. two steel ball bearings in water in a fish tank) and put our ears up against the side of the tank. From the results of two investigations (or gathering information from a video of students doing one of them) we noticed patterns: • As you take air out of the container the sound gets really hard to hear • But when we let air back into the container the sound gets easier to hear. • We could hear the collision of the bearings underwater, even though we were outside the water. This led us to argue from evidence that you need matter to move the sound across a the space that matter is in and sound can move through any state of matter: liquids (as well



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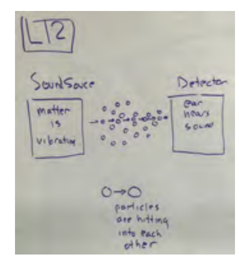
	When you strike two metal balls in a fish tank underwater together and put your ear up to the glass you and the person next to you can hear the sound.		as gases and solids).We showed this in our revised model: This raised a new question for us: *Why would vibrations from a sound source be able to send sound traveling through a gas, solid, or liquid, but not through empty space?* **Next steps: We decided we needed to try to model what makes something a solid, liquid, or gas and how that is different than empty space.**

This Lesson....What we are doing now: Students will develop a model of what all states of matter have in common. This model will include particles, empty space, and motion. You will help students simulate what happens in such matter as a vibrating object is interacting with it. This model will show students that particle collisions are transmitted through the medium from one end to another. This model will motivate the need to explore a simulation of this system, where the frequency and amplitude of the sound source can be changed, and the particle collisions across the medium can be inspected more closely.

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L12: How can we model sound traveling through a solid, liquid, or gas? 2 periods (2 x 40 min)	Previous phenomena related to sound traveling through a tank of water, glass, air)	**Develop and use a model** to describe unobservable parts (particles) *of the* system *and how they would* interact *with each other in any* state of matter, *to* transfer energy through collisions *between one another across a* medium *from a* vibrating sound source.	We develop models of the things that sound can travel through: water, glass, and the air. And we agree on the characteristics of those things that things like liquids, solids, and gases have in common: • Solids, liquids, and gases are made of particles moving through empty space, with different spacing in each state of matter. • Particles can bounce into and off of each other in a gas; particles can push into one neighbors in solid or liquid. With these elements of the model agreed upon, we then wondered what happens to particles that the sound source is vibrating back and forth against (e.g. water or wair)? We wanted to simulate using people as particles of the medium When we simulate this we further developed the model to show that we think that: • Particles push into their neighbors as they bounce off their neighbors when they hit them. • This results in a series of collisions between particles traveling through the medium. • The particles themselves appear only move back and forth (vibrate), even though something else is traveling across the medium. • If a push is given to one end of the medium, it might result in cascading series of collisions between neighboring particles.  Even though all of us agree it isn't the matter itself traveling across the medium, there is something else traveling across the medium is hard to explain. To some of us it seems like it is energy, to others

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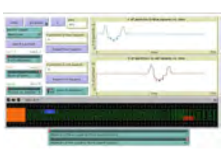
Building toward ⬇ *NGSS PEs: 1-PS4-1, 4-PS4-1, MS-PS4-1, MS-PS4-2, MS-LS1-8*			it seems like it is compression, to others it seems like it is collisions traveling across the medium. *What exactly is traveling across the medium then?* We to explore this more, but we realize it is difficult to do this with the model we are currently using, which has some limitations, particularly related to the number of particle interactions we can simulate in it at once. **Next steps: We decided we need a better simulation that includes:** • **Many more particles spaced closely together like in a liquid (or a solid) medium.** • **A way to apply external vibration we apply to one side of the medium.** • **A way to change the type of vibration we apply (e.g. the number of vibrations, the amplitude of the vibrations, and frequency of the vibrations)** • **A way to inspect and visualize what is happening at different locations in the medium at different points in time.**

This Lesson....What we are doing now: Students will run a computational simulation exploring how particle collisions propagate across a medium from a vibrating sound source. Their investigations will help them develop complementary models for the nature of the wave traveling across the medium, including a particle density model (bands of dense & less dense batches of matter), a transverse wave model (density vs. time at a given location), and ray model (showing the direction of energy transfer across the medium).

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L13: What exactly is traveling across the medium? 2 periods (2 x 40 min) *Building toward* ⬇ *NGSS PEs: 1-PS4-1, 4-PS4-1,*	A Netlogo simulation provides a way to visualize and collect data on particle packing (density) at a point in space over time as sound travels through it, as well as to watch what happens over a region of space over time. 	**Use mathematical and computational thinking** in a computer simulation representing *propagation of sound waves across a medium to describe the patterns in the motion (energy) of each single particle (matter) in the medium, the changes in particle density in a given space (pressure) over time, and the changes in particle density bands (pressure) across the medium (system), that t result from changing the frequency and*	We conducted two investigations using a computational simulation (NetLogo) and describe the patterns we see and collect quantitative data as well. We see patterns in the data: • There are bands of compressed and expanded particles traveling through the medium. • The distance between maximum compression bands appears to always be the same, for when a constant frequency vibration is the sound source. • The distance between maximum compression bands gets smaller when the frequency of vibration at the sound source increases. • The density of compression gets greater when the amplitude of vibration at the sound source increases. When we conducted another investigation using the computer simulation, and collect that data about the density of particles at a location over time. When we make a graph of density of particles vs. time, in that location, is looks like a transverse wave. We produced a 3 frame time-lapse model to make arguments for evidence to answer the original question "What exactly is traveling across the medium" • We argued that an individual particle just moves back and forth repeatedly (vibrations) • But there is a domino effect of collisions/shoves between neighboring particles that leads to dense and less dense regions pushing their way through medium - we decided to call these regions compressed and expanded matter. • We know that all matter is springy, so it makes sense that the matter is moving the way it is (back and forth and return to its original state/density after it vibrates) • There are lots of useful representations to show what is happening. This includes:

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MS-PS4-1, MS-PS4-2, MS-LS1-8		*amplitude of vibrations at the sound source*.	• Bands of "denser packed" particles vs. "less dense packed particles" are a useful model to represent the pressure (pushing) wave that travels longitudinally through any medium due to sound source; The bands have wave like properties including new property of the wave - wavelength - the distance between each peak in particle density. • We can represent the direction of energy transfer across the medium and the propagation of the wave over time using rays (or arrows). **Next Steps: We think we can apply what we know to any new phenomena where sound is being produced, to explain things like 1) how you can hear sound through water and 2) what makes the window shake when the stereo speaker is playing , and we agree to assess our understanding around these two phenomena in our next lesson.**

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This Lesson....What we are doing now: Students take what they've learned from the unit thus far and as a class construct an explanation to explain why we can hear sounds coming from the needle in the original anchoring phenomena. Then as an assessment opportunity, students can apply this to individually construct an explanation for why a sound makes a window move.

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L14: "How does the matter in-between the sound source and my ear help the sound reach my ear?" (or the window) **(Optional Embedded Assessment #2:)** 1 period: 40 min *Building toward* *NGSS PEs: 1-PS4-1, 4-PS4-1, MS-PS4-1, MS-PS4-2, MS-LS1-8*	Previous phenomena	**Construct an explanation** based on evidence obtained from previous class investigations and scientific principles to construct an explanation *(individually or as class) of how the structure of the record causes vibrations in the needle that lead it to produce sound (effect)as the record is spun, which cause particles of matter in the surrounding medium to move, that then collide with neighbors to transfer energy across the medium, via (de)compression bands of matter in the medium (pressure waves)*	We connected this to our anchoring phenomena by arguing that: 1. The needle is springy. 2. The needle is pushed back and forth as it dragged across the wavy grooves of the record. 3. The more the needle is deformed from the pattern in the groove, the greater the amplitude of the vibration in the needle, and the louder the sound it will make 4. When the needle is vibrated back and forth at a particular frequency, it will produce a sound of a particular pitch; the higher the frequency of vibration, the higher the pitch. 5. Forcing the needle to vibrate in many different ways (different frequencies) as it is dragged across the pattern in the record groove is how it can be made to produce so many different sounds. 6. The needle transfer energy to matter that is adjacent to it (the air and the cone), by pushing against it in a repeated pattern (a vibration) 7. The particles in the air) then are pushed into neighboring particles (the matter is compressed at this location. 8. These collisions transfer energy to the neighboring particles, which in turn collide and transfer energy to their neighbors; this is how a wave of compressed and expanded matter moves through the medium (e.g. the air in the room) 9. Which is how sound is produced and travels across the medium to our ear AND... We think we can use this explanation to explain why the window is moving. We try this explanation individually and then come back together and agree that collisions of air particles are transferring energy through vibrations to neighboring particles to the window. Now that we have an explanation for what is happening at a sound source, and how sound travels through the air (or any medium), we realize we never really explained how we can hear the sound. But our ideas about the window led us to come up with some ideas and pose some questions: • *What happens when these particle compression waves reach my ear?* • *What is happening inside my ear to detect the sound?* • *Does my ear move when I hear a sound or is the air inside my ear moving? Does that have something to do with why I hear what I hear?* • *What is going on inside my ear?* **Next steps: This later question led us to want to figure out more about is going on inside our ear and we want to investigate that next.**

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This Lesson....What we are doing now: Students are wondering about how our ears detect sounds so the class decides they need some additional information from experts. After taking a video tour down someone's ear and reading some information they reconstruct the pathway a sound wave travels inside the ear and leads to the brain to decode what the sounds are. They also gather information about what causes hearing loss and our home learning makes us wonder about why certain sound wave frequencies are more damaging compared to others.

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L15 What is going on inside my ear, that can explain how I can hear sounds? (Aycock) 2 days. *Building toward* *NGSS PEs: 1-PS4-1, 4-PS4-1, MS-PS4-1, MS-PS4-2, MS-LS1-8*	Otoscope Video of Eardrum Drum and salt demonstration Information from the experts about the inner ear describing function of the cochlea and hair cells. Animated diagram of vibrations entering the inner ear Video of tonotopical arrangement and vibration of basilar membrane Video of stereocilia vibrating [use from 53 s to 1:33]	**Construct an explanation using a model** *(based on information from interview with experts and a medical diagram of the inner ear, and a video clip of a stereocilia), to support the development of an explanatory model showing how the structures in the ear might interact with each other to transfer vibrations (cause and effect) from one to the other after a sound wave (pressure wave) reaches the first structure (the ear drum).*	We brainstorm possible things that might be happening inside our ear, and we have heard that there is an ear drum inside our ear. Maybe there is a structure that moves like the window moves. We want to check this out. We explore this (ear nose and throat doctor video with stethoscope) and we discover: • The eardrum looks like a drum membrane, but also moves and is pulled tight when it works, This led it to wonder: does the drum move like a real drum would if sound reached it? We try that with a drum and salt (or stereo speaker and a drum with rice) to visualize that possible movement The results showed that sound makes things vibrate, so we argued from evidence that it must make our ear drum vibrate and that is how our ear starts to detect the sounds we hear. This then makes us wonder what is beyond the eardrum, and we consult some experts for that information. *What from the sound waves must be making something vibrate?* Oh yeah, it's really just particles of the matter moving together in bulk so the bunches of particles in the air, etc must be pushing on the drum head and the drum head pushes the salt. After this investigation, we wonder what other structures are beyond the eardrum. Through a reading developed with support from an ENT and a neurobiologist we discover that: • Vibrations are transmitted from the eardrum to small bones, and then a structure called the cochlea. • The cochlea contains the basilar membrane, which has different areas that correspond to different pitches. When these areas vibrate in response to a particular sound, this vibrates tiny hair cells, which send the signal to the brain for that particular pitch. • Hearing loss is caused when one of the structures in the ear is damaged. This damage can be irreversible if the hair cells, or their detectors, the stereocilia, are permanently damaged.  Source: neuroreille.com This made us wonder what types of sounds might be the most dangerous to the structures in our ears: louder sounds (greater amplitude) or higher pitched sounds (greater frequency). Next steps (in home-learning reading): We gather additional information related to: • How do other creatures hear, and why some creatures can hear things we can't (different structures)

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This Lesson....What we are doing now: Students plan an investigation to answer the question, "What transfers more energy to an object, doubling the amplitude or the frequency of a sound wave?" Then, students take the results of their investigations to develop a mathematical model to argue that the amount of energy in a wave is directly proportional to the frequency, but is related to the square of the amplitude.

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L16 What transfer more energy, waves with greater amplitude or waves with greater frequency? 2 days. *Building toward* *NGSS PEs:* *1-PS4-1,* *4-PS4-1,* *MS-PS4-1,* *MS-PS4-2,* *MS-LS1-8*	A bamboo skewer stick used to simulate vibrations from a sound source, marble(s) used to simulate particles in the medium, and a marker used as a target for the vibrations to push against, provide evidence of energy transfer to the marker (sled) based on how far the sled is pushed across the table.	**Planning and Carrying Out Investigations** identify what tools are needed to do the gathering, how measurements will be recorded and how many data are needed to determine, *What transfer more energy, waves with greater amplitude or waves with greater frequency?* **Use mathematical and computational thinking** to determine *What transfer more energy, waves with greater amplitude or waves with greater frequency?*	We saw that stereocilia get knocked over when damaged. And the reading told us that sounds that are louder or higher frequency can be more damaging. We give examples of when we have seen waves knock stuff over. One example we give is sandcastles at the beach. And we argued that more frequent waves or higher amplitude waves would certainly transfer more energy to the sandcastles to wash it away more quickly. Thistled us to wonder, *what transfers more energy to things like sand castles at the beach, is it waves that come at a higher frequency (more often) or waves that come at a higher amplitude (bigger waves)?* We argue that there is similar question related to our compression wave model. • Louder sounds are produced by sound sources that deform with a bigger amplitude in pressure, so if they deform more, then are going to squash more particles closer together. Therefore the sound waves would have higher particle density in their band peaks, which would lead to harder pushes on the ear drum, which would transfer more energy. • Higher frequency sounds are produced by sound sources that deform back and forth a greater number of times in given time period, there there would more sounds waves generated, and each sound wave would push on the eardrum, which would end transfer more energy because of more pushes. But, this then raised a question, *what would transfer more energy to our eardrum or the window: doubling the amplitude of a sound wave or doubling the number of time (frequency) that hit an object with a compression wave.* We made some predictions and have different ideas.  We identified parts of the system that we wanted to include from our previous models as well as way to measure the energy transferred to an object. This included: • a sound source that we can pull back a different amount each time (to simulate creating different amplitude waves) • a medium of particles we can transfer the energy into • a device to "absorb" the energy transfer and measure it. We map the elements of the system we want to an experimental setup that the teacher provided, trying out the device to see how we can pull the stick back and launch a marble, to represent a single back and forth vibration of the sound source pushing on the particles in the medium and the effects on how far the sled/marker is pushed. We try it three times to see how

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			reliable the results are from one trial to the next, and from these results we argue that we should try to do 3-5 trials for each level we test in each investigation. As a class we plan how we could use this device to conduct the first investigation,on the effects of more compression waves in a given time period, the other on more amplitude for a single wave. We decide to test 1 through 4 waves of the same amplitude in a minute, to see how far the sled/marker gets pushed for each condition. We collect our data, calculate averages, and compare our results, and noticed some patterns: ● Doubling the # of waves produced in a time period pushes the sled about twice as far ● Tripling the # of waves produced in a time period pushes the sled about three times as far ● Quadrupling the # of waves produced in a time period pushes the sled about four times as far We argue that this makes sense, since every wave has the same amplitude, it would transfer the amount of energy, and the relationship should be directly proportional. We then make predictions whether the same relationship will hold true for doubling, tripling, or quadrupling the amplitude of the wave we produce. We modify our procedure and collect and conduct this second investigation. After we collected our data and calculated, we noticed some patterns: ● Doubling the amplitude of waves produced pushes the sled about four times as far ● Tripling the amplitude of waves produced pushes the sled about nine times as far ● Quadrupling the amplitude of waves produced pushes the sled about sixteen times as far We developed a mathematical model to argue that the amount of energy in a wave is directly proportional to the frequency, but is related to the square of the amplitude. Home Learning for Lesson 16: We have figure out how hearing works in general (L15), how other creatures hear different things than we do (L15 home-learning), and how energy transfer from louder and higher frequency sounds can lead to hearing loss (L16), so since we know: there's been damage to the a region of the cochlea leading to hearing loss, and the structures in that region can no longer convert mechanical to electrical energy (impulses) to relay to nerve cells to send signals to our brain, maybe we can design a solution to hearing loss. We learn about naturally occurring material properties (galena - piezoelectric) and use what we learn to design a cochlear implant array. We read about why galena doesn't work and some history of materials research to find other materials with this properties (i.e. transistors, diodes), and that those are used today. We compare the design of modern cochlear implant (the diagram from Dr. Lertsburapa) to our own designs.n

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T	**This Lesson....What we are doing now:** Students collect data about the patterns you when standing at different points around a sound source. You will guide your students to draw a model to represent their findings as a class. Although, the model has a issue to resolve, how can we use our model to explain why the sounds are getting quieter/amplitude decreasing? We revise our models to answer this question. This makes us start to wonder, if spreading out sound causes the amplitude to decrease, is there a way to scoop it back together?

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L17 Why do sounds get harder to hear the farther away I am from their source? 2 periods S *Building toward* ⬇ *NGSS PEs:* *1-PS4-1, 4-PS4-1, MS-PS4-1, MS-PS4-2, MS-LS1-8*	Our ears (and a sound detection App) provide evidence of whether the loudness and/or frequency of a sound changes based on how far away from the sound source we are. [the sound source is a computer or phone playing a tone via a google app]. Video 2: (from 0:40-0:45) shows a slow motion view of water waves radiating out from a drop in a previously still body of water. Dropping a single marble into a tightly packed cluster of marbles, shows how collisions spread outward from a single point over a greater number of particles	Conduct an investigation Develop a model (pond and marble drop)	We checked on our driving question board and initial patterns in the phenomena, and we realized we still have some questions about why do sounds seem louder the closer you are to the sound source. We decided we wanted to investigate this further. We collect data on this using our ears with our eyes closed. We notice some patterns: • The further away you get, the quieter the sound gets, but the tone/pitch doesn't change. • You can hear the sound in any direction from the sound source (and it seems to remain the same volume) if you stay at the same distance from it. • You can get far enough away that you can't hear the sound anymore We draw a class model representing what we know from the evidence so far: • We know the sound travels in all directions, so the compression bands in the medium must travel outward in all directions from the sound source (we show this with arrows and dark circular bands) • This means that the sound waves and energy radiate away from a source (we show this with arrows and dark circular bands) • The frequency of the wave isn't changing as we get further away from the sound source (we show this by keeping the dark circular bands equidistant from one another). But we realized a limitation in our initial radiative model. It doesn't have a way of representing that the amplitude of the wave is decreasing the further we get further away. We think this must be happening, because that is the only way to account for the decrease in volume with distance, but we want a bit more evidence to see if other waves also exhibit this behavior (decreasing amplitude as they radiate outward from the source where they started). We analyze a slow motion video of a drop of water in a still pond to visualize whether water waves are doing this. We notice patterns in the data related to the point of the original disturbance.: • These waves also radiate outward from where they originally formed. • The waves appear to decrease in amplitude the further away you get from it. • The circumference of the wave continues to expand the further away it gets from the disturbance.

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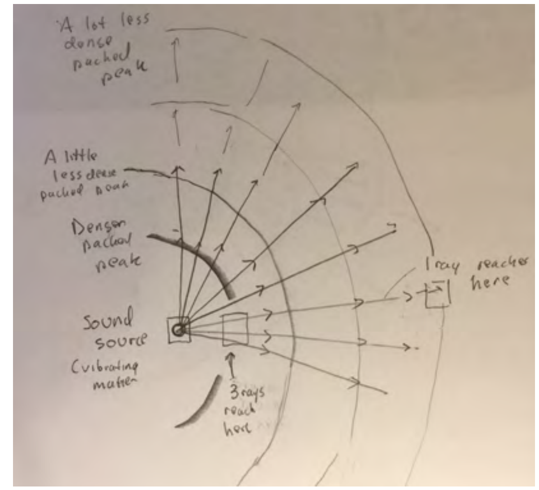
	(marbles) so that particles near the edge get pushed barely at all compared to marbles near the point of impact.		We revise our radiation model to represent this, showing a lighter and lighter semi-circle the further from the sound source we are, representing a compression band of less and less particle density (less amplitude). The represents what the matter is doing. We also still include arrows showing the direction the energy of the wave. We evaluate this model and summarize that: ● As the number of rays decrease in a given area, the amount of energy in that area decreases. ● When we draw this and count the number of rays in "squares" further from the sound source, we realize that there must be less sound energy reaching each square further away.  This matches what we saw with the water waves. The amplitude of those waves got smaller the further away they radiated from the sound source. We think that waves of lower amplitude have lower energy, which is why it sounds quieter the further away from a sound source we get. We revised our consensus model from lesson 13 to simplify it a bit more: ● We can represent the <u>direction of energy</u> transfer <u>across the medium</u> and how the amount of energy that reaches a spot decreases with distance by using rays (or arrows). ● We can represent the amplitude changes as pressure bands that are becoming less dark (less dense) the further away they radiate from a sound source (but this seems kind of hard to draw, so we think we might try sticking with the ray model more and only come back to this other representation if we need it). We wondered if we could see these effects in the anchoring event. We look back at our patterns in the data we see evidence of this, but we also noticed something else in the data. It seemed that people standing in front of the cone could hear the sound better than those behind it. This led us to wonder: ● *Does shape of the cone or the shape of her hand near her ear affect these waves?* ● *Are there ways to channel or redirect or channel the energy of a wave so that it doesn't spread out so much?* **Next steps: We think maybe certain barriers (like the cone) or your hand cupped a certain way can redirect waves and we want to investigate that idea that there may be different materials and different structures we could use to redirect, amplify, or dampen the energy of waves.**

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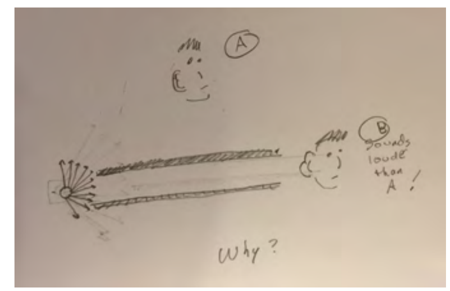
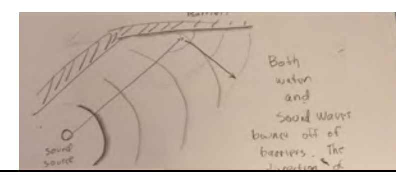
This Lesson....What we are doing now: Students will investigate how to channel sound using various shapes made with paper and tape. Then they used their findings to explain why some shapes worked better than others. This makes the class visualize the particles of matter transmitting the sound wave bounce off objects and reflect in predictable angles. Students represent their thinking by building a model to explain the results of the phenomena they experienced and apply it to how objects might reflect sound to a particular spot.

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L18 If spreading out sound makes it get quieter, can you scoop it back together or prevent it from spreading out to make it louder? 2 days *Building toward* *NGSS PEs:* *1-PS4-1,* *4-PS4-1,* *MS-PS4-1,* *MS-PS4-2,* *MS-LS1-8*	P1) A very quiet sound source (clock ticking) on a computer placed at one end of a long a tube or cone at X inches sounded louder than listening to the sound source at the same distance or even a little bit closer without the tube or cone. P2) When we place the same sound source so that the one tube points toward a gap in the wall, we can adjust the angle of another cardboard tube on the other side of the gap in the wall to determine if there is an angle at which we can hear the ticking sound (and if so, hear it louder that at other angles)	Conduct an investigation (sound barrier) Analyze data Develop a model (marble collision) and apply (direct sound to a particular location) Use a model to explain	We thought that the shape of some objects can keep the sound from spreading out and maybe make them louder so we wanted to investigate that more today. P1) We used paper and tape to make tubes and cones to test this idea and conducted some investigations. We noticed pattern in our data: • Certain shaped tubes and cones make a sound that reaches my ear, louder than it would sound if I remain at the same distance from the sound source, and didn't use the tube or cone.  We brainstorm others examples of where this might be happening. We construct explanations for how that would work → somehow the waves are being redirected or prevented from being spread out. We share out our ideas to show what we think happens to the rays as they spread out and hit the walls -- and propose that some possible alternate models: • Maybe the direction of energy transfer of the sound waves bounces off the surfaces of the object. • Maybe the energy is channeled or redirected when the particles hit the surface of the cone or tube. • Maybe it is like a ball bouncing off a wall. • We can hear the sound louder when listening into the tube, but it sounds a little jumbly This led us to wonder, what exactly happens to waves when they reach a barrier or surface like a wall? We made some predictions about what would happen if we directed a sound wave (using a tube) at another flat wall using a paper tube. We had lots of different predictions about whether the sound would bounce off the wall and/or if there was any pattern to how the sound might bounce off the wall 

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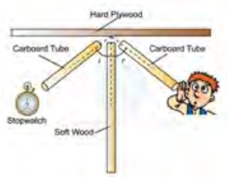
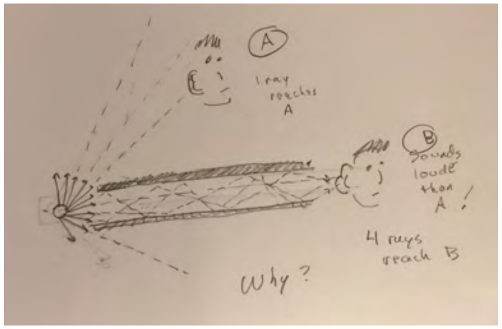
	 P3) A suite of other photos provide us examples of other where barriers might be contributing making the sound louder in that space: - Head in a box with a music player in it vs. no box. - [Playground tube (with bends in it)] - [Acoustic mirrors] - Photo of cafeteria lunchroom filled with students at lunch		P2) We conducted some investigations and noticed some patterns: ● There was a certain angle at which the sound was loudest. ● There was a relationship between the angle at which the sound was loudest and the angle of the tube of the sound source facing the wall. We argue that we can apply these findings to explain why the tubes and cones made the sound louder. We developed a model to represent what we think is happening.  And we applied that model back to our original results and the anchoring phenomena to explain why people in front of the cone heard the sounds better than those behind it. Also, this model might account for why the sound coming from the tube might sound a bit jumbly, since our arrows represent particles bouncing and some of those might get messed up and not all go in the direction of wave transmission. P3) We also use our new principles about how some sound energy bounces off of surfaces to explain how some additional devices might work to reflect sound wave energy to a particular spot. We argue from these examples that: ● Smooth surfaces tend to bounce waves off in a symmetric V pattern. ● Concave surfaces can concentrate the energy of reflected sound waves. ● Tubes and cones can redirect the reflected sound waves so that they keep heading toward a detector *From our model, we didn't put any sound waves right around the outside of the tube, since the sound inside the tube was bouncing or (reflecting) off the sides, so that brought up another question: Is this an area of dead zone where there is no sound?* **Next steps: We really want to see if we can hear something if we were to stand really close to the tube, but not by the open end.**

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This Lesson....What we are doing now: Students think some sound might be coming out of the side of the cardboard tubes after some investigations, we make some patterns about how sound waves travel through objects. Then students use their findings to model what happens when a sound wave reaches a boundary between two different media. Some of the sound energy is reflected back and some is transmitted through, but the modeling seems to bring up a problem. It seems like the sound transmission and reflection can't account for all of the energy! Students wonder where did the energy seem to "disappear" to?

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L19 If the energy of a sound wave is reflected when it reaches a barrier then would we hear anything on the other side of a barrier? 2 days *Building toward* *NGSS PEs:* *1-PS4-1, 4-PS4-1, MS-PS4-1, MS-PS4-2, MS-LS1-8*	P1) Same setup as previously with a paper tube and someone sending a message and another listening on the other end, but this time have someone stand very close to the tube to see if we hear a dead zone. We hear something, but are not sure if it's coming through the tube or from the sender directly on the outside P2) New version of previous two tube investigation: 1 on one side of a door, then another on the other side -- provides evidence of sound going through the door too. P3) Two different stiffness/thickness slinkies chained	Conduct an investigation (sound barrier) Analyze data Develop a model (marble collision) Use a model to explain	P1) We repeat the experimental set up from the previous day where we have a paper tube and someone talking and another person is listening on the other end, but this time we have someone stand very close to the tube to see if we hear a dead zone like our current model predicts. When we listen, we hear something! Although, we can't tell where we are hearing it from. *Is the sound coming through the tube? Or are we hearing the sound only from waves staying on the outside coming directly from the sender?* We decide that we need a more controlled environment to repeat this to see if the sound is coming through the tube or not. P2) We notice patterns in the results from our second investigation: ● You can hear some sounds that are very soft on the other side of the door through the tube We argue that since the sound is quiet, then some, but not of the sound energy must be transmitted through the door. And we know that sound is also reflected off the door. We go back to our particle model and draw out what might be happening. Since all matter is made of particles, when the air particles hit the door, they must push the door particles and the wave continues to be transmitted through compressing and expanding particles in bulk. This led us to wonder *if there is a relationship between how much energy reaches a barrier, how much goes through it, and how much is reflected? So what exactly is happening when sound hits a new medium? What could explain why some sound goes through a barrier and some gets reflected when the sound wave reaches the barrier?* We know that in our two tube investigation, the sound wave must be traveling through the air, and then reaches the door, which is a solid. We know that the particle density in each of these different medium (gas vs. solid) would be different. And we know that all matter is springy up to a point (from L4). It would be nice if we had a way to visualize the waves traveling from a springy medium of one density up to the boundary of another medium of different density. P3) We conduct an third investigation using two coiled springs chained together tightly coiled and one loosely coiled spring together might allow us to do this. First we mess with just the one wide coiled spring (with some ribbons tied to a couple coils) a bit first to see what type of wave behavior it can help us visualize. We try to simulate what we saw in the NetLogo simulation, and it looks very similar (we can see back and forth particle motion as well as propagation of compression bands through the medium). We think that the spring could be a useful model for visualizing waves traveling through one medium. We brainstorm what would have to happen to the spring in order to represent a medium of a different density (like a solid). We think we would need a spring that has more metal, thicker metal, or tighter coils in it. Our teacher showed us an example of such a spring and we chained both of the two together as a class to simulate two different media

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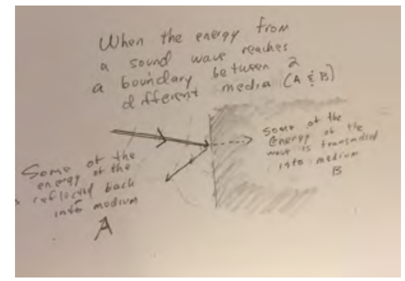
	together shows evidence of a compression wave reflecting back from the boundary between where the two spring meet and a compression wave going into and through the new 2nd spring as well.		(air and door). We laid it on the floor, marked four location on the spring (with colored tape), put cm graph paper under it, and conducted some additional investigations with it, collecting data on how much each piece of tape moved back and forth (amplitude) We notice patterns in the data (shown to to the right): ● Compressions travel across the whole length of the spring, but any one spot in the spring only moves back and forth. ● When we keep track of how much each spot in both media move back and forth and draw a transverse representation of that over time (to visualize the amplitude), we notice patterns across time (see image on the right). ● When either of these waves reaches the spot where the type of spring changes, a reflected wave is produced and another wave that goes into the 2nd spring is also produced; both of these waves appear to have amplitude than the original wave that hit the surface. ● As the wave continues traveling along a medium its amplitude decreases. We argue from this data that: ● Compression waves can travel across any medium (any state of matter) ● The matter in the medium only moves back and forth (not up and down) ● The amplitude of the wave represent the amount of compression in the medium, which is related to the energy of the wave (in the case of sound, this is its volume). ● When a sound wave reaches a boundary between two media, some of the energy is reflected and some is transmitted. ● The relative proportions of how much is reflected vs. transmitted may depend on which medium you are going from or into (e.g. water to air, vs. air to water).  We develop a model to represent our findings, using a ray only representation: when a sound wave reaches a boundary between two different media some of the sound energy is reflected back into the original medium and some of it is transmitted into the new medium AND as it travel through the medium some of that energy seems to "disappear... *We wonder what else might be happening to the energy that is traveling through the medium that seems to disappear? What else might be going on in that medium that could explain why this seems to happen?* **Next steps: We want to investigate this last question more next time.**

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This Lesson....What we are doing now: After students investigate bending a paperclip back and forth and collecting thermal energy data, they figure out that some of the sound wave energy is absorbed as it moves (changed to thermal energy - particle movement in random motion). You will guide your students to summarize their findings in a model thus far about sound wave transmission, reflection, transfer, radiation and absorption.

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L20 What else happens to the energy of the wave as it travels through the medium? 1 days *Building toward* ⬇ *NGSS PEs: 1-PS4-1, 4-PS4-1, MS-PS4-1, MS-PS4-2, MS-LS1-8*	A slow motion video of a vibrating Drum head motion/ string motion reminds us of the deformation of shape that objects that make sounds or absorb sounds P2) Bending and unbending the ends of a straightened paper clip back and forth leads to a temperature increase at the vertex of the U or V that we make in the paperclip.	Conduct an investigation (paper clip) Argue from evidence.	We wondered if anything else is anything else is happening within springy medium that would explain why some seems like it's disappearing sound waves travel through it and it vibrates back and forth. P1) We think about the movement of the drum head or string instruments that we investigated earlier. They are moving back and forth over and over. We can only see this motion when we watch slow motion videos. *Wouldn't it be great if we could control the back and forth movement and see what else might be going on?* P2) We conduct a brief investigation with a paper clip (which we argue is springy). We bend it back and forth many times and notice that it seems to get hotter at the point where it we are bending it. We wanted to collect more data on this with a thermometer to see if there is a relationship between the number of times we bend the paperclip back and forth and how warm it gets. After collecting our data we notice some patterns: • The more times you bend the paperclip back and forth the more the temperature goes up. We argue from evidence that this applies what is happening when sound waves travel through a medium: • When matter is bent back and forth (or compressed and decompressed) some of the energy of the wave is absorbed by the medium and converted into thermal energy (increases in the amount of random particle motion, which is an increase in the temperature of the medium). We revise our model to summarize all the things that can happen to the energy of a wave as it travels through a medium: • It can **radiate** outward over a greater space, leading to a decrease in amplitude the source the wave gets (e.g. the drop in the pond) • When it reaches another object, some of that energy can be **transferred** to the that other object, causing it to vibrate (e.g the shaking window) • Some of its energy will be **reflected** back into the original medium when it reaches a boundary with a new media (e.g. the tube and coes) …. • ...And some of its energy can be **transmitted** into and through the new medium (e.g. the slinky, the tupperware container, the aquarium). • When energy is **transmitted** through a medium; some of the energy may be **absorbed** by the medium and converted to thermal energy (e.g. traveling through air, solids, liquids, and the results of the paper clip)

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This Lesson....What we are doing now: You will help students build a summary table of all the scientific principles they figured out over the course of the unit, and determine which of these would need to be a part of an explanation for different phenomena and related questions that the class explored over the course of the unit. You will help students use this list of principles as part of a "gotta have it" check list for explaining phenomena related to a larger set of questions (What causes different sounds, how do sounds move across a medium, and what is it easier or harder for some people to hear sounds in some places over others?)

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L21 Why do I hear that? (Optional Assessment) 2-3 days *Building toward* ↓ *NGSS PEs:* *1-PS4-1,* *4-PS4-1,* *MS-PS4-1,* *MS-PS4-2,* *MS-LS1-8*	All previous phenomena ...	Construct an explanation Develop a model.	We build a summary table of all the science principles we think we need to include in explanations for questions like: ● Why different objects produce different pitch sounds? ● Why the car speaker makes the window move? ● Why we could hear the sound through the water tank, even though we were on the outside of it? ● Why we couldn't hear the music when there was no air in the container the sound source was in? ● Why louder sounds can lead to hearing loss sooner than softer sounds? ● Why higher pitch can lead to hearing loss sooner than lower pitch sounds? ● Why cupping your hand near your ear helps you hear sound better? ● Why sounds get harder to hear the farther you are from their source? ● Why we can hear so many different sounds from the spinning record from across the room? We update our model to summarize all the science principles that can apply to general categories of questions on our DQB like: ● *What exactly causes different sounds?* ○ *Pushing on an object can deform it, deforming it can cause it to spring back and vibrate* ○ *Vibrating objects are sound sources* ○ *Different vibrations of different amplitude and different frequency* ● *How do sounds move from a sound source to my ear?* ○ *Particle collision → energy transfer* ○ *Compression and expansion of the matter* ○ *Density waves propagating through the medium* ● *Why is easier (or harder) for some people to hear sounds in some places over others?* ○ *Transmission - how the sound get to your ear.* ○ *Absorption by the ear detectors - How the ear works and hearing loss* ○ *Radiation - makes sounds quieter further away due to energy spreading out* ○ *Reflection - redirect (echo) some of the energy in the wave away or toward you* ○ *Absorption within the medium - makes sounds quieter the more energy that is converted to TE in the medium that it travels through to get to your ear.* Next steps (in home-learning reading): We gather additional information related to things we still had questions about: ● How electronic devices "hear sounds". (reverse of the speaker - converted movement of the magnetic to electrical energy which, the pattern of which is stored in the device)

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This Lesson....What we are doing now: You will help students compare how early recordings were made vs. how digital recordings are made today. Students will analyze video, text, and will also work the motion detector one more time to help develop ideas about the structure of digital information storage work in modern electronic devices. And you help them evaluate each method

Lesson Question	Phenomena	Lesson Performance Expectation(s)	What We Figure Out (CCCs & DCIs), *New Questions* and **Next Steps**
L8(c) How were audio recordings made, copied, and played back now vs. in the distant past? 3 days *Building toward* *NGSS PEs: 1-PS4-1, 4-PS4-1, MS-PS4-1, MS-PS4-2, MS-LS1-8*	P1) Historical descriptions and video clips of Edison wax cylinders and vinyl records and how they were stored, how long they lasted, and how susceptible they were to damage. P2) The motion detector sampling rate and the microphone. P3) Digital audio file examples to work with.	Gather and communicate information Use mathematical and computational Thinking	P1) We then look at videos and historical descriptions first invention for recording sounds - the Edison cylinder as well as the material breakthrough that allowed the replacement of vinyl for wax/foil. We draw a model of how we think it works using the cone, needle, and wax/foil cylinder. We argue that the information for the song is: ● Stored on the cylinder/record as a wavy groove. ● The shape of the grove influences how much the needle moves back and forth and how fast it move back and forth, but this is also related to how fast we move the track (continuous groove) under the needle. ● Is relatively hard to copy and transport. ● Is relatively easy to damage (scratching it destroys the information in the groove). P2) We then look at the motion detector and turn off the "continuous curve fitting" function and see that when we measure the vibration of the stick, what is actually being recorded are a bunch of coordinates of time vs. distance. And when we decrease the sampling rate, the detector can't record enough samples to get a good approximate of the shape of the actual graph. We gather additional information about how a microphone works (related to what we learned in a previous lesson about how it is the reverse of a speaker), and apply that to what we learn is being recorded in an iphone/ipod/computer audio file ● The amount of energy (which is related to amplitude that the microphone cone was displaced) is recorded as a number in the computer/devices memory chips. ● Many samples are recorded in a second (a typical sampling rate is 44,100 samples per second) ● The entire series of these numbers is what is saved as a "track" or a "file" ● To playback the music, the computer sends this amount of energy through an electrical wire to the speakers, which with the magnet, coil, and cone, move the cone back and forth generating sound. P3) We work with a series of digits from an audio recording (in excel or other spreadsheet) to reconstruct the graph of the vibrations in that audio clip. And we use mathematical thinking to predict and test what we would need to do to those numbers to make the sound quieter or lounder. We argue that the information for the song is: ● Stored as digits in the computer memory ● Is very to copy and transport (using the internet)

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			● Is relatively difficult to damage when it is stored on flashdrive or on a computer in a closet or at home/ We gather information about the history of digital sound sampling and storage and learn this method of recording and playing back sounds is relatively recent, and before that other methods were analog methods (which all had many of the disadvantages that records and wax cylinders did). *But our parents and others say that music from records sounds better than music digitally, why would some people think that?* As an assessment we used our models to explain that although digital recordings are easier to copy, since they convert information to a discrete number - kind of like rounding, so some information is lost when that happens. In analogue versions like a record, every nuance in the recording is captured and able to be played back - no information is lost (until it is scratched or damaged).

Extension readings & home learning assignments for substitute days:

- Anytime after lesson 2: How do different insects make sounds and how does our voice box works?
- Anytime after lesson 4: In what other ways do rocks and solid ground vibrate (earthquakes)?
- Anytime after lesson 7: How does my dentist and my doctor use sound energy to break off and break up bad things in my body?
- Anytime after lesson 12: How do whales use sound to communicate with each other underwater across the ocean? Article on sound pollution and whales in the ocean
- Anytime after lesson 18: How do scientists use sound and other wave phenomena to figure out where earthquakes originate?
- Anytime after lesson 19: How can doctors use sound to “see” inside of me? How do bats and submarines find where their prey is located using sound?
- Anytime after lesson 20: How can different types of materials and structures reduce the noise we hear in the rooms we work and eat in (and why)?
- Anytime after lesson 22: How were the first audio records made (Edison cylinders - wax and aluminum)?

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