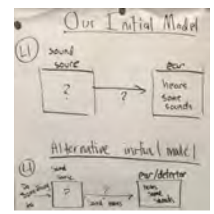
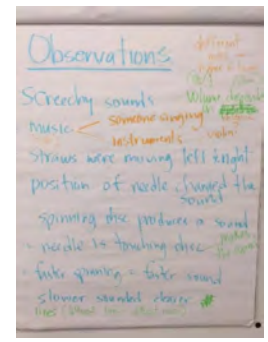
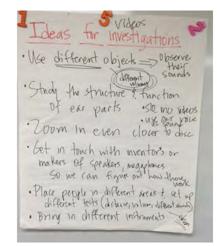
Lesson 1: How can we hear so many different sounds from across the room when we spin the record?

Teacher Guide

Middle School Unit: How Can I Hear Different Sounds From Across The Room?

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 sounds from across the room when we spin the record? 3 periods *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 phenomena and 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 phenomena and *gaps in our current* models to clarify and seek additional information, about patterns in *sound related* phenomena, *and* ***Ask questions*** *that can be* investigated within the scope of the classroom *to figure out how we can sense so many* different sounds *from a distance.*	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.**

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

Getting Ready: Materials Preparation

Materials For Each Student

- Lesson 1 Student Activity Sheets
- Student Home-learning 1 (1)
- Index card (1 or more)
- Dark Marker (1)

Preparation of Apparatus (30 min.)

- Put these materials together to build the apparatus shown the right.
  - A lazy-susan
  - A hot glue gun
  - A record
  - A dissection needle or sewing needle
  - A push pin
  - A heavy coffee cup
  - A paper plate
  - Scissors
  - Ruler (1)
  - Tape (Packing tape recommended).

- This video shows how to operate the apparatus so that it plays the sounds recorded on the record.

Materials Needed for the Whole Class:

- Projector
- Lesson 1 Projected Images (optional)

Preparation of Driving Question Board (15 min.)

- Make a space for a driving question board, that is easily accessible for students. Ideally it should be in a space where students can gather chairs around it and walk up to it to reach any part of it it. They will need to periodically go up to it (over the course of the unit) to post their questions and look at the questions that are posted there. Here is an example.

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Learning Plan: How can we hear so many different sounds from across the room when we spin the record? (3 periods 40 min each)

Day 1

1. (5 min) Inform students, "I am going to show you an interesting phenomena today. In order to observe it carefully we are going to need to move to a different part of the room."

Have students take out their Student Activity Sheets and bring it with them to stand around the record & needle device. Tell students, "I am going spin the disc here on this device and I want you to pay attention to what happens. Make sure to watch and listen carefully, as you observe this phenomena."

To operate the device, lightly use your finger to press on the record (apply a bit of pressure) and turn the record at a steady speed (about 1 full turn every 2 seconds) A**. If students want to try to operate it, tell them they will have a chance to try in a couple of minutes but should just concentrate on observing this first time.**

Now, briefly discuss with students what they observed as you were spinning the record. Most students will talk about what they heard coming from the record. Take a brief moment to probe a bit deeper into just a few these observations to build a sense of mystery B

Next, say "Ok. We have some different ideas about what kind of noises were coming from the device. So, I'm going to operate the device one more time while you observe what happens. You will also have a chance to try to operate the device, after you observe for a second time. Then, you will go back to your seats and write down your observations."

Operate the device again as you did earlier but this time increase the rate of the spin a little

Teacher Supports & Notes

Additional Guidance

A The angle of the needle arm and record is important. So is the direction that you spin the record. **This video** here shows you how to do this.

Strategies for this Sharing Initial Noticings Discussion

B For instance, if a student says *"I heard weird noises coming from the device."*, ask them, "Wait… you heard noises? What type of noises were coming from the device? What do you think the noise was?" Many students will say something like voices or music. Some students may not be quite sure. You can say things like, "You heard voices? Voices coming from this thing? Did some others of you also hear that? Whoa…. interesting."

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above and a little below the rate before as well as the suggested 1 full turn every 2 seconds or fast enough until the music and voices are heard clearly. If students want to try as well, you may want to allow some volunteers to spin it. If students spin it at different rates, that is ok. You may also want to lift the needle and move it over to another part of the record and spin it again.

Now have students go back to their seats (without discussing their observations further) and have them record their observations on their activity sheet.

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2. (20 min.) Tell students, "Now, we are going to share our observations. We are going to start by having you share your observations with each other in your small groups." C

Have students work on this in small groups. While students are discussing their observations, walk around the room and listen into their discussions. Where needed use questions to help students dive deeper into their observations. Do this only when a group is having a hard time getting a discussion started. Use your discretion to determine how long the discussions should continue before moving on with the lesson. Here are some suggested prompts you can use to start or fuel the discussions:

Suggested Prompts:

- ➔ What did you hear when when we spun the disc?
- ➔ Could you hear words or voices? What did they sound like?
- ➔ Could you hear different notes or instruments? What did they sound like?
- ➔ Where did it seem like these sounds were coming from?
- ➔ Was it easier to hear these sounds by standing in some places over other?
- ➔ Did you notice anything different about the sounds when we spun the record faster vs. slower?

As students are discussing in their groups, Listen for *student responses* such as:

We could hear voices, words, and instruments playing songs coming from the cone/record/needle

Supporting Students in Listening & Speaking In Small Groups

C Some classes will benefit for guidelines for sharing and discussing in small groups, to help them become better listeners.

One way to support their growth in this area is to make the speaking and listening routine explicit in small group work. Here is one strategy to support that:

Use a slide (attached resource) to post discussion expectations. Say, "Now, we are going to share our observations in small groups. Before we do this, we will have to follow some guidelines for sharing and discussing." Review the slide with them. Then say, "Now, in your groups, I want you to share your observations with each other. While you are sharing your observations, search for things your observations had that were alike and different. You may now begin to share your observations. Remember to use the guidelines. I will come around to just observe some of your discussions."

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apparatus when we spun the disc (the record).
The closer we are to the record the louder the sound was.
How fast you spin the record affects some aspects of the sounds we heard.

After students are done sharing in their groups, have them pick one member from their group to share an observation from their discussions.

Make sure to record these observations on a piece of chart paper or on the board or in a digital document (like a powerpoint slide or word document) to display as students share them. For each observation ask the entire class if other students also had a similar observation in their groups. D

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3. (15-20 min.) Tell students, "So, we all heard the sound coming from the needle and the record, and we noticed all these interesting patterns in the observations. But now this gets me wondering, how does this happen? How is it possible we can hear all these different sounds from across the room?

We should to model what we think is a happening that could help us explain that question. Turn to page 2 of your student activity sheets. Draw your ideas here of what you think is happening where the needle touched the record, and what is happening t in air in between the sound source and your ear, that would really help show & explain, how is it possible we can hear all these different sounds coming from this thing from across the room? Don't forget to label everything in your model"

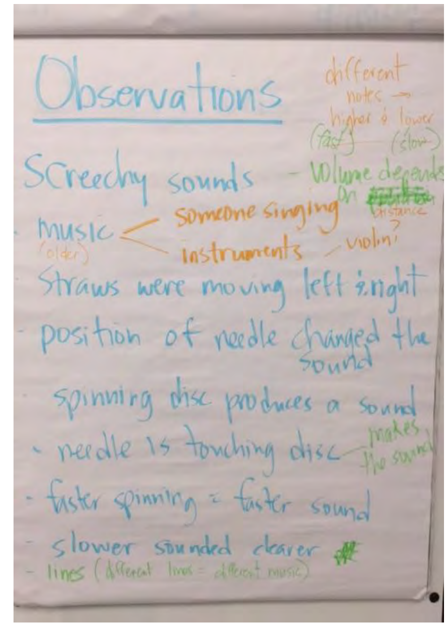
While students are drawing their models, walk around the room and quietly ask probing questions about a few their drawings where you aren't seeing labels.

Suggested Prompts:

What did you draw in the space between the sound and the air? Can you label that?
Where is the sound coming from in your model? Can you label that?

Classroom Artifact

D Here is an example of the observations from a 6th grade classroom.



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How are you showing the sound moving to your ear? Can you label that?
What do these represent? Can you label that?

Have students turn in their first page of their activity sheets so that you can look through their models before day 2 to pick some to have them show next time. E

Day 2

4. (20-25 min) Pick 3 or 4 students with different models to come up and show their models to the class. When they come up, they should explain all the elements in their model. Use probing questions simply to get them to articulate each pieces of the model to the class. F

After each presentation, ask students to look at their models and the one that as just presented to find similarities and differences across them. Keep track of these on the board. If something is repeated several times that's important, emphasize that to the class. G **When all 3-4 presentations are done, analyze all the similarities in the models and have students write these in #3 on page 4 of the Lesson 1 Student Activity Sheet. While they are writing the similarities and differences, lead a brief discussion using the following prompts:**

Suggested Prompts:

- ➔ What did you notice was similar across all the models?
- ➔ What did you notice was different across all the models?

Listen for *student responses*, such as:

We noticed that each person showed something happening where the needle touched the record
We noticed that each person represented sounds traveling from the sound source to the ear.
We noticed differences in how the sound was produced.
We noticed difference in how people represented how the sound travels or what the sound was .

Additional Guidance

E Pick models that are very different. A diversity of ideas in the models will help open up new possibilities in student thinking in the audience. We often see questions that end up on the Driving Question Board that come from new ideas raised in discussion about these models.

Strategies for this Sharing Initial Ideas Discussion

F The purpose of the questions is simply to get the students to articulate parts of the model that may be in their head but not on paper. Don't evaluate whether the elements should or shouldn't be there. Rather, just help them talk out loud about everything that is in their model, and if they say something that isn't clearly shown in the model, push them to say where in the model it shows that or what they would change/or add to the model to show that idea.

G For instance, if a student draws lines going from the spinning disc to the ear, ask the class if they had similar paths or shapes as that student and why they think it's important to show that part of the model. If something is brought up that is not important, have the class analyze that part

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5. (15 min) Have a consensus building discussion and have students add these ideas to their activity sheet:

After the students have listed their similarities and differences.

These are the type of *student responses* related to what is similar.

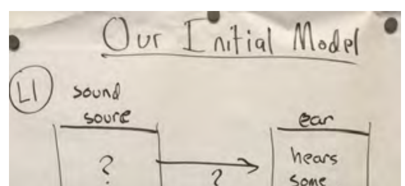
In order to hear a sound we need a sound source, an ear (or detector that picks up sound) .
Sound travels a distance across the room from the sound source to our ear.
The sound comes from a sound source somewhere on the needle & disc device.
Optional: You have to move or push the disc in order to produce a sound.

These are the type of *student responses* related to what is different.

We are not sure exactly what is happening where the needle touches the record.
➔ We are not sure where the sound is exactly coming from
➔ We aren't sure about to represent what is exactly happening in the space between the sound source and our ear, even though we need the sound is traveling through that space.

If students are having a hard time coming to consensus about one of the statements above, use probing questions like:

What is necessary to hear different sounds from across the room? Think about the things all of your models have in common.
How did the sound get to our ear?
Would the sound have been made without the needle touching the disc?

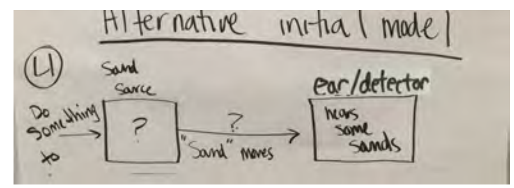


As students come to agreement on these points, draw an initial model as a class that represents everything that students agree

of the model to determine that it's not important. For instance, if someone draws perfume in the air with the sound "waves", ask the class if perfume really affects how sound travels and if you can still hear sound without perfume.

An Alternate Consensus Model

H An alternate possible consensus models is shown below. If an alternative models is used, keep adding all the elements in the future models (e.g. always replace the word ear with "ear/detector")



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upon. H **Include questions marks on the areas where we had lots of different ideas, and weren't in consensus yet. In these models there should be a question mark at the sound source (we aren't sure what exactly is happening that causes a sound to be produced) and a question mark on the arrow from the sound source to our ear (we aren't sure about to represent what is exactly happening in the space between the sound source and our ear, even though we need the sound is traveling through that space**.

After agreeing on this consensus model]have students draw a version of it their Student Activity Sheet pg. 4, under the "Conclusions" section. If time is limited, post them on a sheet of paper in the room and have them write this on their Student Activity Sheets the next day.

Day 3

6. (10 min) Ask students to review what we figure out from last time. Have students summarize the consensus model we developed as class. I

Then tell students, "This model seems like it might have parts to it that explain more than just the record and needle." For example, let's take a different phenomena. Raise your hand if you can hear my voice right now. OK, so then in order to hear my voice, what elements of the model would be similar that could be used to explain that?" **Check each element of the model with students.**

Suggested Prompts:

- ➔ Do you need an ear?
- ➔ Is there a sound source? What is it?
- ➔ Does sound travel from the sound source to your ear? Ho

Listen for *student responses*, such as:

Formative Assessment Opportunities

I You may choose to use an entrance slip asking students to list three things needed to hear a sound from across the room that we agreed upon from the consensus model.

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Yes; or not just an ear, but a working ear or one that can detect sound.
Yes, there is a sound source, it is your mouth.
The sound is coming from your vocal chords
The sound travels from the teacher speaking to our ears.

Next, have students think about examples of other times when they heard a sound or noise. Ask them to write down a brief description of a time they can think of when a sound was made, and it is one which if they think about it, they think it might be kind of hard for them to explain something about that phenomena. Have them record these on Student Activity Sheet under the "Next Steps" section on pg. 3.

After they have finished writing, ask for a few students to share their experience. As they are sharing, emphasize that those phenomena are really interesting and they are making you think of lots of questions.

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8. (5 min) Next, have students write at least 2 questions they have related to sound and how we hear different noises in their Student Activity Sheet under the "Next Steps" section. When they are done, have them choose 1 question per student to write and share on a post it note.

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9. (30 min) Use a large poster board or have a spot in the room to post their questions. Set up the driving question board (DQB), with the question "How Can I Hear So Many Different Sounds From From Across The Room?" across the top J. Put the initial consensus model above the driving question board.

Have students move their chairs around the DQB. Review with students that they each need to post their questions. And that in order to do that, they have to raise their hand to get called on

Classroom Artifact

J The Driving Question Board should be centrally located in the classroom so that it can be referenced throughout the unit. Here's an example of observations from a 6th grade classroom.

Strategies for this Building Understandings Discussion.

K If a student forgets to explain why/how it is linked to someone else questions, press them to try talk through their thinking about this out loud. This is a key way to emphasize the importance of listening to and building off each others ideas and help scaffold student thinking.

Don't worry if there are some questions that are raised that not part of topics in this unit.

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by the previous volunteer. When they are called on they should stand up, face the class, read their question, and explain whose other question (already posted on the board) it is related to and why/how K (the one exception to this is the person who volunteers to go first). And then after they read it, they should post it L. and call on the next volunteer.

Emphasize that we need to hear from everyone, because we want to make a joint mission that reflects what the entire learning community wants to figure out. Reassure students that when we get down to the last people who haven't shared, it may simply be because there isn't an obvious connection to another question they heard. And at that point we can switch we call can work together to help brainstorm ways we might be able to connect that person's question to a previous one on posted on the board.

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9. (5 min.) Introduce and assign the home-learning. Students may need you to do one example together as a class.

For homework, have the students finish page 4 of the Student Activity Sheet. They should think of two to three activities or investigations that could answer one of the questions they heard today posted on the driving question board.

Do one example as a class. When students return the next day, they will share out the investigations they came up with.

Over time students will get better and better at forming testable questions in scope of the driving question. This type of activity gives them practice at doing that.

L If a student can't figure out another person's question it might be connected to, encourage them to ask the audience for help. After an idea is shared, ask the original presenter if they agree and why and then have them post their question

If a question is similar to (or the same as) another one, have students place it on top of the question that it is similar so students can visually see how many of the questions are the same or related. Emphasize that this provides us evidence of where many people are thinking about similar things.

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Alignment With Standards

Building Toward Target NGSS PE

- **1-PS4-1:** Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.
- **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.
- **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.
- **MS-PS4-2**. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
- **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.
- **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.
- **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.]

Building Toward Common Core Standard(s)

Comprehension and Collaboration:
CCSS.ELA-LITERACY.SL.6.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- CCSS.ELA-LITERACY.SL.6.1.B Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed
- CCSS.ELA-LITERACY.SL.6.1.C Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

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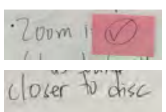
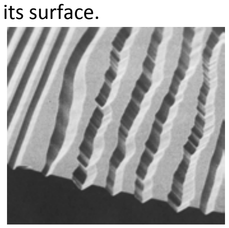
Lesson 2: What Does The Record Look Like Up Close?

Teacher Guide

Middle School Unit: How Can I Hear Different Sounds From Across The Room?

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  *Building toward* ⬇ *<u>NGSS PEs:</u>* *1-PS4-1,* *4-PS4-1*	<u>A video of a record playing a longer song also shows a pattern</u> A magnifying glass and a piece of a record reveals some patterns in the record structure Microscopic pictures of the record show different structures on its surface.  When we observe the motion of a needle tip in the groove of a record as it is spun through watching an <u>electron microscope video of needle on a record player</u> we see some more patterns.	**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 (phenomena) how the structure of the record causes the needle to move back and forth in different patterns and as a result (effect) we heard different sounds being produced.*	 After looking at a piece of the record up close (with a magnifying glass), we notice some interesting <u>patterns</u> in its <u>structure</u>: ● 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 decide on our next step:** ● **We want to see if there are any visible structural differences in the lines if we zoomed in closer.** 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 <u>structure / function</u> relationship connected to a <u>cause and effect</u>: ● The <u>structure</u> of the groves <u>causes</u> a push on the needle in different directions as the record spins. ● This generates an <u>effect</u>: 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?*

Getting Ready: Materials Preparation

Materials For Each Student

- Lesson 2 - Student Activity Sheets

Materials For Partners

- A record
- A magnifying glass

For the whole class

- To project on computer monitor / screen with sound:
  - Downloaded youtube video of record needle following an audio track being played off a vinyl record. A downloaded copy of this this video is included as L2 - Video 2 - path of the needle in a vinyl LP under the microscope.mp4
  - L2-PI-Microscope Photograph of Record Surface (to project)
  - Electron microscope view of needle on record (15 second video clip) A downloaded copy of this video is included as L2 - Video 2 - path of the needle in a vinyl LP under the microscope.mp4

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Getting Ready: Teacher Preparation

Background Knowledge	Alternative Student Conceptions	Linking Our Understanding to Scientific Terminology
.... from the FRAMEWORK:		

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Learning Plan: What Does The Record Look Like Up Close? (2 periods 40 min)

Day 1

1. (3 min) Ask students to review what we figure out from last time, if you haven't done this with students on day 3 of Lesson 1. If you have you can skip this step. Have students summarize the consensus model we developed as class. A

Check each element of the model with students

Suggested Prompts:

- ➔ Do you need an ear?
- ➔ Is there a sound source? What is it?
- ➔ Does sound travel from the sound source to your ear? Ho

Listen for *student responses*, such as:

Yes,..... or maybe not just an ear, but a working ear or one that can detect sound.
Yet, there is a sound source, it is your mouth.
The sound is coming from your vocal chords
The sound travels from the teacher speaking to our ears.

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2. (17-20 min) After reviewing the statements, ask students to share their investigation ideas from last night's homework. B

Teacher Supports & Notes

Formative Assessment Opportunities

A You may choose to use an entrance slip asking students to list three things needed to hear a sound from across the room that we agreed upon from the consensus model.

Strategies for this Sharing Initial Noticings Discussion

B One example of how to start this discussion is as follows: "Hello class! So, we are going to continue investigating the unit we began yesterday with sound. Yesterday, we observed noises coming from a cone while a needle touched a spinning disc. From this activity, we made three consensus statements- One was that in order to hear a sound, we need a sound source, a detector which yesterday was our ear and we had to be close to the sound being made. The second statement we made was that the sound somehow traveled to our ear from the source. We had a lot of ideas how but still were not sure. The last statement we made was that the sound was the result of the

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Post these ideas next to the Driving Questions Board. C **As students are sharing their ideas, underline repeated statements to keep track of common ideas between students. If students didn't suggest looking at the needle and record closer, use questioning about what they think it is about the structure & function of the record that makes it play different sounds, to lead them to this idea for an investigation.**

For any idea that might be drawn out, encourage students to share that idea under a document camera. Emphasize that the list is our action plan of what it is we want to do to try to actually answer our questions, and that we can add to this list and our DQB throughout the unit as we go.
D

---

2. (10 min) Shift to starting the first investigation. Tell students that we will begin some of these investigations today. Emphasize that one of the ideas that they shared was to "Zoom in even closer to the disc". Put a post it check mark on a post it note and put that note on the relevant part of the ideas for investigations poster, emphasizing that we are going to do what you suggested, but that you are wondering how we would do that.

Suggested Prompts:

➔ What tools would we need in order to zoom in closer to the discu?

Listen for *student responses*, such as:

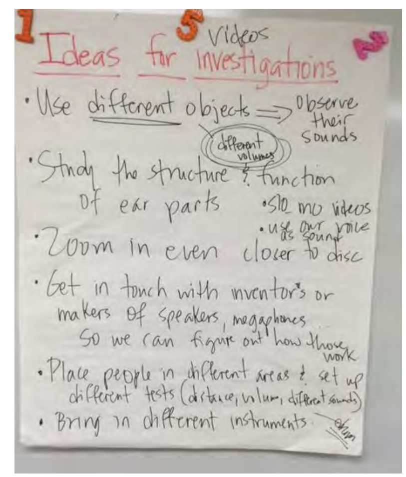
We need to have a disc to feel and look at up close
A magnifying glass or microscope might also be useful.

Tell students, "OK let's do that". **Give small groups a record and direct them to examine the surface of the record and write their observations in Row (A) in the table in Part 1 of their**

needle touching the spinning disc. So, for your home learning, you were asked to come up with a few ideas we could use to begin investigating why we heard this sound. We will need lots of ideas of how to go about investigating our questions, so who wants to start out first with sharing an idea they came up with?"

Classroom Artifact

C Here are is sample set of ideas from one class of 6th graders:



Alternate Activities

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Student Activity Sheets.

Then do the following:

A. **Pass 1 record piece and 1 magnifying glass to a person from every group of 2-3 students.**
B. **Collect the record and the magnifying glass after a few minutes.**
C. **Give students a couple of minutes to briefly discuss what they saw and record their observations. As students are recording their observations, walk around and ask probing questions, as appropriate.**
D. **After each student has examined the record, have them share their observations. Keep track of their observations on a poster or a whiteboard.**

Suggested Prompts:

➔ What patterns did you notice?
➔ What did you notice about the structure of the record on its surface?

Listen for *student responses*, such as:

There are many lines on the surface of the record
The spacing of lines varies in different parts of the record
The record feels rough
The lines look like they might be different thickness

---

3. (About 3 min) Next, inform students that you will next play a video that is focused on the needle on the record as the record plays 2 minutes of a song. Direct students to focus on the what is happening to the needle and record as the song plays. As the video plays, students should record their observations of the needle and the record from the start to the end of the song in

D Though the existing storyline is designed to target the typical range of 75% to 90% of the questions that students raise in the unit, and over half the ideas they come up with for investigations, if they come up with a new idea for an investigation that gets at a core idea, consider altering the storyline to include it. Or, you can use it as enrichment investigations at the end of the unit.

Alternate activities

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Row B in the table in Part 1 of the Student Activity Sheet.

After giving these instructions, ask students if they have any questions. Answer any questions and make sure students are clear on this activity. Next, project or play the video on a screen. As the video is playing, walk around and make sure students are recording observations on their sheets.

---

4. (3 min.) After the observations for Part 1 are completed have students share their ideas for the question in the "Making Sense" section of their Student Activity Sheet for Part 1 with a partner[E] or in small groups. After this brief discussion, bring students together to summarize the patterns they noticed in this phenomena.

Suggested Prompts:
➔ What patterns did you notice?

Listen for *student responses*, such as:

When the record plays a song the needle appears to move from one line to the next.
The record appears to have lines that make a spiral around it.
The lines are like a track that the needle follows.

Suggested Prompts:
➔ So why do different parts of the record play different sounds/songs when the needle is on it and it is spun around?
➔ How could we investigate this further?

Listen for *student responses*, such as:

E Sharing ideas verbally with an elbow partner is the most time efficient way to brainstorm some initial ideas before looking at the next set of phenomena. The space on the bottom of the Student Activity Sheets is provided as optional support for students who need time to "stop and jot" their ideas down before talking with a partner, but may not be necessary to do for some classes or students.

As students are sharing their ideas, walk around to make sure they are connecting the rough parts of the record being scratched/ rubbed by the needle to make the sound. If they are not connecting the needle to the record in this manner, use probing questions to help them make the connection.

Some examples of probing questions that can be used are:

- So, do you think the needle is important to making the sound? Why?
- What would happen if there were no needle and the record was just spinning alone? Why?

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Something about those lines must be different.
If we could zoom in more, maybe we'd see something different about the lines?
Can we look at surface of the record to see those lines under a microscope?

Summarize that it sounds like we have some really productive ideas of what we need to investigate further next time.

Day 2

5. (10 min.) Ask students to summarize what we figured out and what we wanted to investigate next about these lines on the record.

Then tell students that they will observe some more phenomena that will attempt to provide them what they wanted - a closer look at the lines on the surface of the record.

Show L2-PI-Microscope Photograph of Record Surface. Explain that this is photograph of the surface of a broken piece of record from the side. Have students record their observations in ROW C of the Student Activity Sheet.

Then tell students that you will show them a short video from a microscope of a needle on the record. Play the play the L2 - Video 2 - path of the needle in a vinyl LP under the microscope.mp4 You may wish to replay it a few times. Have students record their observations in Row D of the Student Activity Sheet.

---

6. (5-7 min.) After all the students finished recording their observations, have students complete the "Making Sense" question for Part 2 on their Student Activity Sheet individually. F **Make sure to walk around the room and observe what students are recording and provide additional assistance, if needed. Ask probing questions, when possible to encourage students to**

Additional Guidance

F This is a critical time to have students write their ideas down. Give enough time for this and look at some different ideas that students are writing down that are useful to use in the next section. Call on those students to share their ideas.

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think deeper about their observations.

---

7. (10 min.) When students are all finished with their observations, have students share their ideas for what might be causing the record and the needle to make different sounds as it is spun. Use a variety of probing questions to initiate and facilitate this discussion.

Suggested Prompts:

- ➔ Did others observe similar structures that provide evidence for that claim?
- ➔ How did the patterns in the grooves cause the needle to move?
- ➔ Why do you think their were different across a groove between grooves
- ➔ How might that help provide us clues as to what is producing the different sounds we can hear from it from across the room?

Listen for *student responses*, such as:

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 is pushed back and forth as it moves across the grooves.
The moving back and forth in different ways might be what is producing different sounds.

After this discussion, students should arrive at the following conclusions about patterns they observed from the electron microscope. Record the ideas on poster to refer to in later lessons and have students record these in the Conclusion section of their Student Activity Sheets.

- **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.**

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- **The needle moves back and forth as it moves across the grooves.**

Once they have arrived at these conclusions, continue the discussion by probing students to connect the grooves being scratched by the needle to the sound.

Suggested Prompts:

➔ Why do you think the grooves looked different?
➔ How might that help provide us clues as to what is producing the different sounds we can hear from it from across the room?

Listen for *student responses*, such as:

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.

---

8. (10 min.) After the class has agreed on the possible cause and effect relationship between the motion of the needle and the structure of the grooves, begin connecting this to other experiences with sounds sources:

Suggested Prompts:

➔ Are there other times in your life when you heard different noises coming from something that you think might have been moving back and forth like this?
➔ Can moving the needle back & forth in different ways really be what is producing different sounds?
➔ What are other objects doing when they are making sounds?
➔ Do other objects move back and forth when they make sounds.

Strategies for this Sharing Initial Noticings Discussion

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<u>**Listen for *student responses*, such as:**</u>

Maybe instruments or speakers do something like this.
I think instruments like a drum or violin string move back and forth.
I feel something vibrating when I play my clarinet. Is that related to this?
Not sure, but maybe. We should investigate this.

Have a Consensus Building Discussion G to help the class narrow in on the next steps and future investigations to pursue for the next day related to the new question that has emerged. The Next Steps section can be assigned as home-learning, if time is short; it can focus on what specific ways we might use instruments to investigate the new question that has emerged (do other sound sources move back and forth when they produce sounds). Make sure to leave time for students to update the Driving Questions Board and Investigation Plan Poster.

G One example of how to start this discussion is as follows: "So, it sound like we have something new to investigate. We still do not know if moving the needle back in forth in different ways is really what is producing different sounds. And now we are wondering if other sound sources, like instruments might move back and forth too when they produce sounds. I see on our Investigation Plan poster the idea of looking at instruments. Let's think more about how to investigate instruments more closely to see if they are moving back forth too when they produce sounds. Are there any new questions we need to add to the Driving Questions Board or ideas for investigations we want to add to our investigation plan poster to keep track of for next time?"

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Alignment With Standards

Building Toward Target NGSS PE	Building Toward Common Core Standard(s)
• **1-PS4-1:** Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.	**Comprehension and Collaboration:** CCSS.ELA-LITERACY.SL.6.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly. • CCSS.ELA-LITERACY.SL.6.1.B Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed • CCSS.ELA-LITERACY.SL.6.1.C Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

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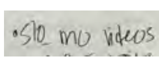
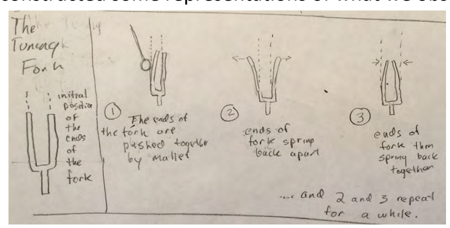
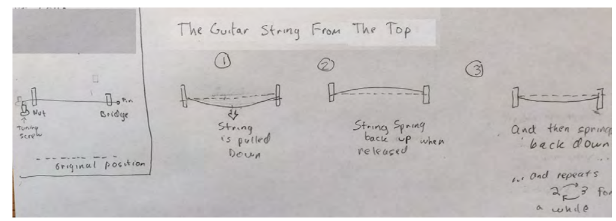
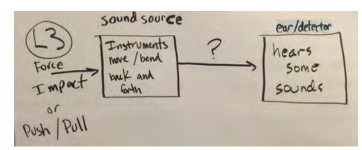
Lesson 3: What are other objects doing when they are making sounds?

Teacher Guide

Middle School Unit: How Can I Hear Different Sounds From Across The Room?

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)*; develop and revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena *in order 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 update 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 want to investigate this controversy and question more next time.**

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Getting Ready: Materials Preparation

Materials For Each Student

- **Lesson 2 - Student Activity Sheets**

For the whole class

- **One of each of these: cymbal or drum and drumstick, guitar or violin, xylophone and mallet, tuning fork**
- **Slow motion videos (included here) and computer with projector.**
- **Poster paper and marker**

Getting Ready: Teacher Preparation

Background Knowledge

.... from the FRAMEWORK:

Alternative Student Conceptions

Linking Our Understanding to Scientific Terminology

- Vibrating
- Vibration
- Deformed - Changed shape
- Springy or Elastic

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Learning Plan: What are other objects doing when they are making sounds?

1.5 Periods:
Day 1: 40 min
Day 2: 20 min

Day 1

1. (5 min) Begin the lesson through a Consensus Building Discussion. Ask students to summarize what we figured out from the previous lesson.

Listen for *student responses*, that summarize the big ideas such as:

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.

Then, ask students to connect yesterday's lesson and what was figured out to the new question we are investigating today- "What are other objects doing when they make sounds?" If there were other questions that were added to the Driving Questions Board, review those as well.

Suggested Prompts:

➔ Can moving the needle back & forth in different ways really be what is making different sounds?
➔ Does a similar thing happen when other objects are making sounds?
➔ What are other objects, like instruments, doing when they are making sounds?

Teacher Supports & Notes

Strategies for this Consensus Building Discussion

A One example of how to start this discussion is as follows: "Even though we came to consensus on how the structure of the grooves were causing the needle to move the way it did, we raised a new question and we came up with some new ways we could investigate that question.

We discussed other things we heard that made sounds and what they did when sounds were made. Many of the things you mentioned were instruments and we were thinking that looking more closely at instruments might be another productive investigation to pursue.

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Remind students that one of their investigations they suggested in lesson 1 or 2 was to look at instruments. A **Point out to students that there are instruments around the room that we can use to today to investigate our questions further.**

Now have students write their predictions down to the first question that is on their activity sheets, "What causes a drum, guitar string, or a xylophone to make a sound?" .

---

2. (5 min.) Have 4 student volunteers come up to make a line at the front of the class. Each volunteer will play one of the instruments (strike or pluck it) for each observer that comes up to it. These volunteers (the musicians) will strike or pluck their instrument lightly so that the rest of the students (in a line) can come by to feel the string, bar or surface of each instrument right after it was struck it.

Instruct students that they will make a single file line to walk from instrument to instrument, to observe what, if anything you can feel when you get your hand very close the the object making the sound immediately after it is plucked or struck.

Demonstrate what you are expecting each student to do before beginning the activity. Start off in the beginning of the line and walk from one musician to another with your hand in front of the instrument, as you expect students to do. This should be quick (take about 10-15 seconds). After the demonstration, ask the students if they understand or have any questions. Answer questions and clarify the activity until all students understand what they are expected to do.

After selecting the four students that will play the instruments, have them come up to their instrument and begin to play. Then have the other students make a single file line to walk by the musicians to quickly take an observation from each instrument by placing their hands in front of the instrument as well as watching the instruments as they are being played. Make sure each student places their tips of their finger very lightly on the surface of the instrument to make

Additional guidance

B Many students will start using the word "vibrating" to describe what the instruments are doing.

Only at the end of the lesson will the class come to consensus that this word means something more than just what we feel. By the end of the lesson, students will start to use the word **vibrating** or **vibration** to describe the way the position & shape of the object is changing over time that can account for what we feel.

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proper observations of what they feel. B

After moving through the line of instruments have students return to their seat to record their observations in Row A of their table on their Student Activity Sheet. Make sure to give an opportunity for the students playing each instrument to observe what happens as the instruments are played as well.

---

2. (5 min.) Immediately begin the next activity after they have written their observations. Inform students that they will observe 4 slow motion videos of similar objects as they are struck or plucked. As they view the videos, they should record their observations in Row B on their Student Activity Sheet after each video. Tell them to be as detailed and accurate as they can when writing their observations. Then, ask each student if they have questions about the activity.

Then, if there are no questions, show the videos. As the videos are playing, be sure to walk around the room to observe what each student records in their Activity Sheet.

---

4. (10 min) After the videos have played and students have recorded their observations on page 2 of their Student Activity Sheets, instruct students to discuss their observations with a partner first and explain to their partners using the prompts on the top of the page 2: C

- How is what you observed with your fingers related to what you observed with your eyes (in slow motion)?
- How is it related to what you heard?

As students are discussing, walk around and monitor discussions.

After sharing with a partner, ask a few students to describe some of the shape changes and motion changes they observed in all the cases. It's important that they begin to connect the

Alternate activities

C Sharing ideas verbally with an elbow partner is the most time efficient way to brainstorm make these comparisons

The space on the top of the Student Activity Sheets is provided as optional support for students who need time to "stop and jot" their ideas down before talking with a partner.

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shape changes in the objects to the sound.

Suggested Prompts:

- ➔ What type of shape changes did we see in the object when it was initially struck or plucked?
- ➔ How did the shape of the object keep changing after the initial force from the strike or pluck was removed?
- ➔ What is similar about the motion of the guitar string and tuning fork?
- ➔ What was different?

Listen for *student responses*, that summarize the big ideas such as:

As the object was struck or plucked it started to change shape and bend
After the initial force (or impact) from the strike or pluck was removed the object started to change shape back (like a trampoline)
In all cases the object didn't directly return to its original shape, it overshot its starting position and changed shape in the other direction.
Then in repeatedly changed shape back and forth around its starting shape/position.
In some cases it bent back and forth in an up and down direction, in other cases it was back and forth in a left and right direction.
In all cases part of the object bent more than other parts; some parts seemed to not move or be tied down (e.g. the ends of the guitar string, edge of the drum face, bottom of the tuning fork).

---

5. (15 min.) Summarize that all of this is what the object is doing when we say we feel these objects vibrating.

Suggested Prompts:

- ➔ "So, we are using the word vibrations to describe what we feel. We also discussed earlier that this is related to th shape changes we observed. Let's put these two observations together to come to a consensus for what we mean when we say an object is vibrating?"

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Listen for *student responses*, that summarize the big ideas such as:

Vibrations can be detected in many different ways (e.g. felt and seen)
Vibrations can be seen as a back and forth motion that repeats for a certain amount of time.

After this discussion, create two models to represent the chain of cause and effect that connects the following ideas:

a) When a force was applied to an object (push or pull) D , it bent (or deformed) the object.

b) The vibrations occurred because of how the object responded to the initial force (the shape changes and it spring back (it is elastic or springy) E and wants to change back to its original shape).

An example of how to lead the discussion is as follows: *"So, earlier we all felt the instruments vibrating as other students played them in class. When we saw the video, we also observed the vibrations of the strings on the guitar and tuning fork. We need to figure out what caused the vibrations. Let's try to draw out a representation of what was happening to these objects over time. What was the first thing we saw happen?"*

Listen for responses. Give each student a chance to give a response and then allow students to analyze each statement for accuracy and to ask questions or to suggest modifications. Then, draw each step the students saw in order as they are telling you what they saw on a poster or a whiteboard in the class. Include a brief description of what is being drawn under each picture. Continue to use questions until all the observations are drawn and labeled. F

Below are two suggested models to co-construct together as a class and leave posted in the room. It is suggested that the class draw one of these models together (e.g. the drum) and after talking conferring with students about each of the representations used in each drawing. Have

Additional Guidance

D Scientifically, a force and push/pull are similar. In some classes, students use the word "impact" (a force applied over a short period of time). So, in models and discussions, use whatever word the students converge on.

You could introduce the word deformed to refer to conditions when the object has "changed shape". But if you do, use the scientific word "deformed" in concert with the phrase "or changed shape" in future discussions to help build familiarity with the idea that both of these are expressing the same idea.

Additional Guidance

E Using a word like elastic or springy will help setup the next lesson - which is motivated by the question of whether all objects are spring/elastic (up to a point). Again use the scientific word "elastic" in concert with the word phrase "or springy" in future discussions to help build familiarity with the idea that both of these are expressing the same idea.

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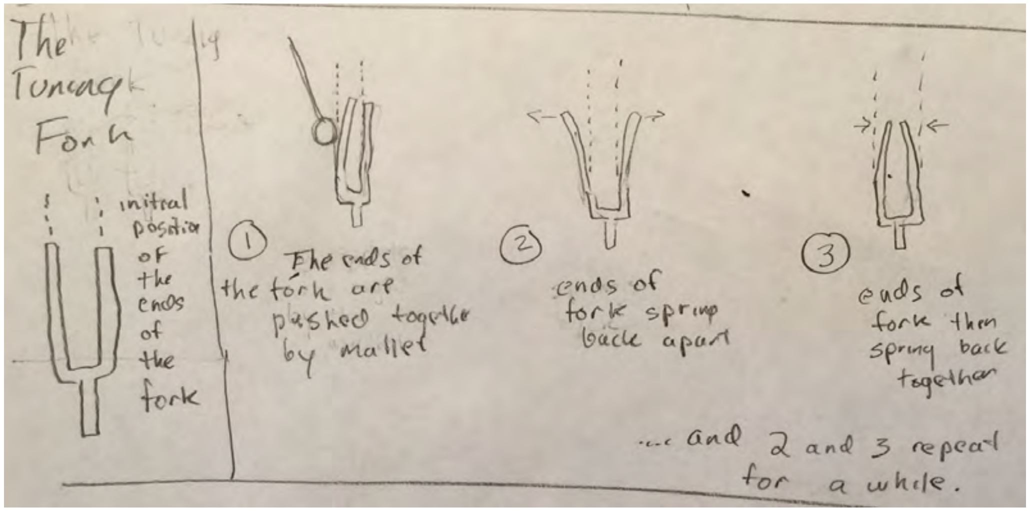
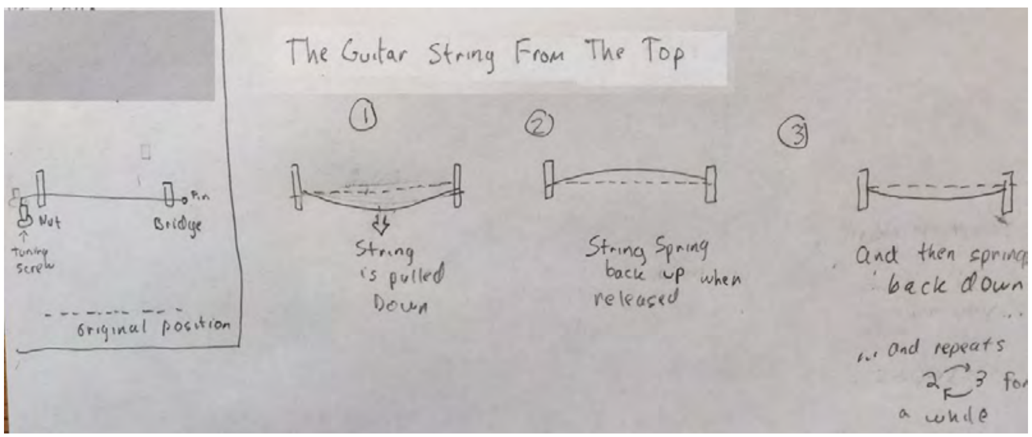
students draw this in their student activity sheets in the Part 1 : Conclusions section





After drawing one together as a class F , have students apply the model to either a different representation or a different instrument. This can be assigned as a Home-Learning assignment

Additional Guidance

F An example of another teacher conducting this part lesson with her students is provided for you as reference.

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which students can draw out in Part 2: Conclusions on their own.

Alternatively, if you think your class needs more practice or a different representation of what they drew out, you could co-construct a written description of what is happening to each object and record that in the part 2 - Conclusions section together the next day. Either way you will follow up on how to model these vibrations occurring in the objects on day 2

Day 2

5. (10 min.) Have a few students share their home-learning assignments (the second model they drew). Alternatively you could ask students to help you summarize in words, what we showed in our model last time, that we think is happening in all the instruments. Here is an example of that:

- **Striking or plucking these objects, applies a force to that object (a push or pull on it).**
- **This force temporarily bends (deforms) the object G.**
- **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 (vibrate) for a while.**

You may want model this ideas using another example for some classes. H.

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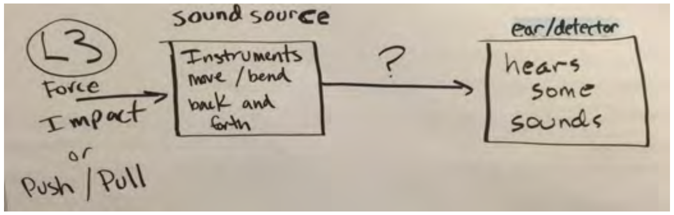
5. (5 min.) As a class update the consensus model in the room for how the sound was made. The model should be similar to the following:



Additional Guidance

G Students may point out that some objects permanently change shape when they are deformed. If they do, you can ask whether the metal tuning fork can also be bent far enough so that it permanently change shape. Students will likely say yes. Use this opportunity to reframe the question, as this: If we know that we can bend objects far enough that they can either be permanently deformed or broken, then our new question is "can all objects be bent at least a small amount (before they are bent far enough to become permanently deformed or break) and then spring back and forth until they return to their original shape.

Additional Guidance

H Some students may need to see something like a wooden ruler to demonstrate these concepts in the following way: 1) Striking or plucking these objects, applies a force to that object (a push or pull on it). Explain to students that when an object is struck or hit, that's a force being applied to it. Then, have one student hold the ruler and instruct another student to hit

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6. (5 min.) Now shift to a Sharing Initial Ideas discussion, to help motivate the to next steps and future investigations. The first goal of this discussion is to think about whether the observations made with the guitar string and tuning fork is also true for other objects that produce sound.

Suggested Prompts:

- ➔ Can forces be applied to other objects to deform them?
- ➔ Do other objects exhibit some elastic behavior after they are bent (they will spring back after they are deformed a small amount)?
- ➔ Do all objects change shape back and forth (vibrate) as they are making sounds?. .

While leading this discussion, use the model to probe students. Point to the sound source ask if we could put anything in place of the word instruments.

Suggested Prompts:

- ➔ Could we put things like a "the table" (when we hit it and it makes a sound) in place of "instruments" there in the model? Or the floor?
- ➔ Do those things vibrate back and forth, bending and changing shape as they produce sounds?

Accept all *student responses*, as it is controversy and differences in these predictions that motivates the next lesson

Some students will claim that more solid objects like the table, walls or floors do not vibrate when they make a sound, because they don't bend, not even a little.
Other students will claim that it may bend and vibrate just a bit.

If time permits, have students complete the "Next Steps" section of their Student Activity Sheets. If time is short, pose the last question in the suggested prompts above to students and have them talk with an

it. 2) This force temporarily bends (deforms) the object. After the ruler is hit, point out to students that the ruler's initial shape was deformed. It was straight but the force made it somewhat "curved or bent". 3) When the force is removed, the springiness of the object (its elasticity) causes it to try to return to its original shape. As the ruler is moving back and forth, point out that the ruler is springing trying to go back to its original shape- straight. 4) And this leads it to repeatedly bend back and forth (vibrate) for a while. When the ruler stops moving, point out that after it stops moving, it's straight again. 5) Then, connect the springing to the vibrations we felt in the instruments. The vibrations occurred when the instrument was hit and was attempting to go back to its original shape.

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elbow partner for 30 seconds. Tell them you will post the question on the driving question board (and refer to it at the start of the next lesson): "Do all objects vibrate back and forth when they are making sounds?"

Alignment With Standards

Building Toward Target NGSS PE

- **1-PS4-1:** Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.

Building Toward Common Core Standard(s)

Comprehension and Collaboration: CCSS.ELA-LITERACY.SL.6.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- CCSS.ELA-LITERACY.SL.6.1.B Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed
- CCSS.ELA-LITERACY.SL.6.1.C Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

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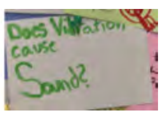
Lesson 4: Do all objects vibrate when they are making sounds?

Teacher Guide

Middle School Unit: How Can I Hear Different Sounds From Across The Room?

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? <u>1 period:</u> 40 min.  *Building toward* ⬇ *<u>NGSS PEs:</u>* *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 "do all objects* vibrate (cause) back and forth *when they are* making sound (effect)?" *by* providing and receiving 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 want 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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Getting Ready: Materials Preparation

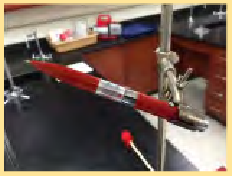
Materials For Each Student

- **Lesson 4 - Student Activity Sheets (1)**

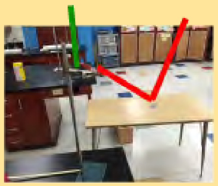
Materials for the whole class

- **A drum**
- **pen laser (1)**
- **clothes pin (1)**
- **A lab stand and clamp (1)**
- **Plastic mirror (2)**
- **1 rock that fits in the palm of your hand (about 2-3 inches across)**
- **2 pieces of 1 mm. Graph paper and tape**

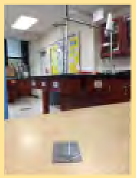
Setting Up the Apparatus (15 min.)



Step 1: Mount a laser pen light onto a lab station clamp. The clamp is holding the "on" button down so the laser light is shinning out of the left side (back end) of the pen. You can also use a clothes pin to hold down the on switch.



Step 2: Point the laser so that it hits a spot in the middle of the table. Then slide a small plastic mirror onto that spot on the table. This will cause the laser light (which is outlined by the graphic red line on the left to reflect off the table onto a wall or ceiling)



Step 3: To check that the laser is hitting the mirror, move to where you can see a red dot on t he mirror surface. Or place a piece of white paper over the mirror to help find where the red dot is hitting.

Also place a small plastic mirror on the surface of the drum.

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Getting Ready: Teacher Preparation

Background Knowledge

Linking Our Understanding to Scientific Terminology

- Elastic
- Deforms

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Learning Plan: Do all objects vibrate back and forth when they are making sounds? (40 min)

1. (5-7min) Introduction to the lesson

Start off the lesson by asking students what question we left thinking about investigating next in at the end of the last lesson.

Listen for *student responses* such as:

"Do all objects vibrate back and forth when they are making sounds?"

Have students write this question on their Student Activity Sheet and record their prediction. Then have students share out their predictions to re-elicit the area of controversy that is motivating the need for this next investigation. A

Summarize the discussion around the ideas that since we are still not all in agreement on this question, we will need to collect some additional evidence to figure this out.

---

2. (5 min) Tell students that you brought in a device that might help us detect vibrations.

Have students come up to the setup of the laser, mirror, table, drum and graph paper. Then, show the students where the laser is pointed (at the mirror on the surface of the drum). After this, place a piece of paper over the mirror so students can see that the light travels to the mirror. Then, remove the paper and point to where the dot of light appears on the wall.

Inform students that you are going to strike the drum with a mallet in a moment, Have them predict what they wil see the laser dot do, based on what they know happens to the shape of the drum when you strike it and share their predictions with their partner.

Teacher Supports & Notes

Additional Guidance

A An example of a teacher having this conversation with her class is shown in L4 - Sample discussion video.

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Turn off the lights and strike the drum softly. Then, have students record what they observed the laser dot doing as the drum is struck. B

Then, strike the drum harder and have students record what they observe. Repeat if necessary. C

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2. (5 min) Next ask students how this setup could help us figure out if something like the table is vibrating when it makes a sound. Have them discuss this with a partner.

Have students predict what we will see the laser dot do if the table doesn't vibrate vs. if the table does vibrate, when we drop a small rock onto it so that it makes a sound. Give 1 minute for this elbow partner talk.

Discuss this prediction as a class for a minute or two. Again there is likely to be some controversy as to whether bigger, stiffer objects actually bend or not when they are struck by relatively small, low mass objects. D

Then adjust the laser during this discussion, so it is directed at the mirror placed in the middle of a student table. Have students finalize their predictions about what they will observe the laser dot do if the table vibrates vs. if it doesn't vibrate.

Next drop the rock and have students record their results. Repeat if necessary. E

Ask students to predict what will happen if a larger rock was dropped on the table. Remind them that a larger rock will exert a bigger force on the table due to the difference in its mass. Give them a few minutes to discuss this. Then, drop the larger rock and have students record their observations.

Then, have students return to their seats and complete the "Making Sense" question on their Student Activity Sheet.

Additional Guidance

B Students should observe that the position of the dot moved a lot, very quickly. Some students may even see that the dot moves both higher and lower on the wall than in its initial resting position during the time the drum made a sound.

You can tape a piece of paper on the wall to where the dot is projected at first, and ask a student to mark the initial position of the dot as well as the highest and lowest position that the "laser blur" makes on the paper.

C If you repeat the paper marking measurement from above, use a new sheet of paper taped to the wall. Then you can compare both papers to see what is different between both results.

Additional Guidance

D Many students don't think that materials like rocks or large tables can bend. Other students may claim that it might be bending, but just such a small amount that we can't see it. This is an opportunity to point out that we are arguing about an

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3. (5 min) Switch to a for Pressing for Understanding discussion to make sure the class agrees on the claims we can make related to the original question that motivated this lesson, and the evidence we have for those claims.

Suggested Prompts:

- ➔ What claims did you make in the making sense section?
- ➔ What evidence do we have to support the claim that vibrating objects make sound?
- ➔ What evidence do we have that the objects that are vibrating are moving or bending back and forth?
- ➔ How did the blur change when the object was struck harder?
- ➔ How did the blur change when a louder noise was made?

Listen for *student responses* such as:

Everything must vibrate when it makes a sound, because even the table (something we thought was hard) gave evidence of vibrating.
When we struck a drum, with a laser beam (dot) bouncing off of a mirror on it, the dot that showed up on the wall/ceiling moved and shook above and below the point which it started.
When we dropped a rock onto the table with a laser beam (dot) bouncing off of a mirror on it, the dot that showed up on the wall/ceiling moved and shook above and below the point which it started.
The harder we struck either surface, the louder the sound and more the dot shakes back & forth (distance & duration).

---

3. (15 min) Switch to a consensus building discussion. The goal of this discussion is to have students connect the concepts of larger forces producing larger vibrations and smaller forces producing smaller vibrations. You also want to connect the sounds begin made to the type of vibration; loud sounds produce larger vibrations and quieter sounds produce smaller

important idea in science related to whether what is happening is at **scale** that is too small or too fast to see.

Additional Guidance

E Students should see a similar result in the position of the laser dot as before, but its duration and spread in the blur will be much shorter. This provides us evidence that even the table is vibrating when it makes a sound.

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vibrations.

Have students keep track of the discoveries you write together as a class in their "Conclusion Section" on their Student Activity Sheet and keep a poster of these discoveries in the class. The conclusion of this discussion should result in the following findings:

- **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)**

Then, continue the discussion to help kids connect these principles learned from the investigation to the anchoring phenomena with the record making noises as the needle scratched it. Ask them "How do the interaction between the needle and the record produce sounds?"

When this discussion is complete, students should have a full cause and effect relationship that explains why the record made noises as the needle scratched it. You may use the following questions to guide this discussion:

Suggested Prompts:

- ➔ What is the sound source?
- ➔ What objects are interacting with each other to produce sounds?
- ➔ Are these objects elastic and springy?
- ➔ What is pushing the needle back and forth or bending it back and forth as the record spins?
- ➔ How does each push from the wavy grooves in the record cause the needle to vibrate?

At the end of this discussion, students should arrive at the following explanation of the cause and effect relationship of the needle scratching the record to make noises. Have students record this outline of an explanation that you co-construct together in the Conclusions section of their

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activity sheets:

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.**

---

4. (3 min.) As time permits, help students brainstorm new questions that arise from our explanation that we want to investigate in our next lessons. If time is short, assign these questions as home-learning.

Suggested Prompts:

➔ Was the difference in the pattern in the groves somehow responsible for all the different sounds we heard? Explain.

➔ What might be different about the vibrations of all these other objects we observed (guitar strings, tuning forks, xylophones, drums, tables), that caused them to produce different sounds?

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Alignment With Standards

Building Toward Target NGSS PE

- **1-PS4-1:** Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.

Building Toward Common Core Standard(s)

Comprehension and Collaboration: CCSS.ELA-LITERACY.SL.6.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- CCSS.ELA-LITERACY.SL.6.1.B Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed
- CCSS.ELA-LITERACY.SL.6.1.C Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

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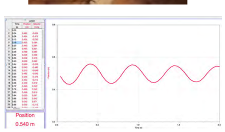
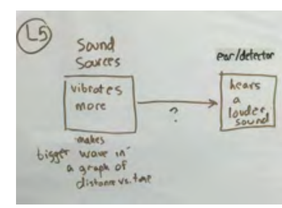
Lesson 5: How do the vibrations of the sound source compare for louder vs. softer sounds?

Middle School Unit: How Can I Hear So Many DIfferent Sounds From Across The Room?

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  *Building toward* *NGSS PEs:* *1-PS4-1,* *4-PS4-1* *MS-PS4-1*	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.  	**Analyze data** from a motion detector to determine what is changing and what is stable between two graphs showing the distance of the end of a vibrating object from a detector vs. time for two different conditions (a hard strike and soft strike). **Use mathematical thinking** to identify patterns in repeating features using the y-values on the graph (e.g distance between a peak and valley) and x-values on the graph (e.g. time between a peak and a valley). 	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.**

Getting Ready: Materials Preparation (Total prep. Time is 45 min)

Materials For Each Student

- **Lesson 5 - Student Activity Sheets**

Materials for each group

- **Music boxes (amazon sells music boxes for under $5, from Kirkland)**

Gather materials for the whole class (15 min)

- **A 4.5 ft. piece of 1/4 in. x 1-3/8 in pine trim work (homedepot link here) and a 3.5 ft. piece of the same trim work for the next lesson. This thin trim work vibrates at a low enough frequency for the motion detector to detect it. This will become the yardsticks that students will first experiment with that you will then clamp to the table and measure with the Vernier motion detector. Yardstick are a bit too thick and therefore vibrate a bit too fast to use for the motion detection.**
- **A c-clamp or spring clamp**
- **A computer with LoggerLite installed and configured (see additional directions below)**
- **A Vernier motion detector**
- **A ruler.**
- **A guitar or other stringed instrument**
- **A xylophone and mallet**

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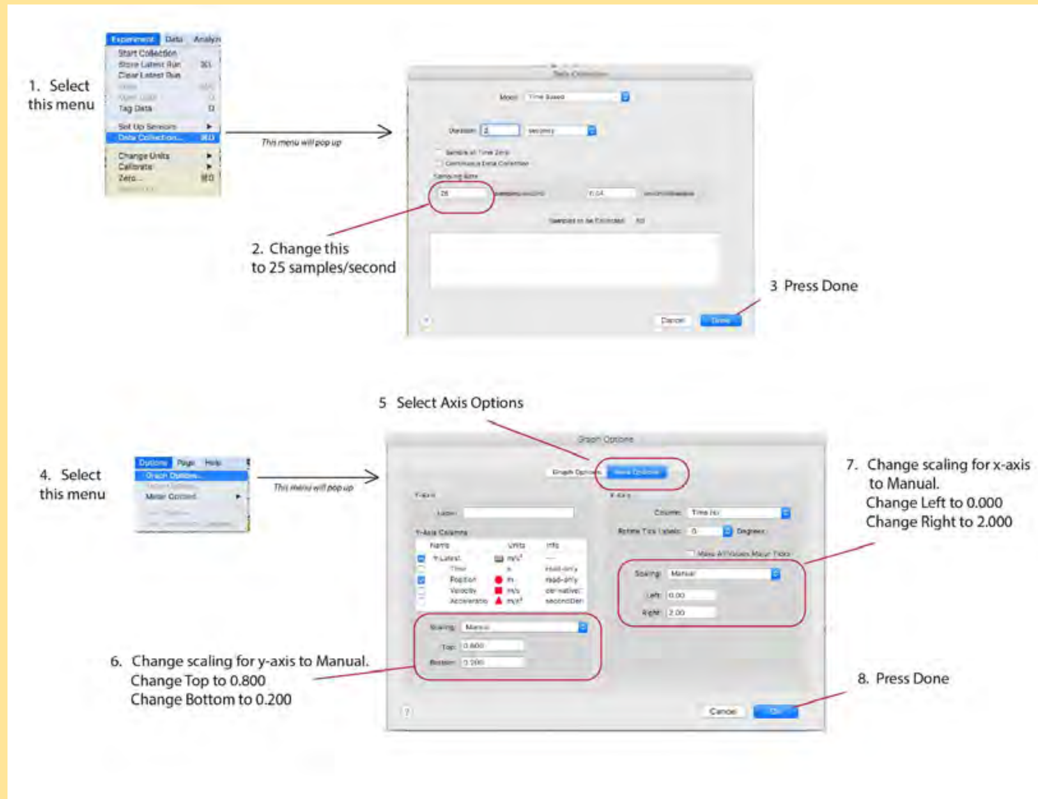
Getting Ready: Software Preparation

Downloading, Installing, and Configuring the Software (10 min.): If you quit the program and restart it or restart you computer, you will need to repeat this process

- **Download and install LoggerLite (http://www.vernier.com/downloads/)**
- **Plug in the vernier motion detector to your computer using the USB cable provided**
- **Open LoggerLite software on your computer.**
- **The following the directions to the right to configure the graph settings.**



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Getting Ready: Setting up the detector & clamp & stick (15 min.)

1. Clamp the stick to a vertical flat surface so that it sticks out like a train crossing gate when it is lowered.

2. Set the detector on a surface so that the circular sensor is facing a spot near the end of the stick, but not the very end of it. The detector should be at a distance of 50 cm from the stick. The detector should be at the same height as the end of the stick AND at a 90 degree angle to the end of the stick

This is the circular sensor

Another option is to clamp the stick to a horizontal flat surface so that it sticks out like a diving board. If you do this option, then place the detector near the end of the board, (but not at the very end) so that it is half of meter (50 cm) away from the end of the board and pointed up toward the board. Only do this option if the one above doesn't work, as the one above is a more useful bridge to visualizing an idea that students will develop in later lessons (compression waves traveling through the medium).

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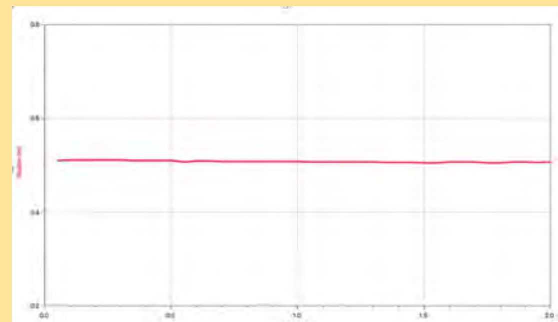
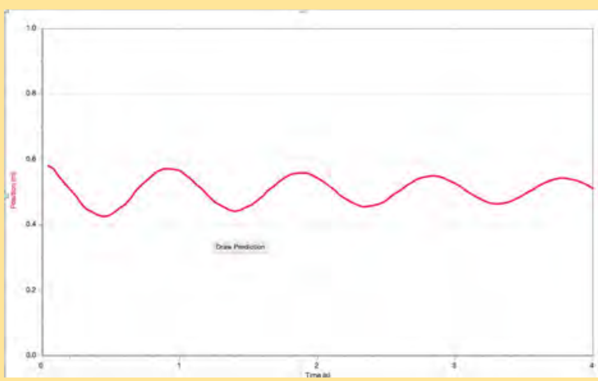
Getting Ready: Testing the Whole Setup

Testing the setup (15 min.):

- **Now that you setup the software and the detector, the stick and clamp as shown on the previous pages, test the entire by doing the following:**
    - **Press the collect button in the Logger Lite Software -------------**



    - **You should see a graph like this produced. It should be a flat line, at a constant y-value of 0.5 meters. The axis should have the values shown here:**
    - **Give the end of the stick a small pluck (deform it about 5 cm), release it, and press the collect button again.**
    - **A graph similar to this should appear:**



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

Getting Ready: Teacher Preparation

Background Knowledge

Alternative Student Conceptions

Students are likely to make prediction that the stick will go up and down. But most students will predict that the shape of the graph will be a series of up and down straight lines (saw tooth) rather than sinusoidal. This makes sense from the students perspective, because there is nothing in the phenomena up to this point that suggestions that the vibrations will produce curved lines in the distance vs. time graphs. Remember that middle school students in are mostly exploring linear relationships. Non-linear relationships and graphs aren't the focus of the Common Core until 8th grade.

Make sure students see how the motion detector works and what it is keeping track of by having a volunteer move around in front of the detector and collect data on the graph.

Ask them what is being graphed and what each axis represents before having them make prediction on their student activity sheets for the stick.

Students may ask why the vibrating stick doesn't make a sound. If they raise this idea have them write down the two questions, "Why doesn't the vibrating stick make a sound we can hear?" and "If we know that all sounds, come from sound sources that are vibrating, does that mean that everything that vibrates produces sound?"

Linking Our Understanding to Scientific Terminology

- Wave
- X-axis (or horizontal axis)
- Y-axis (or vertical axis)
- Distance
- Peak
- Valley
- Frequency (optional - it recommended to introduce this in the next lesson)

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Learning Plan: How do the vibrations of the sound source compare for louder vs. softer sounds? (45 min)

1. (7 min.) Ask students to summarize the type of shape changes we observed in the instruments when they were vibrating from last time.

Tell students that in order study these sorts of shape changes more closely, you brought in a much larger object that we can make vibrate. Show students the meter stick you will be using for this demonstration. Ask students if this object also would change shape in a way similar to the guitar string and tuning fork.

Demonstrate [A] what happens to a meter stick, when it spans between two tables or books and you push down on the middle of it and release. Do the same for when you clamp one end of the meter stick down to the table and lightly pull the end down and release.

Have students complete the questions in the "Planning Our Investigation" section of their activity sheets. Once completed have students share out their ideas.

Suggested Prompts:

- ➔ Describe some of the ways that the behavior of the long wooden stick is similar to a guitar string or tuning fork when you push or pull on it and release it?
- ➔ What are some advantages to investigating vibrations in a larger scale [B] object than a tuning fork?

Listen for *student responses* that refer to the following:

It vibrates (changes shape back and forth), which the wooden stick and guitar string (and table

Teacher Supports & Notes

Additional Guidance

[A] Alternatively you can pass out a meter stick to groups and have students show what type of shape changes they think the table experiences after being struck, and then vibrating.

Additional Guidance

[B] Here is an opportunity to again emphasize the cross cutting concept of **scale**. You can make connections to the idea that scientists often develop scale down or scaled up system of things that they want to study that are too small or too large to study first hand. And they do the same with things that are happening too quickly or too slowly, but then they try to figure out a way to slow it down or speed it up in a different system.

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and everything) does when it makes sound.
The vibrations in a large scale object might be easier to observe and see.

(Re)emphasize that scaling stuff up could be useful for the reasons that the students shared and say that when scientists study things that happen too quickly, or too slowly, or that are too small, or too large to study first hand, they try to think of devices they can build that help them observe the same processes on a different size or time scale (sped up, slowed down, zoomed in, blown up, shrunk down)

---

2. (8 min.) Have students bring their activity sheets up to gather around the motion dectorfor a demonstration. Demonstrate how the range finder works by having someone holding a book a stand about 0.5 meters from the end of it. Tell students that the probe measures the distance between it and the nearest object in front of it. Have them slowly walk away from the range finder when you say go. Have another student press the play button on Logger Lite.

Students should see the graph change.

Suggested Prompts:
- ➔ Why does the graph have the shape it does?
- ➔ What does the y-axis (or vertical axis) represent?
- ➔ What units is the y-axis in?
- ➔ What does the x-axis (or horizontal axis) represent?
- ➔ What units is the x-axis in?

Listen for *student responses* that refer to the following:

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It goes up because that shows you are getting further away from the detector.
The y-axis represents the distance the object is from the from the detector.
The y-axis is in meters.
The x-axis represents the time since the detector was started.
The x-axis is in seconds.

Now ask another student to demonstrate what happens if they move even more slowly, but this time they move toward the range finder. Again have another student press the play button on Logger Lite.

Suggested Prompts:

- ➔ Why does the graph have the shape it does?
- ➔ Why isn't the graph as steep as before?

Listen for *student responses* that refer to the following:

It goes down because that shows you are getting closer to the detector.
It isn't as steep as before because you are moving more slowly.

Have students record what they noticed in the procedure section on page 1 of their activity sheets.

Next place two pieces of tape at 0.5 meters apart on the top of a table. Place the probe at one one tape location, pointing the detector at the other tape location. Now line up the end of the large wooden stick so that it is above the 2nd piece of tape and a flat face of it is directly facing the range finder detector. Tighten the clamp down for the base of the stick so that it doesn't move when you push it. Show students this setup. Tell them that the end of the wooden stick is 0.5 meters from the the end of the detector.

Ask students what they predict the shape of the graph would be, if the we press the record button, but the object doesn't move.

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Suggested Prompts:

➔ What will the shape of the graph look like for this stationary object?

Listen for *student responses* that refer to the following:

It should be a straight horizontal line.

C **Press the play button on Logger Lite to confirm their predictions. Have students record what they noticed in the procedure section on page 1 of their activity sheets.**

Then have students turn to the next page of the activity sheet.

Tell them that, "In condition 1 we are going to strike the wooden rod softly with a mallet. And in condition 2 we are going to strike the wooden rod harder, in order to simulate what happens when a sound source makes a louder sound."

Have students label the titles for both predicted graphs on page two of their student activity sheets and have them sketch their predicted shape of their graphs. D

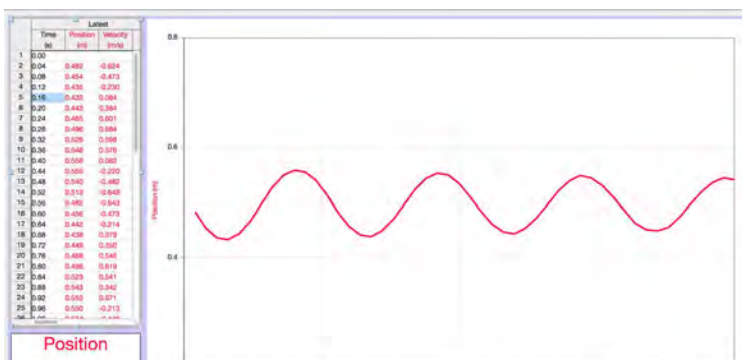
---

3. (5 min.) Ask for a student volunteer to press play on a new experiment, right after you strike the wooden rod lightly with a mallet.

Your goal with this strike is to get the rod to deform about 5 to 8 cm with the strike.

Keep the graph projected on the screen. Have students record their observations on their activity sheet.

Take a screenshot of this graph (cmd +



Additional Guidance

C For this part of the setup and the later parts, make sure no one's body is behind the wooden stick. The detector might detect that person's body if they are in line with the detector.

And when you strike or pluck the stick later, again make sure you aren't in line with the detector. Strike it with a mallet from the side, so that the position of your body doesn't interfere with the detector readings.

Additional Guidance

D At this may be easier for some students to sit in a chair while drawing the predicted shape of their graphs.

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shift + 3) to save to your desktop to display later (in the Conclusion section and in the next lesson).

Remind students that you are going to simulate a sound source that we strike or pluck to make a louder sound.

Again ask for a student volunteer to press play on a new experiment, right after you strike it. Your goal is to get the rod to deform about twice as far as before (e.g. around 15 cm).

Keep the graph projected on the screen and have students record their observations.

Take a screenshot of this graph (cmd + shift + 3) to save to your desktop to display later.

---

4. (5 min.) Drag both images into a word file so they are stacked one above the other. E **Zoom out so that both graphs can be seen at the same time.**

Ask students to summarize the patterns they notice between both graphs in their making sense section of their activity sheets.

Walk around to check student responses. Look for responses that hit on the major points to pull out of the discussion in the conclusion section below. Call on these pre-selected students to share out their responses for the next section.

---

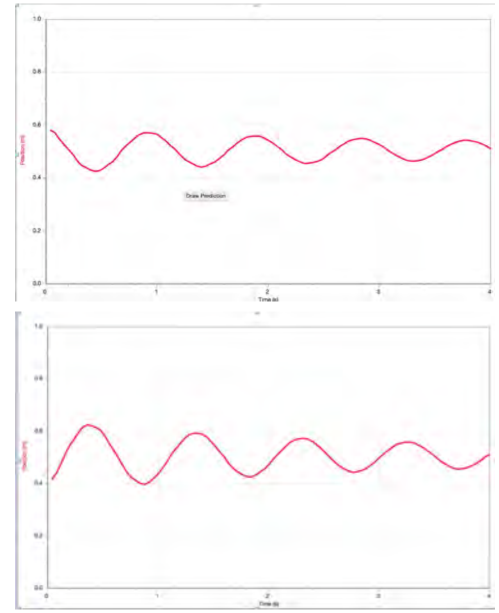
5. (15 min.) Have a consensus building discussion around these features in the graphs. Make a public record of these ideas and have students record them or a sketch of them as well in the conclusion section of the their activity sheets.

<u>**Suggested Prompts:**</u>

➔ What did your class decide where some important features in these patterns?

Additional Guidance

E An example of this is shown here:



Additional Guidance

F Students may ask why the vibrating stick doesn't make a sound. If they raise this idea have them write down the two questions, "Why doesn't the vibrating stick make a sound we can hear?" and "If we know that all sounds, come from sound

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Listen for *student responses* that refer to the following: F

There is a s-shape or wave shaped pattern in both graphs. G
The pattern repeats.
The spacing between the high and low points gets smaller as time goes on. G
There are high points and low points in both graphs. H
The spacing between the high and low points was less in the graph that we pulled back the stick less.
The spacing between the high and low points gets smaller as time goes on.
The time between a high and low point appears to be the same in each graph and between graphs. H
The time between two high points appears to be the same in each graph and between graphs. H

Have students complete the two conclusion questions together as a class. Talk through the first question together:

Suggested Prompts:

➔ How does what we see in the graphs, help us answer our original question, "How do the vibrations of the sound source compare for different sounds?"

Listen for *student responses* that refer to the following:

The distance between peak and the valley of the vibrations from the sound source would decrease as the sound gets quieter.
The number of vibrations are the same in the same amount of time, even as the volume of the sound changes.

Sketch and write a version of this idea on a poster to keep in the room. Have students record the

sources that are vibrating, does that mean that everything that vibrates produces sound?" and add them to the driving question board.

Emphasize that we had other questions on the driving question board related to why we sometimes don't hear sounds, or why some people or animals can hear some sounds that others can't., and that we should make sure to follow-up on these questions in future lessons

In later lessons students will discover that the human ear can't hear sounds produced by objects vibrating at frequency of less than 20 vibrations per second. The board will be vibrating at a frequency much slower than this (about 2 to 5 vibrations per second)

Additional Guidance

G Help the class articulate what they mean if they say it is wave shaped:

- What do you mean it is shape wave?
- How many waves?
- Where does one wave start and another stop?

Additional Guidance

H Ask students to describe what part of the spacing they are referring to, the

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same in their student activity sheets.

Summarize that even though we know how to describe the difference in vibrations for sounds of different loudness, we know there are other ways that sounds can differ. Prompt students for what other ways that sounds differ.

Suggested Prompts:
- ➔ Besides loudness, how else do sounds differ?
- ➔ What other ways can we describe the difference between two sounds from a musical instrument?
- ➔ What should we investigate next about this related to vibrations?
- ➔ What would the shape of the graph look like if we make a different pitch sound?
- ➔ How could we do that?

Listen for *student responses* that refer to the following: J

Sounds can be different notes or pitches
We should investigate how the vibrations of sounds from sound sources producing different notes compare.

Suggested Prompts:
- ➔ What would the shape of the graph look like if we make a different pitch sound?
- ➔ How could we do that?

Have students show some predictions on the board and listen for *student responses* that refer to the following:

Accept all responses

Have students record ideas for how we might go about investigating these predictions next time, in their student activity sheets.

vertical spacing (distance) or the horizontal space (time).

Ask students to point to these parts of the graph. Students are likely to refer to the high and low points in both graphs. Suggest that we call these **peaks** and **valleys,** so we have a common way to refer to this feature.

This will help us see that there is a repeating pattern from one peak to the next or from one valley to the next. Use this to have student show how we can count how many times that pattern repeats (or how many waves are visible across the duration of the graph)

Encourage students to calculate the differences between y-values from peak to valley or differences between values from one peak to another. Student should see that the time between peaks doesn't appear to be changing, only the distance or vertical elevation between a peak and a valley seems to be shrinking. You can connect this to what students observed in the laser demo too, where the blur of the laser spread over less space as the volume of the sound dies out.

Optional: You can introduce the idea of frequency in this lesson or wait until the next one (recommended), by saying it appears that the vibrations are being produced just as often in both graphs (the same number of vibrations in the same amount of time). When vibrations are

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Assign students the Lesson 5 - Home learning at the end of this lesson or the end of the next lesson. To motivate this assignment, ask students how many of the students heard a ticking sound when the motion detector was recording data. Tell students that each tick they heard was the motion detector recording a sample, and that tonight they will learn more about how the motion detector does that.

occurring just as often or just as frequently in two sound sources, scientists refer to this feature as the **frequency** of the vibrations.

Additional Guidance

J Your goal is to help students articulate that differences in pitch/note as another productive difference in sound to investigate time. And to help them start thinking about whether there might be something different about nature of the vibrations at the sound source when there is something different about the pitch/note.

If students don't raise this idea, look back at questions from the driving question board or from pattern chart from the initial anchoring event (lesson 1) and point out the most closely related noticing or wondering and use that as a reference point to motivate that as a potentially useful direction to head in the next lesson.

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Alignment With Standards

Building Toward
Target NGSS PE

- **1-PS4-1:** Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.
- **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.
- **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.

Building Toward
Common Core Standard(s) ELA

Comprehension and Collaboration:
CCSS.ELA-LITERACY.SL.6.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- CCSS.ELA-LITERACY.SL.6.1.B Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed
- CCSS.ELA-LITERACY.SL.6.1.C Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

Building Toward
Common Core Standard(s) CCSS.MATH

- **Leveraging this standard:** CCSS.MATH.CONTENT.5.G.A.2: Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation.
- **Building toward this standard:** CCSS.MATH.CONTENT.8.F.B.5 Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). Sketch a graph that exhibits the qualitative features of a function that has been described verbally.

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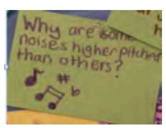
Lesson 6: How do the vibrations of the sound source compare for higher vs. lower pitch notes?

Teacher Guide

Middle School Unit: How Can I Hear So Many DIfferent Sounds From Across The Room?

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? 1.5 periods (60 min. total)  *Building toward* *NGSS PEs:* *1-PS4-1,* *4-PS4-1* *MS-PS4-1*	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* 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) compare for* different pitch sounds.	 Last time we were wondering, *what would the shape of the graph look like if we make a different pitch sound?* So we first brainstormed ways to investigate vibrations by making different pitches, which included Ideas for using different instruments that have parts that play different notes as sound sources that could make different pitches. We observed three different musical instruments playing different notes (a guitar, xylophone, and, music boxes) and noticed patterns: ● 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 and detector to investigate what is happening at the sound source when higher or lower notes are produced. We have to simply cut the length of the stick to make a shorter "tine" (which was what was making a higher pitched note) and compare its vibrations to those made when it was a longer tine (a lower note). We prepared to cut about ⅓ of the length of wooden rod off and got ready to collect some more data after we made some predictions to our original question, *what would the shape of the graph look like if we make a different pitch sound?* We had lots of different ideas. We 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)

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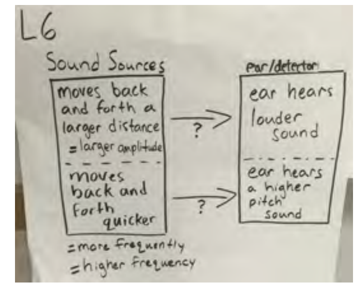
		Develop a model: Modify our consensus model—based on evidence – to match what happens if a variable or component of a system is changed, showing *how causing a sound source to vibrate with greater amplitude produces a louder sound (effect), and how causing a sound source to vibrate at an increased frequency produces a higher pitch sound (effect*	This led us to realize we needed a way to refer to all these features we are seeing across all the graphs: ● We decided we needed a way to refer to the distance between a high point and the next low point. 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. 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) We applied our mathematical model to the graphs of the wooden rod 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 recap what we know so far and update our model. 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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Getting Ready: Materials Preparation (Total prep. Time is 45 min)

Materials For Each Student	Materials for each group	Gather materials for the whole class (15 min)
• **Lesson 5 - Student Activity Sheets**	• **Music boxes (amazon sells music boxes for under $5, from Kirkland)**	• **A 4.5 ft. piece of 1/4 in. x 1-3/8 in pine trim work (homedepot link here) and a 3.5 ft. piece of the same trim work for the next lesson. This thin trim work vibrates at a low enough frequency for the motion detector to detect it. This will become the yardsticks that students will first experiment with that you will then clamp to the table and measure with the Vernier motion detector. Yardstick are a bit too thick and therefore vibrate a bit too fast to use for the motion detection.** • **A c-clamp or spring clamp** • **A computer with LoggerLite installed and configured (see additional directions below)** • **A Vernier motion detector** • **A ruler.** • **A guitar or other stringed instrument** • **A xylophone and mallet**

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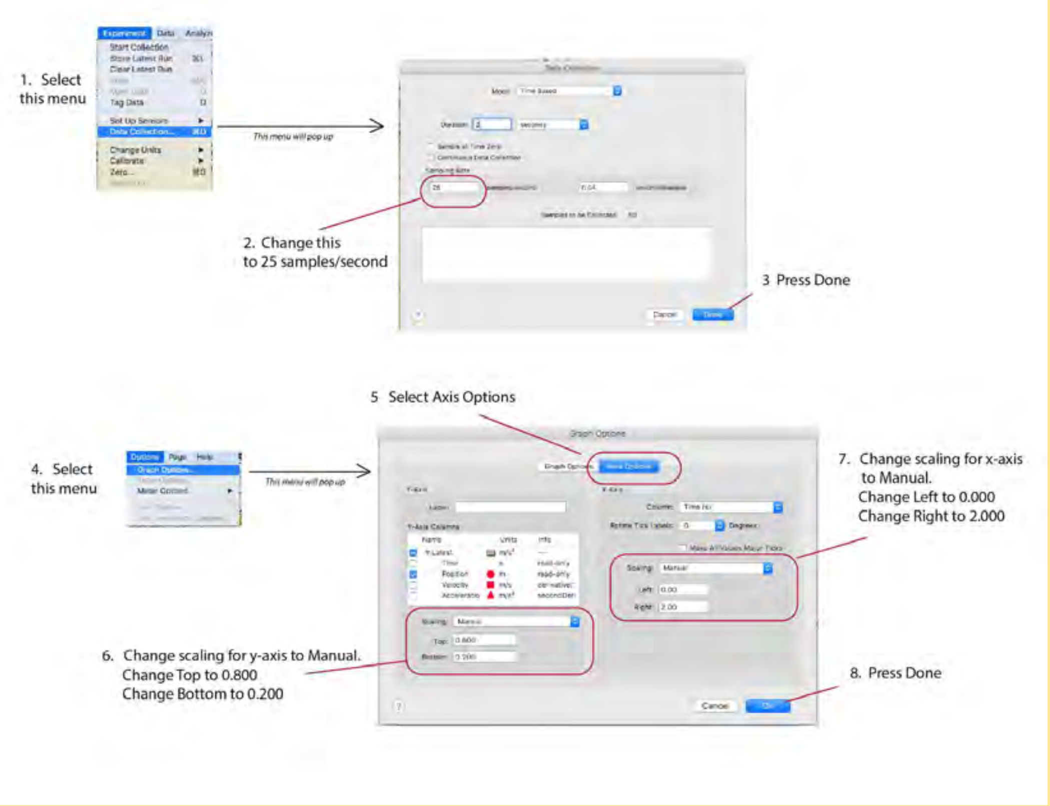
Getting Ready: Software Preparation

Downloading, Installing, and Configuring the Software (10 min.): If you quit the program and restart it or restart you computer, you will need to repeat this process

- **Download and install LoggerLite (http://www.vernier.com/downloads/)**
- **Plug in the vernier motion detector to your computer using the USB cable provided**
- **Open LoggerLite software on your computer.**
- **The following the directions to the right to configure the graph settings.**



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Getting Ready: Setting up the detector & clamp & stick (15 min.)

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1. Clamp the stick to a vertical flat surface so that it sticks out like a train crossing gate when it is lowered.

2. Set the detector on a surface so that the circular sensor is facing a spot near the end of the stick, but not the very end of it. The detector should be at a distance of 50 cm from the stick. The detector should be at the same height as the end of the stick AND at a 90 degree angle to the end of the stick

This is the circular sensor

Another option is to clamp the stick to a horizontal flat surface so that it sticks out like a diving board. If you do this option, then place the detector near the end of the board, (but not at the very end) so that it is half of meter (50 cm) away from the end of the board and pointed up toward the board. Only do this option if the one above doesn't work, as the one above is a more useful bridge to visualizing an idea that students will develop in later lessons (compression waves traveling through the medium).

Getting Ready: Testing the Whole Setup

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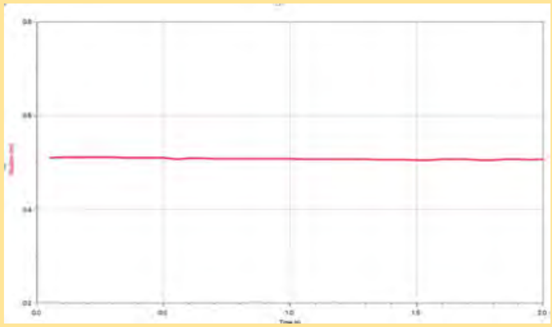
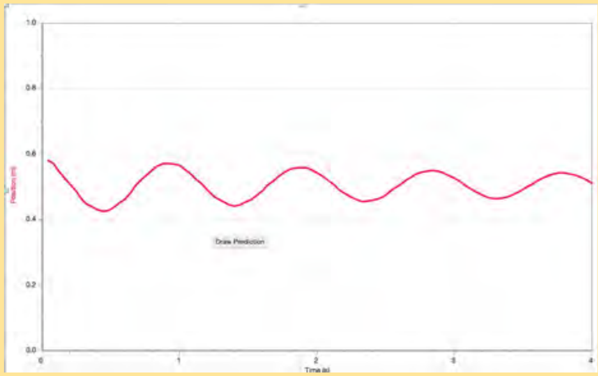
Testing the setup (15 min.):

- **Now that you setup the software and the detector, the stick and clamp as shown on the previous pages, test the entire by doing the following:**
  - **Press the collect button in the Logger Lite Software -------------**

  - **You should see a graph like this produced. It should be a flat line, at a constant y-value of 0.5 meters. The axis should have the values shown here:**



  - **Give the end of the stick a small pluck (deform it about 5 cm), release it, and press the collect button again.**
  - **A graph similar to this should appear:**



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Getting Ready: Teacher Preparation

Background Knowledge

Alternative Student Conceptions

Now that students have seen the curved shape of the graph produced in the previous lesson, they are likely to draw curved graphs in their predictions here.

But for many students they will be drawing predictions in lesson 6 showing the amplitude of the graph changing for a high versus low pitch note. Few students will predict the frequency of the graph to change.

Linking Our Understanding to Scientific Terminology

- Wave
- X-axis (or horizontal axis)
- Y-axis (or vertical axis)
- Distance
- Peak
- Valley
- Frequency
- Amplitude

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Learning Plan: How do the vibrations of the sound source compare for higher vs. lower pitch notes?

1.5 periods (60 min)

1. (10 min.) Ask students to summarize what our question was that we wanted to investigate last time. Have students brainstorm some musical instruments that we could use to help us investigate this question.

Ask students to make observations about 3 instruments, two of which you will demonstrate, and 1 of which they will manipulate. Emphasize that you want them to pay attention to anything they notice about the structure of the instruments as you play different notes. A

Demonstrate plucking a guitar or violin string (Device A), and press your finger down on the string to shorten the length of the part of the string that is vibrating each time you pluck it. Then reverse this pattern. Have students record the name of the musical instrument and what they observed in their student activity sheets.

Demonstrate striking different bars on xylophone. Work you way up and down the scale. Have student record the name of the musical instrument and what they observed. B

Lastly tell students that you are going to pass around a music box, for each small group to investigate. Tell students that they have to crank the handle in one direction for it to work, and to look closely at the structures of the device as it plays notes.

Pass around a music box to each group. Collect them after a three minutes. C

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3. (5 min.) Have students complete the making sense section and next steps section in small

Teacher Supports & Notes

Additional Guidance

A You may want to emphasize the relationship between **structure** and **function**, by introducing the idea that similar structures tend to have similar functions.

Additional Guidance

B Write the name of the word xylophone on the board, as some students will ask how to spell it.

Additional Guidance

C You may also want to put one under the document camera with the view zoomed into the tines for the students to see as they work with music box in their hands.

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groups. Then ask students to briefly share these out.

Suggested Prompts:

- ➔ What did you observe was making the different notes in the music box?
- ➔ What happened to the small metal fingers (tines) to make them produce notes?
- ➔ How is the differences in the structure of these similar to differences in structure in the bars of the xylophone?
- ➔ How is this related to what I did with the guitar string to make it play different notes?
- ➔ What would we need to change about the rod from the last investigation, if we wanted to (re)use it to represent the different structures that were producing different notes in the music box?

Listen for *student responses* that refer the following:

Shorter bars, tines, or strings create higher notes when struck or plucked.
Something about how it vibrates (changes shape back and forth), should be different between a short stick and a long stick, that would explain why it produces higher or lower notes.
Striking a shorter stick and measuring its position should help us simulate what is happening with a tine (or a xylophone bar, or a guitar string) that is producing a higher note.

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4. **(5 min.) Show students that you are going to start with the large wooden stick from the setup the first time and then replacing it with a smaller wooden stick the second time, and each time you are going to pull both of the sticks back the same distance (.1 meters or 10 cm). Have students record the following as titles for the two graphs they are predicting:**

- **condition 3: Lower pitch - long stick pulled back .1 meters or 10 cm**
- **condition 4 Higher pitch - shorter stick pulled back .1 meters or 10 cm**

Have them sketch their predictions for how vibrations of both of these objects will compare in the graphs on their activity sheets.

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5. (5 min.) Ask for student volunteers. One to pull the stick back 0.1 m (10 cm) and then release it. And one to press play on a new experiment right after the other student releases the pulled back stick. D

Collect the data and then keep the graph projected on the screen. Have students record their observations on their activity sheet.

Take a screenshot of this graph (cmd + shift + 3) to save to your desktop to display later (in the Conclusion section and in the next lesson).

Replace the long wooden stick with a shorter wooden stick. Again ask for a student volunteer to press play on a new experiment, right after you strike it. Keep the graph projected on the screen and have students record their observations.

Take a screenshot of this graph (cmd + shift + 3) to save to your desktop.

---

6. (20 min.) Drag both images into a word file so they are stacked one above the other. E **Zoom out so that both graphs can be seen at the same time.**

Ask students to summarize the patterns they notice between both graphs in their making sense section of their activity sheets.

Then project the two graphs from the last activity next to the two graphs from this activity. Direct students to gather around the projected images and compare both sets of graphs. Have them complete the next set of making sense questions.

Then ask students to describe patterns they notice.

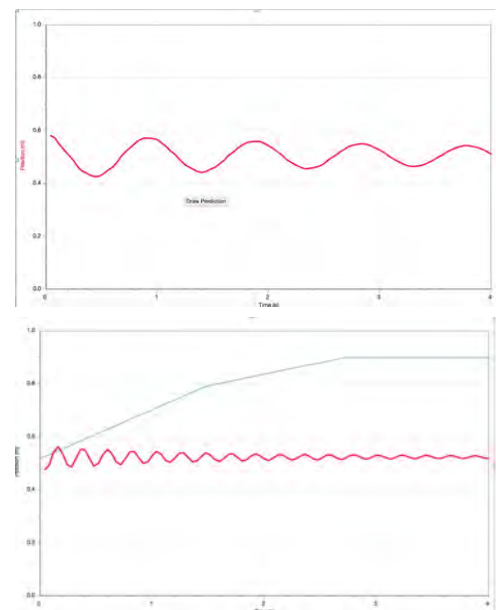
Suggested Prompts:

Additional Guidance

D Make sure no one is standing behind the stick as you do this. Have the student stand off to the side as they pull the stick back, so that the position of their bodies aren't detected by the motion detector.

Additional Guidance

E An example of this is shown here:



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➔ What patterns do you notice between between this graph and the two graphs you made in the last activity?

Listen for *student responses* that refer the following:

There are more waves for the 2 seconds we recorded them in the shorter rod than there were in the longer rod.
The amount of time it takes for one vibration is shorter for this shorter rod than it was for the longer rod.
A single wobble back and forth looks like it takes the same amount of time across all the vibrations from a single rod (the period looks constant).
How far it moves back and forth gets progressively smaller after the initial force is removed; this is the same as what we saw with the longer rod.

Emphasize that there is a something that can be kind of confusing about talking about the waves being shorter or longer. Because sometimes we are talking about shorter along the y-axis (distance), and sometimes we are talking about shorter along the x-axis (time). Motivate the need for some new ways to describe these two different types of shorter vs. longer. F

Say that, "Scientists have a way to describe the vertical differences between the y-values the peak and the trough of a wave. This distance is referred to as the amplitude G of the wave. They also have a way to describe how far apart the waves are in time by looking at home many waves occur over a time period. They refer to the time between the crest of one wave and the next (or the valley of one wave and the next) as the period of time for a single wave. But more often they refer to how many waves happen in a certain amount of time as the frequency. The more rapidly the waves are repeating the more frequent they are the less rapidly the waves are repeating the less frequent they are. We can calculate the frequency of waves, by marking of the number of waves that happen in a certain amount of time, and dividing the number of waves by that amount of time."

Work through a calculation of the highest

Strategies for this Building Understandings Discussion

F Play up the potential confusion about "bigger vs. smaller" waves to motivate the need for new language and representations to help clarify which of the two different ideas (bigger in time vs. bigger in distance) we are referring too. Emphasize that this what motivates scientists too, to come up with new words to describe subtle, but important differences between characteristics of phenomena.

G Students may bring up the connection to amps as devices that increase the volume of an instruments like electric guitars and pianos.

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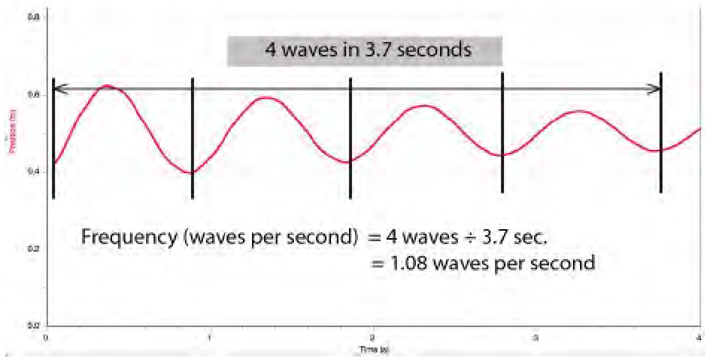
amplitude on one of the graphs. An example is show to the right.

Add a sketch of this representation (or add it an annotated print out of this) to the word wall or a poster paper in the room titled "characteristics of waves".

Then show how to count the number of waves and corresponding amount of time for those waves (the period). Use these two numbers to show how to calculate the frequency. An example is shown to the right:



Add a sketch of this representation (or add it an annotated print out of this) to the word wall or a poster paper in the room titled "characteristics of waves".

Project the wave from the same length rod, when it was struck or pulled back a different amount and have student calculate highest amplitude of the wave and its frequency. Ask students, "what patterns they noticed?"

Listen for *student responses* that refer the following:

The amplitude is less when you pull it back more or strike it harder, and gets less and less with over time.
The frequency doesn't seem to change the harder or softer you strike it.

Project the wave from the longer vs. the smaller length rod. Have student calculate highest amplitude of the wave and its frequency. Ask students, "what patterns they noticed?"

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Listen for *student responses* that refer the following:

The amplitude is less when you pull it or strike it harder, and gets less and less with over time.
There are more waves in the same amount of time.
The amount of time for one wave (period) is less.
The frequency of waves (number of waves per second increased).

Then ask students to make some predictions

Suggested Prompts:

➔ What do you predict would happen to the frequency of vibration waves if we made the rod even shorter and struck it just as hard?
➔ What do you predict would happen to the frequency of waves if we made the rod even longer and struck it just as hard?

Listen for *student responses* that refer the following:

If we made the rod even shorter the frequency would increase
If we made the rod even longer the frequency would decrease.

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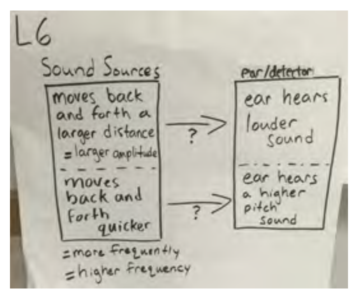
6. (10 min.) As a class complete the conclusion questions together. Come to consensus on the following ideas:



- **The surface of a vibrating object, makes a repeating wave pattern (for distance vs. time).**
- **The amplitude of the vibration cycle/wave increases as the sound gets louder.**
- **The frequency of the vibrations don't change as loudness changes.**
- **The frequency of the vibrations change as pitch changes;**

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higher pitch sounds/notes come from sound sources that are vibrating more quickly.

Summarize these ideas in a an updated Consensus model that you co-construct as a class and leave posted in the room to replace the old consensus model.

Ask students if they think they could apply this model to another phenomena such as the sounds coming from their iphone when they play music, or the sounds coming from a piano and how we would know if we really can reuse these ideas to explain a new phenomena. H

Suggested Prompts:

- ➔ What would we need to do next to see if we could apply these ideas to another sound related phenomena?
- ➔ How could we find out if each of us can use and apply these ideas to something new?

Listen for *student responses* that refer the following:

We need another phenomena to look at.
We would have to each try to use those ideas to apply to that phenomena

Establish Consensus that we should try to assess our understanding by doing this. When the class agrees this is a logical point to see what we can do with the ideas we figured out, then you can start lesson 7 at the end of this lesson, which is starts with a short assessment, followed by trying to explain something new (non-assessed) in a sound related phenomena

If you haven't assigned the Lesson 5 - Home learning, do so at the end of this lesson. To motivate this assignment, ask students how many of the students heard a ticking sound when the motion detector was recording data. Tell students that each tick they heard was the motion detector recording a sample, and that tonight they will learn more about how the motion detector does that.

Supporting An Assessment Opportunity in the Next Lesson.

H The goal here is to get the class to argue for a need to check our understanding individually, so that each of us can really see what it is we have figured out so far.

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Alignment With Standards

Building Toward
Target NGSS PE

- **1-PS4-1:** Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.
- **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
- **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.

Building Toward
Common Core Standard(s) ELA

Comprehension and Collaboration:
CCSS.ELA-LITERACY.SL.6.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- CCSS.ELA-LITERACY.SL.6.1.B Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed
- CCSS.ELA-LITERACY.SL.6.1.C Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

Building Toward
Common Core Standard(s) CCSS.MATH

- **Leveraging this standard:** CCSS.MATH.CONTENT.5.G.A.2: Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation.
- **Building toward this standard:** CCSS.MATH.CONTENT.8.F.B.5 Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). Sketch a graph that exhibits the qualitative features of a function that has been described verbally.

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Lesson 7: What can we explain and what new patterns do we notice in another phenomenon? (Embedded Assessment #1)

Middle School Unit: How Can I Hear So Many Different Sounds From Across The Room?

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**
Lesson 7: 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	**Construct an explanation** that includes qualitative or relationships *(patterns)* between variables that predict *how the vibrations of the sound source in the truck that are 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)

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Getting Ready: Materials Preparation

Materials For Each Student	Materials for each group	Materials for the whole class

• Lesson 7 - Assessment #1 (1)	• none	• **2 different Videos clips:**
		  ○ **1st half of video of music in the truck**
		  ○ **Full video of music in the truck**
		• **Computer with projector**

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Learning Plan: What can we explain and what new patterns do we notice in another phenomenon? 25 min

1. (5 min.) Remind students that in Lesson 6 we agreed that we were ready to take stock of our understanding so far. Explain that, "in order to do so, we'll observe a new phenomenon, and then try to explain it individually. Use your first two pages of Lesson 7 - Assessment #1 to do this".

Show students the 1st half of video of music in the truck. Replay the video a 2nd time. Then ask have students complete Lesson 7 - Assessment #1.

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2. (15 min.) Allow students to complete Lesson 7 - Assessment #1. Once students have completed this, have them turn the first two pages of their Lesson 7 Student Activity Sheets and continue with the rest of the lesson. A

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3. (5 min.) Review the questions from the assessment with students: B

Suggested Prompts:

- → 1. What is the sound source in this phenomena?
- → 2. If you could zoom into the sound source, what would you expect to see it doing any time it produced a sound?
- → 3. If you could zoom into the sound source, what would you see it doing differently when it produced a louder sound?
- → 4. What would you see the sound source doing as it produced higher pitched sounds/notes?
- → 5. What two things would you see the sound source doing differently as it played a note that was both softer and lower pitched sounds/notes than before?

Teacher Supports & Notes

Assessment Opportunity

A This assessment was designed to provide a quick check in for the teacher to assess student understanding, while also motivating additional investigations.

B While it is easier to review the assessment outside of class before returning it to students it feedback, providing feedback to the whole class immediately after all students have turned in the assessment (as shown in step 3) helps students consolidate their ideas.

Step 3 also motivates the need to inspect a speaker more closely in order to confirm what we think the speaker is doing.

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Listen for *student responses* that refer the following:

1. Something in the car/ truck's (e.g. speakers in the (stereo, radio) must be the sound source.
2. The speaker would be vibrating back and forth.
3.The louder the sound it produces, the further the movement would be back and forth (or more amplitude).
4. The speaker would be vibrating more quickly/frequently when a higher pitched note was playing (higher frequency)
5. The speaker would be vibrating more slowly/less frequently when a lower pitched note was playing (lower frequency) and it would be vibrating back and forth less distance if it was softer (less amplitude)

If 10 or more minutes remain in the period, it is recommended that you start lesson 8, as it picks up on this question of what the speaker is doing and uses it to motivate that lesson, and both lesson 7 and 8 together should take a total of 80 minutes.

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Alignment With Standards

Building Toward
Target NGSS PE

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- **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

Building Toward
Common Core Standard(s) ELA

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- CCSS.ELA-LITERACY.SL.6.1.B Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed
- CCSS.ELA-LITERACY.SL.6.1.C Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

Building Toward
Common Core Standard(s) CCSS.MATH

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- **Building toward this standard:** CCSS.MATH.CONTENT.8.F.B.5 Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). Sketch a graph that exhibits the qualitative features of a function that has been described verbally.

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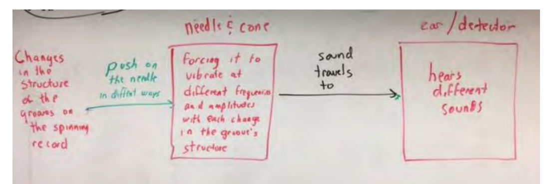
Lesson 8a: How can one object, like a stereo speaker or a needle, make all these different kinds of sounds anyway?

Middle School Unit: How Can I Hear So Many Different Sounds From Across The Room?

This Lesson....What we are doing now: You will help students look into the speaker more closely at a stereo speaker, by analyzing slow motion videos of it playing music. 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**
Lesson 8a: How can one object, like a stereo speaker or needle, make all these different sounds anyway? 1.5 periods (60 min) *Building toward* *NGSS PEs:* *1-PS4-1,* *4-PS4-1,* *MS-PS4-3*	Two video clips: 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. Speaker deconstruction	**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 claimed 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. **(Optional: we took off the grill of a speaker to feel what the cone/plate under it was doing as it was playing sounds).** We looked at a slow motion video of a stereo speaker and noticed patterns in the motion of the cone (or saw it through two video clips) • It vibrated when it made sounds • There appeared to be differences in how much it moved back and forth for different sounds produced. We argued that if the speaker can produced lots of different notes, it 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. We revisited the surface of the record and used the wooden stick to visualize how the needle on the record would be forced to vibrate in different patterns (at different amplitudes and frequencies over time) based on the structure of the bumps and waves in the grooves. We revised our model to include the 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 speaker that makes it move?*

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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

Getting Ready: Materials Preparation

Materials For Each Student

- Lesson 8a - Student Activity Sheets (1)

Preparation of Materials (5 to 15 min)

- 5 min: Make sure test all 3 videos of the speaker movement for this lesson.
- Add an additional 10 min. Of prep time to test the speaker with the grill removed hooked up to your computer to see if it plays music and you can see the paper cone move (or feel it)

Materials for the whole class

For the demo at the end of the lesson:

- Lesson 8a -Video 1
- Lesson 8a -Video 2
- Lesson 8a -Video 3- path of the needle in a vinyl LP under the microscope (same video as was used in lesson 2)

- Record player and needle setup from from lesson 1
- Wooden stick from lesson 4

Optional:

- (a speaker with a grill removed) hooked up to a computer, playing music, that the students can feel (the cone/ plate that is vibrating is very fragile and can tear easily). Have students touch this lightly if you have them feel it.

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Learning Plan: How can one object, like a stereo speaker, make all these different kinds of sounds anyway? 35-40 min

Teacher Supports & Notes

1. (3-5 min.) Ask the class how we get evidence for all these claims that the class has agreed on is happening with the speaker in the truck video.

Suggested Prompts:

- Let's go back to some of these claims we made about the stereo speaker. We are claiming that differences vibrations can explain all the different sounds it made. This is the same explanation we are giving for how the needle on the record can make all those different sounds. But, honestly I'm still not convinced from our original investigation that a needle can produce something like Michael Jackson's voice, or that a speaker from a car can really be making all that different kinds of music just from vibrating. I know we all agreed that the needle is vibrating, and that different kinds of vibrations can make different kinds of sounds, but it it is still kind of hard for me to believe. And now we are claiming that speakers are also vibrating in different ways to make these different sounds.
- How would we know for certain that this is what a speaker is doing? How could find out?

Allow students a few minutes to brainstorm different ways to figure out what's going on inside a speaker using the Lesson 8 Student Activity Sheets, then regroup to share some of their ideas.

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Listen for *student responses* that refer the following:

Play a speaker and watch it
Ask someone who makes/installs speakers
Take the speaker apart and look inside

Optional: Tell students that many speakers have a cover or grill on them. If you have a speaker available that you can take apart, invite students to see what is behind the grill by removing it and showing them the structures behind it.

If you have a speaker with the grill removed that you can hook up to a electronic music player or computer, play that for students too. A

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3. (7 min.) Ask students to record observations about how the inside of a speaker moves as it plays different sounds in Q1 on their student activity sheets.

- **Play video 1 and have them record their observations.**
- **Then play video 2 and have them record their observations.**
- **Then ask students to complete Q2 and Q3 with a partner**

---

3. (15 min.) Clamp down the wooden stick form lesson 5, and ask the students to picture the wooden stick like the needle and to think about how the needle would interact with the grooves on the record as it spun. B

Suggested Prompts:

➔ If the wooden stick was representing the needle on the record, then what would the grooves on the record do to the needle as it traveled through them?
➔ We saw differences in the structure of the grooves, how would those differences affect how the record pushes on the needle?

Additional Guidance

A The grill protects a fragile cone/ plate that is vibrating when sounds are being produced. You may want to have some (or all) students touch this lightly as it is playing sounds. If you have them feel it, because it can tear easily

Additional Guidance

B For example a smooth section wouldn't move the needle, but one with lots of bumps closely spaced together would make it vibrate at a higher frequency than one with bumps spaced far apart. You can show this by grabbing the end of the stick and shaking it back and forth at different frequencies.

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- ➔ Would every change in the structure of the grooves push on the needle with the same force?
- ➔ Would every change in the structure of the grooves on the needle move it in the same direction?

Listen for *student responses* that refer the following:

The grooves will push the needle back and forth.
Differences in the structure of the grooves would affect how much the needle is pushed in one direction.
Every change in the structure of the grooves might affect the direction it moves and how hard it is pushed.

Play the Lesson 8a - Video 3. Remind students that this is the same video we looked at in lesson 2.

Suggested Prompts:

- ➔ As the record spins, why is the needle being forced to move back and forth?

Listen for *student responses* that refer the following:

The waves in the structure of the grooves are pushing the needle back and forth.

Project L8a-PI . Remind students that this is the same microscopic image of the surface of a record we looked at before. Have students annotate the drawing by answering questions Q4 through Q6.

Have students share out their answers to Q4. Grab the end of the rod and show what the end of the rod (or needle) would be forced do in each of the parts of the record the students identify as it travels over that section of groves.

Then ask students what they claim would happen to the pitch of the sounds in their response to

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Q6.

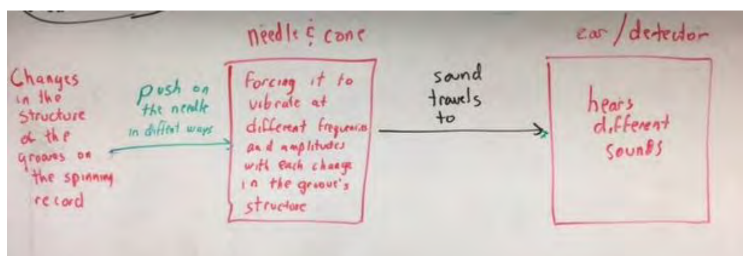
Suggested Prompts:

- ➔ What should happen to the pitch of the sounds produced by the record when we spin it faster? Why?
- ➔ Slower? Why?
- ➔ Did we observe that happening in lesson 1?

Listen for *student responses* that refer the following:

The pitch of the sounds should get higher when we spin it faster, because the bumps in the groves would hit the needle more often, leading it to vibrate at a higher frequency, producing higher pitch sounds.
The pitch of the sounds should get lower when we spin it slower, because the bumps in the groves would hit the needle less often, leading it to vibrate at a lower frequency, producing lower pitch sounds.
We did see that in Lesson 1! C

4. (5 min.) As a class co-construct a summary of what we figure out about how the record helps the needle & cone produce different sounds, using the modeling representations we have developed in previous lessons:



Additional Guidance

C Showing that phenomena again should only take a minute or two if the record and needle is all setup. If time permits, it is highly recommended to that - spin the record fast and spin it slow to see how the pitch of the song and words change.

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6. (5 min.) Problematize a new aspect of the model. Point out to students that, "We have made lots of progress on understanding how what is happening at the sound source is related to the sounds we hear. But there is a few parts of the model we really haven't talked much about since the first lesson. And we had lots of questions about this part of the model that are still on our Driving Question Board." **Point to the arrow "sound travels to" and ask the following questions.**

Suggested Prompts:

- ➔ What does this exactly mean?
- ➔ 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?

Have students talk and turn to an elbow partner to share initial ideas.

---

7. (3-5 min) Optional: have students go back and share their answers to Q3 if you want to motivate doing lesson 8b next (or later). Lesson 8b is optional, and can be done at various points in the unit before it is completed. If you raise new questions from Q3 (or Q7), post some of them on the driving question board to foreground that we may need/want to figure out more about what is going on inside the speaker in future lessons too.

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Alignment With Standards

Building Toward Target NGSS PE(s)

- **1-PS4-1:** Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.
- **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
- **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.
- **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.
- **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.

Building Toward Common Core Standards) ELA

Comprehension and Collaboration:
CCSS.ELA-LITERACY.SL.6.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- CCSS.ELA-LITERACY.SL.6.1.B Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed
- CCSS.ELA-LITERACY.SL.6.1.C Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

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Lesson 8b: How can one object, like a stereo speaker, make all these different kinds of sounds anyway?

Middle School Unit: How Can I Hear So Many Different Sounds From Across The Room?

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**
Lesson 8(b): How can one object (a stereo speaker) make all these different sounds anyway? 1 period: 45 min. *Building toward* ↓ *NGSS PEs:* *1-PS4-1,* *4-PS4-1,* *MS-PS4-3*	Speaker deconstruction 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) and how they interact together (when plugged into an electronic music device), to play back music stored on the device (function).*	Taking the grill of a speaker and seeing what was inside that appeared to vibrate when it produced sounds raised more questions. *How does that happen? How is the cord going from the ipod/computer to the speaker getting it to move?* We thought maybe there was something inside the speaker (maybe electronics) that makes it do this, so we decided to take apart the speaker further (as a demo or virtually via video clip). When we did this we noticed three main structures to the speaker: a coil of wire, a magnet, and a surface that vibrates (a cone, pad, or plate). We wondered, *if putting these three structures together would make it function like the speaker does when we hook it to an electronic music device (tablet, phone,etc)?* We were a bit skeptical that hooking those three things up would make a functioning speaker system for something like a smartphone, unless we put it together it a specific order similar to the way the speaker was put together, but we wanted to try. We conducted an investigation, following a simple procedure, and discovered some interesting patterns: • Attaching a wire coiled in many loops to an object (with hot glue) and attaching the wires on an aux. Cord to the ends of the wire coil, makes that object into a speaker that plays music, when we bring a magnet near the center of the coil of wires! • Different objects can be made to vibrate and produce sound from a electronic music source • The material and shape of the object seems to affect the quality of sound produced. We argued from evidence: • Speakers somehow use magnets and a electricity in coil of wire to somehow to make the cone vibrate to make all kinds of different sounds. • We think there is some sort of signal or electricity coming from the electronic device, through the wires, that makes this happen. **Next step: We want to figure out what is in the music player that is being sent through the wires that makes this happen; and we want to know how the music player knows how to make the object that is vibrating, move the way it needs to in order to produce a sound. We will investigate this a bit more through our home-learning readings.**

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Getting Ready: Materials Preparation for teacher

Materials needed for teacher prep.

- 30-50' of Magnet / electromagnet wire (this is a very thin, enamel coated copper wire). Do not use uncoated copper wire. The link here will get you 6414' for about $7. That is enough for 50' for every group, and 128 groups, which is plenty for 50 winds of the wire.

- Sandpaper or steel wool
- Tape
- Lighter or matches
- Wire stripper
- 1 stereo audio cable (auxiliary cord) for every 2-4 students. One cord like the following (link here) will provide 2 pieces for groups to work with once you cut it in half. (1 per group).

Teacher preparation (60-90 min).

There are two sets of wires you will need to prepare **Lesson 8a - Teacher Video B - Speaker Prep.mov** shows how to do both preparations below

Preparation #1:

1. Take the stereo audio cable Auxiliary cord. Cut the cord in half.
2. On each half strip the two wires inside the cord to expose the wire inside them. This will give you 2 pieces.
3. Repeat this for another cord, until you have 1-2 pieces for every group of 4 students.

Preparation #2:

1. Cut off 30 ft. to 50 ft. long piece of magnet/electromagnet wire
2. Coil it around and around, making a series of 1" to 1.5" diameter loops.
3. Tape the looped coils together, but leave about 6" of each end of the wire loose.
4. Use a lighter or match to burn the end of the wires (this will melt the enamel covering off of them)
5. Sand or steel wool the end of wires until you see copper.

Repeat these steps to make another coil. Make enough coils for every group of 2 students to have one to work with. You can make more if you wish. Have students save and reuse coils between classes and between experiments.

Make sure you build your own speaker first (see directions on the next page) and test it to make sure you can get one working before having students try the same. Watch **Lesson 8b - Optional video B - Speaker Build.movv** if you need another

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example.

Getting Ready: Materials Preparation for Students

Materials For Each Student

- Lesson 8b - Student Activity Sheets (1)
- **<u>Optional:</u> Lesson 8b - Optional video B - Speaker Build.mov** (this is a short video showing how to put the speaker pieces together)

Materials for each group

- 2 Alligator clips
- Auxiliary cord-clipped, stripped, and sanded at one end (see previous page)
- A stack of 5 Circular ceramic magnet(s) and or a neodymium magnet
- A coil of electromagnet wire already coiled and stripped at the end taped to keep its shape.

- 1 glue gun
- A electronic device to play music (phone, mp3 player…) out of the "headphone jack" (this is a jack for an aux. cord).

Materials need for the whole class

<u>For the start of the lesson:</u>

- Lesson 8b - Dissecting the first speaker video.
- Lesson 8b - Dissecting the second speaker video.

<u>For common supplies for the groups:</u>

- Materials for making cones such as:
  - Plastic and paper cups of made of different materials
  - Plastic lids
  - Paper and plastic bowls
  - Paper and paper plates
  - Cardboard
  - Aluminum foil
  - Tape

<u>For the demo at the end of the lesson:</u>

- L8 -Video - path of the needle in a vinyl LP under the microscope (same video as was used in lesson 2)
- Record player from lesson 1
- Wooden stick and C-clamp from lesson 4 & 5

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Getting Ready: Teacher Preparation

Background Knowledge

Alternative Student Conceptions

Here is an additional video clip that demonstrates other investigations and some potential extensions:

https://m.youtube.com/watch?v=00GzczOWu6o

Linking Our Understanding to Scientific Terminology

- Electromagnet
- Aux. cord
- Digital (in the reading)

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Learning Plan: What is inside a speaker that makes it vibrate and produce different sounds? (45 min)

Teacher Supports & Notes

1. (5 min.) Ask students to review what we figured out last time from taking apart a speaker.

Suggested Prompts:

- ➔ When we looked at the surface of a speaker what structures did we see?
- ➔ What did we see it doing when it produced different sounds?

Listen for *student responses* that refer the following:

We saw something that looked like a cone or a pad or a sheet.
It moved up and down (vibrated) when sounds were produced; a how much it vibrated changed when it produced louder and softer sounds or sounds of different pitches.

Ask for student volunteers to share the ideas they brainstormed in responses to Q3 with a partner, in response to the question, "What do you think is making the speaker vibrate in these different ways?"

Listen for *student responses* that refer the following:

Maybe there is some kind of electronic equipment in the speaker that makes it move
Maybe the signal from the electronic device it is hooked up to tells it how to vibrate.

---

2. (5 min.) Motivate the need to dissect the speaker further (and put it back together) in order to figure out more about how it works.

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Suggested Prompts:

➔ How could taking apart a speaker even more help us figure out how it might work?

Listen for *student responses* that refer the following:

We could see what parts are inside of it, and maybe that would give us clues of how it works.

Show both videos:

- **Lesson 8b - Student Video 1 - Dissecting the first speaker video.**
- **Lesson 8b - Student Video 2 - Dissecting the second speaker video.**

Have students underline some of the parts they heard mentioned in both videos.

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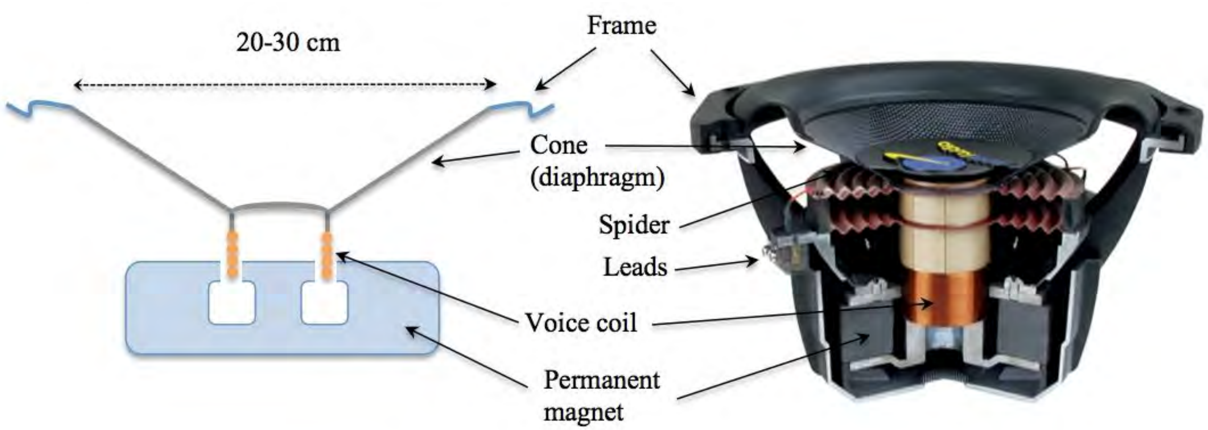
2. (5 min.) Direct students attention to the left part of the speaker diagram on their student activity sheets. Have student identify the three main parts shown on that left side of the diagram



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Listen for *student responses* that refer the following:

Cone, voice coil, and permanent magnet

Suggested Prompts:

- ➔ If we put a coil of wire (a voice coil) and and a magnet together on some kind of object like a plate, pad, cone, bowl, or cup, and hooked it to a electronic music player, do you think it would function as a speaker?
- ➔ Do you think the order we put the parts together matters?
- ➔ Do you think the thing we attached it to, like a plate, pad, cone, cup, or bowl, would vibrate and produce music?
- ➔ Should we try that? Should we try and build our own speakers?

Listen for *student responses* that refer the following:

Maybe it would make music, but it seems kind of hard to believe it would.
The order of how you put the parts together probably matters.
Should we build our own speakers? For real? Oh yes, let's do that!

Have students record these three parts on the "planning your investigation" section of the student activity sheets:

- **Coils of wire hooked up to an electronic music device (computer or smartphone, etc..)**
- **Magnet**
- **A plate, pad, cone, bowl, or cup that we want to try to make vibrate.**

---

3. (5 min.) Read through the three main steps on page 1 of the student Activity Sheets with students, shown next to the photograph of what students will be building.

Emphasize that you have lots of supplies besides (or in place) of cups to try as a surface that might

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vibrate and produce sound. Suggest that maybe some surfaces or objects might work better than others. Encourage students to think about how they could maybe even build their own "speaker" shape to try out of the group supplies available (e.g. foil, paper, plastic, tape, etc...)

Give students a couple minutes in groups of to plan two types of objects they want to test as "cones".

---

4. (15 min.) Read the top of the 2nd page of the student activity sheet with students, saying, "Now that you know what the 3 main parts of a speaker's are, you will need to follow a more detailed procedure to build your 1st speaker. Work in teams of 4-5 people. Have one pair of students try your 1st object (in place of the plastic cup shown above), and have the other pair of students try your 2nd object. Each pair students should try to build their own speaker, so that the group can compare results from both objects they tested."

Have students work in groups to follow the procedures on their student activity sheets and record their observations as they test their devices. Allow time for having students take the wire coil off the object they attached it to and return the supplies for the next class to use. [A]

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5. (5-10 min.) If no students built a working device, demonstrate the one you built now.

Have students briefly summarize some of the interesting patterns we figured out from this investigation. Here are three main findings that you can help students pull out of their investigations:

- **Attaching a wire coiled in many loops to an object and attaching the wires on an aux. Cord to the ends of the coil, makes that object into a speaker that plays music, when we bring a magnet near the center of the coil of wires!**
- **Different objects can be made to (forced to) vibrate and produce different sound from a**

Additional Guidance

A Based on what we have seen in previous pilots of this unit, students want to stick with this task to see if they can get their speaker working.

One option for this is to put the equipment to the side for now, and return to trying to build it again on a day when you have a half period, or extra time.

Another option is to encourage students to come in outside of class to work on it (in study hall, before school, etc…)

A final option is to extend step 4 to the end of the period, and then follow-up on step 5 at the start of the next period.

It is not recommended that you extend step 4 into a 2nd class period, however, as building a working speaker is not essential to the learning goals in NGSS. Rather, it is designed to motivate a need to figure out how digital electronic devices record, store, transmit, and play back information and compare these to analog devices. The foundation for that was laid in Lesson 5 reading, and is built upon further in the Lesson 8b reading. So make sure to assign the Lesson 8b reading for tonite, after step 4, even if you don't wrap up step 5 until the following day

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electronic music source.

- **The material and shape of the object seems to affect the quality of sound produced by a speaker.**

Ask students to brainstorm ideas in response to Q1 and Q2 with a partner.

Suggested Prompts:

➔ Why would attaching ends of the coil of wire in your device, to wires coming out of an electronic device like a smartphone or a computer get it play songs?

➔ How is the music in an electronic devices like smartphones or computer stored inside of it so that it can play it back later?

Tell students that we are going to investigate these ideas and questions further in a home-learning tonight as well as learn more about how speakers work. Assign Lesson 8b - Reading for home-learning.

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Alignment With Standards

Building Toward Target NGSS PE

- **1-PS4-1:** Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.
- **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
- **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.
- **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.
- **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.

Building Toward Common Core Standards ELA

Comprehension and Collaboration:
CCSS.ELA-LITERACY.SL.6.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- CCSS.ELA-LITERACY.SL.6.1.B Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed
- CCSS.ELA-LITERACY.SL.6.1.C Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

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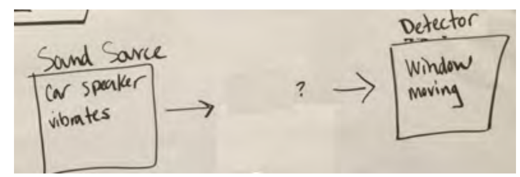
Lesson 9: How does a vibration at the sound source actually make something far away move?

Middle School Unit: How Can I Hear So Many DIfferent Sounds From Across The Room?

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? (40 min) *Building toward* *<u>NGSS PEs:</u>* *1-PS4-1,* *4-PS4-1,* *MS-PS4-1,* *MS-PS4-2*	Blasting music in the truck Video shows additional patterns as we play the 2nd half of the video, related to effects in 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 (traveling) *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 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 to"?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 with our class and compared 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?* 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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Getting Ready: Materials Preparation

Materials For Each Student	Materials for each group	Materials for the whole class
• Lesson 9 Student Activity Sheets (1) AND • Lesson 10 Student Activity Sheets (1) • Student models from Lesson 1	• None	• **Lesson 9: Full video of music in the truck**.

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Getting Ready: Teacher Preparation

Background Knowledge for the Teacher

Connections to the FRAMEWORK Preamble for PS4.A

- Sound is a pressure wave in air or any other material medium. Think of a can of hairspray under pressure. Many particles are squashed together - they are under pressure. Then if those particles are allowed to be free, they spread out from one another and bump into a bunch of their neighbors. Then those neighbors get squished together, and then they are allowed to spread out hitting neighbors next to them and the chain continues. The series of compressions and expansions of the particles is how a sound wave travels.
- Sound is not a separate state of matter. The particles of the matter that already exists in the world around us transmit the sound wave energy. So, in this new phenomenon that the kids experience, the speaker pushes a bunch particles of air close together, then those particles expand out together, hitting another group of air particles next to them. This goes on until the group of particles right next to the window get pushed together, and when they expand, they hit the particles that make up the window, causing the widow to get pushed. This detailed model will only be put together by the students much later in the unit, and an explanation is here for teacher background knowledge only.

Alternative Student Conceptions

Students may think that sound is a separate state of matter (particle or fluid) that has to move in between air particles. This conception should be left unresolved at this lesson. In fact, we encourage teachers to bring out these alternate conceptions from the students into the public domain in this lesson so that we have a reason to investigate if air has anything to do with the sound traveling at all.

Linking Our Understanding to Scientific Terminology

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Learning Plan: How does a vibration at the sound source make something move that is far away? (45 min)

Teacher Supports & Notes

1. (7 min.) Tell students that you want to revisit the phenomena of the truck speaker, just to make sure that we feel we can explain everything in that phenomena.

Now show students the [Full video of music in the truck]. After showing it once, say "You may have noticed some things you didn't notice before. This is because the earlier video was only the first half of this phenomena. Let's watch this again, but this time record your observations about other things you notice occurring in the later half of the video."

Have students turn to their [Student Activity Sheets] and record what patterns of change they observe in the windows in the building across from the truck as the music is playing after playing again Play the video one more time.

Have students share their observations.

Suggested Prompts:
➔ Okay, and what did we see the windows in the building across the street doing in the second half of the video?

Listen for *student responses* that refer the following:

*The windows were moving back and for a lot. Maybe they also are vibrating? Was the music from the truck actually **causing** the windows to move?*

Suggested Prompts:
➔ So now we've seen two different situations where something simple-a needle and a coil of wire-were vibrating, and that produced real music! So we can definitely agree that vibrating matter, even a needle or a coil of wire, can make sound, but we still haven't explained how the

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video with the truck works. We know that the speakers in the truck were vibrating, and we know that made the windows move back and forth and appear to be vibrating, but what new questions does this now raise?"

Listen for *student responses* that refer the following:

How could the speaker cause the windows to vibrate?
How does the sound make the window move?
How does the sound get to the window?

Agree that there are a bunch of next questions for us to look into related to "How does the vibrating speaker make something far away like the window vibrate?"

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2. (5 min.) As a class co-construct a model of what we know is happening in this new phenomena: A

Suggested Prompts:

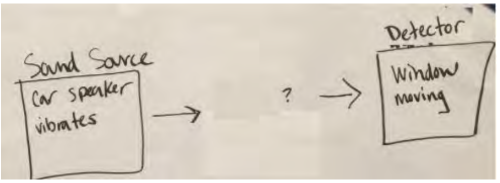
- ➔ If we said our old model can explain the sounds we heard coming from the speaker in the car, then maybe it can also explain what we see happening in this phenomena. Let's see what is similar and what is different. What is our sound source in this phenomena?
- ➔ What is the object that we can see responding to the sound? So can we say that the window is a detector of sorts? It somehow is responding to the sounds being produced by the speaker?
- ➔ This phenomena really makes us think, what exactly is going on in between these two things. Can we agree to leave this as a question mark for now?
- ➔ We haven't yet really tried to explain what is happening between the sound source and our ears since lesson 1. Maybe we should pull those back out and to remind ourselves what we thought was happening between the sound source and our ears?

Listen for *student responses* that refer the following:

The sound source is the stereo speaker in the car.

Classroom Artifact

A As a class, map this specific, new phenomena to our generalized model of how sounds are made, travel, and get detected. Use this co-constructed model to point to the question mark in the middle, pointing out that it still leaves us with many unanswered questions-many of them may still be sitting on the Driving Question Board.



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

We know the car speaker is vibrating.
The window is like a detector - but it might be different than our ears in that we can see the windows were moving back and for a lot in response to the sounds being produced.
We can't see what is happening between the truck and the building, so it make sense for us to leave it as a question mark for now.
Yeah! We totally forgot what we thought was going on. Let's take a look at our models and maybe the models of other classmates.

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3. (5 min.) Hand back the lesson 1 models and have students focus on the second circle where we modeled what was happening in a spot in the air in between the sound source (record) and your sound sensors (ear) to refresh themselves about what they thought was happening.

Suggested Prompts:

- ➔ This was our model to try and explain what was going on with the record player, but now we are trying to figure out this new phenomena. Let's map this new phenomena on to our original models. Instead of a record player what is our new sound source again?
- ➔ So, let's draw a car with a speaker next to the record player. Instead of an ear, what's our new detector?

Listen for *student responses* that refer the following:

The sound source is the stereo speaker in the car.
The new detector is the windows moving back and forth.

Next to the picture of the girl cupping her hand around her ear, have students draw a window and show that it's moving in some way (maybe just write the words "moving back and forth" next to a drawing of a window). Tell students to fold their papers so that only the second circle is showing. B

Additional Guidance

B We want kids to focus on what they put in the second circle to describe "A spot in the air in between the sound source and your ear"

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4. (10 min) Then have students post their models around the room to do a gallery walk. During the gallery walk students should think about the question, "HOW does a vibration actually make something far away move?" Students should walk around the room to compare models, recording what is similar and different between them on the student activity sheets. Also, students should take post it notes to write down any questions they have for a classmate's model and post those questions on their classmate's paper.

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5. (10 min.) Have the class gather around in a scientist's circle. Share out similarities and differences and record these on a poster paper or on the board. Have students look at their individual models and check out any questions left from classmates.

Summarize the similarities, and have students record these on their student Activity Sheets emphasizing two important ideas that were represented across all the groups:

- **Sound travels from the sound source to other objects**
- **Sound can make other objects far away from the sound source vibrate.**

Ask students to give other examples where they noticed a sound, particularly a loud sound, causing something else to vibrate.

Then point out that, "We all agree that something is going from the sound source to the window. But we had lots of different ways of represent the sound going from the car to the moving window. Some students may represent the sound moving in different ways (i.e. waves, lines, dots/ particles, notes, etc.). So this raises lots of unanswered questions for us!"

Suggested Prompts:

➔ What, if anything, is actually moving through the air?
➔ How can a sounds make things move a distance?
➔ Why can't we observe that with all sounds, for example when we are talking, the same way we

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observe it with certain sounds?

- ➔ How can we investigate what is actually happening to the air between the sound source and the window? Or the sound source and our ears?

At the end of the discussion, some students will think sound is moving in the air to their ear and others will not know or agree that sound is moving. This is will lead to the investigations in the next 3 lessons.

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6. (7 min.) Ask students to talk with their elbow partners about the question, "How would we know for example whether air is being moved from the sound source to the window when sound is being made?"

As home-learning you can assign the Next Steps question 4 and 5 for students to complete to help suggest ideas for what we need do in the next lesson. C

Then, have students brainstorm a way we can test if air is carrying sound to our ear. Instruct them to write the some ideas of how we can test this on the Student Activity Sheet number 5.

Strategies for Supporting the Next Initial Ideas Discussion

C You will see some ideas related to blocking the air. Since you will be pursuing an investigation with students next time where you block all the air around a sound source, collecting their brainstorming ideas now will allow you to start class next time by sharing some of their ideas as a way to launch the next lesson.

If time is short you can assign question 5 as home-learning due for next time.

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Alignment With Standards

Building Toward Target NGSS PE

- **1-PS4-1:** Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.
- **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
- **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.
- **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.]

Building Toward Common Core Standard(s) ELA

Comprehension and Collaboration:
CCSS.ELA-LITERACY.SL.6.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- CCSS.ELA-LITERACY.SL.6.1.B Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed
- CCSS.ELA-LITERACY.SL.6.1.C Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

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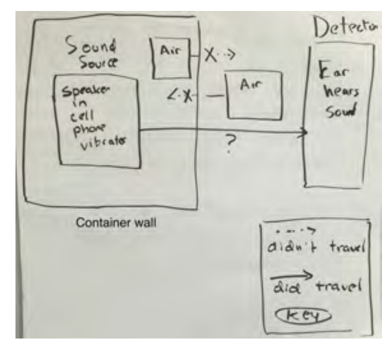
Lesson 10: Is the air being moved from the sound source to my ear, when I hear a sound?

Middle School Unit: How Can I Hear So Many DIfferent Sounds From Across The Room?

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 from the sound source to my ear, when I hear the sound? 1 period (40 min) *Building toward* ⬇ *NGSS PEs:* *MS-PS4-1,* *MS-PS4-2*	A cell phone in a ziplock bag filled with air, which is playing music is placed on a scale. The scale shows no change in mass, between before and after when the phone made sounds.	**Engaging in Argument From Evidence** Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute (an explanation or a model for a phenomenon) *why 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)"* **Develop or use a model** Modify a model— based on evidence – to match what happens if a variable or component of a system is changed *based on evidence gathered after changing whether air* can move between the sound source and sensors (systems and system models). **Planning and carrying out investigations** Conduct an investigation and revise the experimental design to produce data to serve as the basis for evidence to *test whether* air was moving from the sound source to the sensor (systems and system models).	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 in previous grades that all matter has weight, so we could weigh it. One kind of idea that we came up with for how to do this 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 after it made a sound. • No air appeared to escape from the bag, but we still could hear a sound.  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 inside the container, since the sound is moving, but the air isn*t;. This led to some different predictions as well as some ways that we could test those. **Next steps: We want to try to remove the air from the container and we want to try to replace the air in the container with something else (like water)**

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Getting Ready: Materials Preparation

Materials For Each Student

- Lesson 10 Student Activity Sheets (1)

AND

- Lesson 11 Student Activity Sheets (1)

Materials for each class

- Unopened soda bottle (so for six classes this would be six bottles)

Materials for the whole class

- Tupperware tub
- Ziplock bag
- Cell phone that is charged
- Electronic scale (500 g)
- Sealed tin can of food from the grocery (e.g a can of corn, or beans)
- You will use one sealed soda bottle in each class.
- **Optional** (if students don't have a prior experience with thinking about air as matter and having mass):
    - Air pump with ball needle, Ball inflation needle and Volleyball

Getting Ready: Teacher Preparation

Background Knowledge

Make sure to mass the sealed sound source in its bag or tub only before and after it plays music. That will ensure that there is no fluctuation in the reading recorded on the scale.

If you continuously mass the sealed sound source while it is playing music, you may see fluctuations in the reading on the scale. This is due to to sound source jumping up and down on the scale as it vibrating within the bag/tub.

Alternative Student Conceptions

If students haven't developed lines of evidence from previous grades (PS1 in 5th grade) that air is matter and therefore air has mass, you may need to conduct the recommended additional investigation at the 2nd step.

Linking Our Understanding to Scientific Terminology

- Mass
- Closed system
- Open system

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Learning Plan: Is the air being moved from the sound source to my ear, when I hear a sound? (35-40 min)

1. (5 min.) Post some responses to questions 4 and 5 from the Lesson 9 student activity sheets that students either completed last class or for home learning. Display them anonymously for students to compare at the start of the period. A **Hand out Student Activity Sheets for Lesson 10. Have students record our question, "Is air moving from the sound source to our ears?" in row one.**

Suggested Prompts:

- ➔ Last class we were wondering if air helped the sound move from the sound source to the sound detector. After looking at a couple student examples, what should we try to do to investigate this?

Listen for *student responses* that refer the following:

Let's try to block the air around the sound source!

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2. (5 min.) After you allow have talked though a few of students ideas related to blocking the air, emphasize the need to block all the air around the sound source.

Point out the objects we have in the room that might be able to do that for us like a Ziplock bag or a tupperware container. Suggest we can try to use it to see what happens when we trap air from moving with the Ziplock bag or tupperware.

Ask students we might use a sound source like a cell phone ringing and one of these containers to see if blocking air moving from the sound source to my ear prevents us from hearing a sound. B

Once students have agreed that one of materials available can be used to keep the air trapped in

Teacher Supports & Notes

Strategies for this Initial Ideas Discussion

A If time was short last lesson, you can ask share their responses with partners or small groups from question 2 lesson 2 and then ask a few of the small groups to share out some of the ideas they came up with. Giving groups a minutes to discuss will help you eavesdrop in on conversations to find a few examples of students who brought up the idea of blocking the air.

Then when you come back together, you can make to call on those groups to share. Or you can summarize some of the themes you heard. If you take the later approach, you may want to take a piece of paper around with you to take some notes, and then read back the notes you took to students, emphasizing that you took notes on some of the ideas you heard.

Additional Guidance

B If a student has an idea for a different sealed container to use, swap that in if it is doable.

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the container, have students record the plan in their Student Activity Sheets in row 1 under the "How will we test it" column. Then ask students the following questions to come up with a class hypothesis:

Suggested Prompts:

- ➔ So if the air near the sound source needed to be moved all the way to our ears in order to hear the sound, and we block the air, what should happen?

Listen for *student responses* that refer the following:

Then we shouldn't be able to hear the sound?

Have students record this hypothesis in the second part of the box under the "How will we test it?" column. Hypothesis: If the air near the sound source needed to be moved all the way to our ears in order to hear the sound, and we block the air, then we shouldn't be able to hear the sound.

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3. (7 min) Place a cell phone in the ziplock bag and fill it with air or put it in a tupperware container. Play the music from the phone in the bag. The class can hear it!

Suggested Prompts:

- ➔ Talk to the person next to you. What do you think of these results?
- ➔ Are you convinced that the air was blocked by the bag/container?
- ➔ How could we make sure air is really being blocked and that no air is getting in or out ?

Listen for *student responses* that refer the following:

Hmmm. maybe the bag is leaky.
We're not totally convinced that the air was blocked.

Supporting Students in Using Cross-cutting concepts

C If students haven't used the idea of **closed systems** vs. o**pen systems** before, here is a good opportunity to introduce it. If they have used it before, then emphasize the distinction. Systems thinking is a cross-cutting concept in NGSS.

Emphasize that in a closed system no matter can get in or out, not pieces of stuff can enter or exit.

Hold up a sealed can of beans or corn and ask students if it is closed or open system.

Hold up a soda bottle and ask students if it is a closed or open system (students will say it depends if you open the cap or not)

An Additional Activity May or May Not Be Needed At this Point

D If students haven't developed lines of evidence from previous grades (PS1 in 5th grade) that air is matter and therefore air has mass, you may need to conduct these additional investigations first.

A quick one is to mass the soda bottle before opening it. Then ask students what will happen when the bottle cap is opened and why. And then remass the bottle and cap after opening it (the mass will decrease from

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Accept all ideas.

Have a short initial ideas discussion on how can you make sure air is really being blocked and that no air is getting in or out. If they do not suggested weighing the bag before and after sound is played inside of it, ask prompts about what students predict would happen to the mass of the bag plus the phone would change for various possible outcomes. C

Suggested Prompts:

- ➔ What if we put the sealed bag and cell phone on a scale? If air leaves the sealed container when sound is being played, how should the mass of the entire system of the sound source plus air plus bag afterwards compare to the mass of the entire system before hand?
- ➔ If air enters the sealed container when sound is being played, how should the mass of the entire system of the sound source plus air plus bag afterwards compare to the mass of the entire system before hand?
- ➔ If air doesn't move in or out of the sealed container when sound in being played, how should the mass of the entire system of the sound source plus air plus bag afterwards compare to the mass of the entire system before hand?

Listen for *student responses* that refer the following D **:**

If air escapes, the mass should decrease
If air enters, the mass should increase.
If no air moves in or out of the container than the mass shouldn't change.

Have students record the "What we are wondering" and "What we are going to do" sections in row 2. Record their hypothesis/predictions in the what we are going to do section.

1. **Put the cell phone in the place Ziplock bag (or tupperware tub). Mass the phone and bag on the scale. Record the mass of the phone and bag and write the mass on the board.**
2. **Remove the bag and phone from the scale. Call the phone number of the phone so that it rings**

some of the gas that escapes upon opening) Another suggestion is to test an inflated volleyball. Mass it and then pump it up a little bit more, and mass it again. In both cases you may need to use a piece of tape to keep it on the scale. If so, use the same piece of tape throughout the massing.

Additional Guidance

D *Here are example responses:*
What we are going to do: We sealed the phone (our sound source) in an airtight container and weighed it before and after calling it to get it to make sound. **What we figured out:**
- mass before calling the phone was 180.5g - mass after calling the phone was 180.5g .

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3. **Once the ringing is done, place the bag and phone back on the scale. Record the mass of the phone and bag and write the mass on the board.**

Have students describe the results in the "What we figured out" sections of their Student Activity Sheets. And then have them discuss with a partner what they conclude. E

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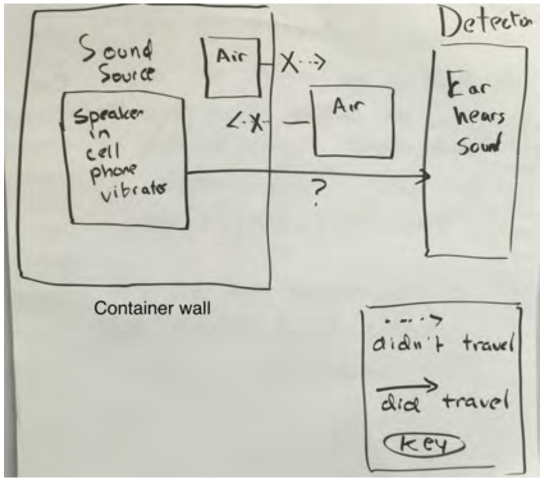
4. (8 min.) Next, lead students into a discussion to make sense of what they observed and what they can now conclude related to the original question.

Listen for *student responses* that refer the following:

The mass of the bag and cell phone didn't change as it made a sound, so air couldn't nor get out.
No air appeared to escape from the bag, but we still could hear a sound.
Air isn't moving carrying sound to our ear since it didn't leave the bag and we still heard the sound.
Somehow the sound is moving through the matter (the air which is a gas), but the matter itself isn't moving all the way from the source to our ear.



After they have summarized the main points from this investigation, revise the model from the previous lesson as a class. Draw the consensus model from the previous lesson on the board and ask students what changed in the model. F

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6. (5 min) Summarize the main points of what our current model is suggesting:

- *The air itself isn't actually moving all the way from the source to our ear.*

Differentiation and Alternate Activities

E Space is provided on the back of the student activity sheet to write a conclusion if you want to use it. But having students turn and talk with a partner is probably more time efficient for seeding the ideas needed for the final model and discussion

Differentiation and Alternate Activities

F Once the class agrees on the new model, you may (or may not) want to have them draw it in their Student Activity Sheet.

The goal of the model at this point is to represent the current status of what we know to problematize new questions that the model raises. Since the model will be revised by the teacher and the class together in this lesson and in the next two, it may make more sense to simply keep a public record of this model, rather than also have students record a copy of it in their student activity sheets.

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- *Yet, somehow the sound is still moving to our ear.*
- *And the mass of the container didn't change, so sound can't be matter, because matter has mass, and the mass didn't change even after sound came out.*

Ask students turn to talk with their partner about these two questions:

- What is sound if it isn't matter?
- Is this air inside the container even needed for sound to travel to our ear?

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7. (5-10 min) Then after talking with a partner, have students write down the new question, "Is the air inside the container even needed for sound to travel to our ear?" in the next row of their Lesson 10 student activity sheets (for the next lesson). On a separate sheet of paper ask students to brainstorm ideas to test the question "Is the air inside the container even needed for sound to travel to our ear?"

Tell students that we are going to try to use some of these ideas in our next investigations in class next time, so you'd like to collect them to introduce some of their possibilities next time. Collect brainstorming ideas to look at before next time. G

Strategies for Supporting the Next Initial Ideas Discussion

G You may see two themes in the brainstorming ideas that students come up with. One of these is that you could replace the air in the container with something else (like a liquid). The other is that you could remove the air from the container somehow (like with a pump).

Both of these types investigations are ones you will pursue with students next time, so by collecting their brainstorming ideas now you can start class next time by sharing some of their ideas at the start of class as a way to launch the next lesson, and tell students that we should try to investigate a couple of these. If time is short you can assign question 2 as home-learning due for next time.

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Alignment With Standards

Building Toward Target NGSS PE

- **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.
- **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.]

Building Toward Common Core Standards ELA

Comprehension and Collaboration:
CCSS.ELA-LITERACY.SL.6.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- CCSS.ELA-LITERACY.SL.6.1.B Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed
- CCSS.ELA-LITERACY.SL.6.1.C Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

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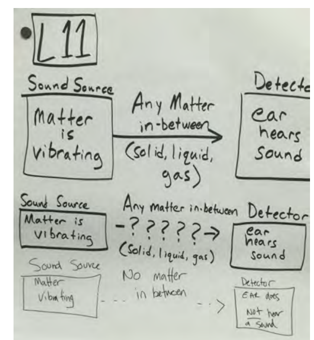
Lesson 11: Do we even need air in between to hear the sound from the source?

Middle School Unit: How Can I Hear So Many Different Sounds From Across The Room?

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? 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. 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.	**Engage in Argument From Evidence:** Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon *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)* **Develop or use a model** Modify a model— based on evidence – to match what happens if a variable *(air)* or component of a system is changed (can move between the sound source and sensors (systems and system models)). **Planning and Carrying Out Investigations** identifying what tools are needed to do the gathering and what data are needed to support a claim *whether* air was moving from the sound source to the sensor (systems and system models).	**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 our our two investigations (or from analyzing 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 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.**

These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University.

Getting Ready: Materials Preparation

Materials For Each Student

- Already completed Lesson 10 Student Activity Sheets (1)

AND

- Already partially filled out Lesson 11 Student Activity Sheets (1)

Materials for the whole class

- Cell phone or digital music player
- Foil duct tape (easy to remove from music player) or packing tape
- Vacuum pump, with pressure gauge and Vacuum chamber and a valve to shut or open the air line. If you don't have this, then project the Lesson 11 Vacuum Pump investigation. #1 Video
- 10 gal fish tank filled with water that you can reach into and students can learn their ears against
- Two steel ball bearings (about 1" diameter each or larger)
- Poster paper set up near the last investigation location

These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University.

Learning Plan: Do we even need air in between to hear the sound from the sound source? (40 min)

1. (5 min.) Post some responses to the brainstorming ideas for investigations that you collected last class (anonymously) for students to compare at the start of the period. A

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2. (5 min.) After you allow have talked though a few of students ideas related to removing or replacing the air during a building Consensus Discussion, two ideas should emerge:

- **We could try to take the air out the container**
- **We could try to replace the air in the container with something else (like water)**

At this point emphasize that we might need additional materials and different types of equipment to help us do this.

Pass back their Lesson 10 Student Activity Sheets, have students record what the class will do under the "How will we test it" section, and have them bring them to the first investigation setup. B

---

2. (7 min.) Introduce the vacuum pump and chamber by saying, "We have a device right here (point to the vacuum pump) that can remove air from this container (point to the vacuum chamber). Let me show you how the pump works"

Turn on the music player on the phone so that songs are playing from it.

Turn on the pump until the pressure gauge reads 0 psi (or as close as it gets to it). Turn off the pump and immediately shut the valve in the line. Have a couple students record data for the

Teacher Supports & Notes

Strategies for this Initial Ideas Discussion

A If time was short last lesson, you can ask share their responses with partners or small groups from question 2 lesson 2 and then ask a few of the small groups to share out some of the ideas they came up with. Giving groups a minutes to discuss will help you eavesdrop in on conversations to find a few examples of students who brought up the idea of blocking the air.

Then when you come back together, you can make to call on those groups to share. Or you can summarize some of the themes you heard. If you take the later approach, you may want to take a piece of paper around with you to take some notes, and then read back the notes you took to students, emphasizing that you took notes on some of the ideas you heard.

Alternate Activity Order

B You can switch the order of the first and second investigation if you wish. This lesson assumes that you will do the

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class on the board. Record the air pressure reading and what they hear from the sound source now as a class.

Then after a minute release the pressure gauge until it reads around 5 psi and then shut it again. Record the air pressure reading and what they hear from the sound source now as a class.

Then release the pressure gauge again until it returns to around 14.6 psi and no more air flows into the chamber. Record the air pressure reading and what they hear from the sound source now as a class.

Individually have students fill out the what did we figure out sections of their activity sheets. Have student talk to the person next to them about what they thinks our results mean. The sound gets quieter as we remove more and more air! So

Listen for *student responses* that refer the following:

The sound gets quieter as we remove more and more air! So this means that we DO need air to hear a sound.

---

3. (10 min) Bring students over to the aquarium tank. C **Explain that you are going to knock the two steel bearings together in order to make them vibrate and make a sound. Demonstrate this in the air as you hold them in front of you and knock them together. Ask students what question was this going to help us answer again? Have student record their answers in the "what are we wondering" and "how will we test it" columns of their Student Activity Sheets.**

Ask students to predict what they think will happen and form a hypothesis on their activity sheets. Hypothesis: If air inside the container is needed to hear the sound, then when we only have water in the container, we shouldn't be able to hear the sound.

Then gently lower the ball bearings into the tank of water. Tell students that you are going to knock them together again in a moment as some student volunteers come up to the edge of the tank and press their ears against it.

vacuum pump investigation first and the water aquarium investigation second.

If you don't have a vacuum pump and vacuum chamber, then play the Lesson 11 Vacuum Pump investigation. #1 Video in place of a live demo.

Additional Guidance

C Make sure you have students bring chairs over to this demonstration area, so that you can keep them there to work through the next step (creating a consensus model). And make sure you have a piece of poster/chart paper near this area to draw out the class consensus model when complete.

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Reach into the tank and get ready to knock the two bearings together. Have student volunteers gently press their ears against the side of the tank. Knock the bearings together. Repeat this if other students want to observe directly. Otherwise have the observer's report what they heard. Have students record what happened in the what we figured out column. D

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4. (13 min) Have students work in small groups on Q1.

Suggested Prompts:

- ➔ What does what we figured out in each of our investigations tell us about the answer to our original question?
- ➔ So if we know that the sound can go through water, and through air, and through the container wall (which is a solid), why can't it go through the container when the air is removed?

Listen for *student responses* that refer the following:

If there is no air, sound cannot be heard.
As air was put back in, the sound came back and could be heard.
Somehow the sound is moving through the matter (the air which is a gas)
Air is needed for sound to travel through - but if we but this together with what we found in Q8, then it isn't that air is needed, it is just that you can't have an empty space with nothing in it for air to travel through.
It seems like air needs matter to travel through - a solid, liquid, or gas.

Ask students whether they have heard the claim that you can't hear sound in space and how this experiment helps provide evidence for that claim.

Then introduce a way of summarizing what we found out, by saying, "Scientists refer to any matter that is needed for sound to travel through as a medium. A gas, or a liquid, or a solid can be a medium for the sound to travel through. But not empty space. We also know that the matter in the medium doesn't move all the way from the source to our ears, nor all the way from the stereo speaker to the

Additional Guidance

D If students suggest their is still air because we just pressed our ears up to the glass, ask the class if they have ever tried to talk to their friend underwater. Could they hear them being completely submerged? Chances are someone in the class has tried this and can attest to that they still hear sounds when being completely submerged underwater.

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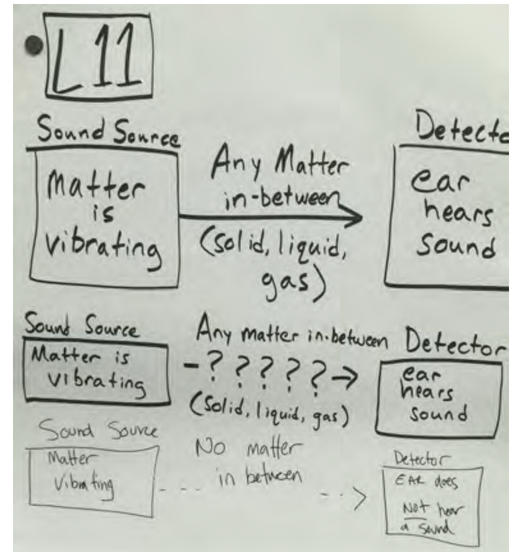
window that moved in response to it"

After they have summarized the main points from this investigation, Refer to consensus model from the previous lesson on the board and ask students what changed in the model. Once the class agrees on the new model E**, have them draw it in their Student Activity Sheet if time permits.**

Classroom Artifact

E An example model for how we can hear different sound from across the room showing an example of how it should now look after the final revision at the end end of this lesson:



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Alignment With Standards

Building Toward Target NGSS PE

- **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.
- **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.]

Building Toward Common Core Standards ELA

Comprehension and Collaboration:
CCSS.ELA-LITERACY.SL.6.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- CCSS.ELA-LITERACY.SL.6.1.B Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed
- CCSS.ELA-LITERACY.SL.6.1.C Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

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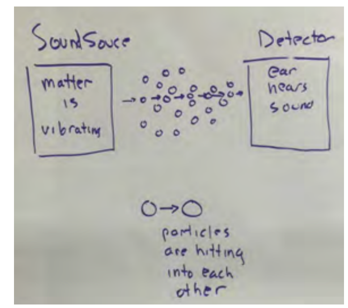
Lesson 12: Why does sound need matter to travel through?

Middle School Unit: How Can I Hear So Many Different Sounds From Across The Room?

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 and empty space. 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: Why does sound need matter to travel through? 2 periods *Building toward* ⬇ *NGSS PEs:* *1-PS4-1,* *4-PS4-1,* *MS-PS4-1,* *MS-PS4-2,* *MS-LS1-8*	Previous phenomena related to sound traveling through a tank of water, glass, air) A human model of particles in a solid or liquid, shows us that a vibration at the sound source could cause collisions between neighboring particles that transfer a pulse across the meidum	**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 air)?* We wanted to simulate using people as particles of the medium to try to figure this out.  When we simulated this we further developed the model to show that we think that: • A vibrating source source could push particles in the medium it is adjacent to. • Those particles transfer energy to their neighbors, bounce off their neighbors when they hit them. • If a push (e.g. our high-fiving a neighbor) is transferred into one end of the medium, it might result in cascading series of collisions between neighboring particles across the medium. We decided we can use this model to explain the results from our earlier investigations: *why we can hear a sound through a solid or liquid or gas even though the matter doesn't move all the way from the source to our ear, and why we can't hear a sound through empty space (a vacuum)?* **Next Steps: We brainstormed what it was we wanted to include from our discoveries in a computer simulation to use next time, to help us investigate how sound travels across a medium further, such as:** • **Things we want to be able to adjust about the sound source** • **The sort of particle interactions we wanted to include** • **The sort of things would we wanted to be able to visualize.**

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Getting Ready: Materials Preparation

Materials For Each Student	Materials for each group	Materials for the whole class
• Lesson 12 - Student Activity Sheets	• none	• Poster paper and markers

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Learning Plan: Why does sound need matter to travel through? (2 periods 45 min each.)

Teacher Supports & Notes

Day 1 - Lesson 12 - Part 1

1. (7 min.) Remind students (invite their participation) in constructing a summary table of the scientific principles that we figured out from last time we were together A**, we figured out that:**

- **Vibrating matter (like a needle, an instrument, or a speaker) produces sound; and the same piece of matter can be forced to vibrate at different frequencies and amplitudes to produce many different sounds.**
- **Sound is not matter, but it needs matter (a medium) to move across that space that matter is in - and that can be any type of matter-gas, liquid, or solids.**
- **When the sound moves through the matter, the matter doesn't move all the way from the sound source to the ear or detector.**

Create a summary table of these scientific principles on the board

Suggested Prompts:

→ This made us wonder why or how vibrations are moving across matter, and why they would move across matter, but not across empty space?

→ This brought us to our question: What does matter have in common that is different than empty space?

Ask students to explain what they mean by 'matter'-what does it mean that things are made of matter?

Listen for *student responses* that refer to the following:

Everything is made of matter.

Additional guidance

A You can add these principles right next to the Consensus model that the class drew together last time.

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Matter is little particles.
Everything is made of little particles-even air.
Everything is made from small parts,, like atoms or molecules.

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2. (5 min.) Establish purpose for the day's lesson: to begin investigating the Lesson question: Why does sound need matter to travel through? Remind students we need common understanding of what different kinds of matter: solids, liquid, and gases have in common.

Suggested Prompts:

- ➔ We all agree that matter is the smaller stuff that things are made of-particles B But it's important for us to understand what we really mean by that for all these different types of matter we are thinking about: gases, liquids, and solid. Are all of these made of particles?
- ➔ What if anything then is different when we are thinking about how to represent the particles that solid water like ice is made of, versus water that has been boiled into the air (water vapor)?
- ➔ How about liquid water vs. water vapor?

Listen for *student responses* that refer the following:

Air particles are spaced way apart
Solid and liquid particle are spaced close together.

---

3. (10 min.) Have students work in pairs to complete Matter Models in the Lesson 11 Student Activity Sheets. To do this, assign each group two states of matter to represent: solid water (ice), liquid water, and water vapor (water as a gas).

---

4. (15 min.) Once complete, have a couple groups present their models to the class. During

Alternate Activity Order

B Students should have developed a particle model of matter in 5th grade for things like air, and mixtures like dissolved salt in water.

If students have explored particles of matter further in the middle school grades, then they may be referring to these particles as molecules or atoms.

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sharing, ask the class if we agree on three important representations that need to be included across our models:

- **Particles of the matter are included in any state of matter model**
- **There is different amount of space between the particles of matter - gases have more space between the particles than liquids or solid.**
- **The space between particles is empty space.** C

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5. (3 min.) Revisit the lesson question to establish the continued need for investigation-the next day will need to include a closer look at what's happening between sound and matter. Use this to motivate what we want to try to model in the home-learning, and the need to have those models ready to share at start of next class.

Day 2 - Lesson 12 - Part 2

6. (5 min.) Remind students of the lesson question: Why does sound need matter to travel through it? Then have students share their models from home learning with their teams, and encourage team members to share interesting pieces that they heard from their peers, or pieces from their peers' models that helped them better understand how sound moves across matter.

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7. (5 min.) Establish the need to work with the students' models further by simulating what type of interactions we think our happening between the particles of matter. Refer to yesterday's student models of air-the spacing of the particles, and any student work that shows how students think the sound moves across the air.

Have students bring their activity sheets with them and set themselves up around the room (with a bit of space between them) to represent the 'air particles'. The teacher will hold the

Alternate Activity Order

C Student at middle school will at some point, have explored the relationship between temperature and speed of particles, or have the relationship between temperature, particle motion, and states of matter related to phase changes.

If students are familiar with this idea, that it too should be included in the particle representations (particles in gases are moving faster than particles in solids or liquids).

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sound source (a large sheet of cardboard labelled sound source.

Ask students for ideas of how they could represent what would happen to show the sound moving across the room from the sound source.

Listen for *student responses* that refer the following:

Talk to each other/whisper
Bump into each other
High five

Agree to try two of the different types of ideas: talking/whispering, and high fiving.

---

8. (5 min.) First try talking/whispering. After testing this idea, discuss what worked about this representation, and what didn't. Allow students to work their way towards understanding the model's limitations, and then allow them to record their findings in their Student Activity Sheets.

Suggested Prompts:

- What about talking/whispering fits with what we think about how sound moves?
- Did we have to move a lot to do it?
- Do we think that every little particle in the air is actually 'saying' the sound out loud?
- What might that sound like if every particle was actually saying every sound we heard?

Listen for *student responses* that refer the following:

It shows us how the sound could move without us having to move too much-this fits with what we did in Lesson 9, where we figured out that the air wasn't coming out of the bag.
Yes-every little particle 'says' the sound to the next one, and that passes the sound across the matter.

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No, because if every little particle was 'saying' the sound, then it would get crazy loud and there would be echoes everywhere because the sound would be all over the room.

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9. (10 min.) Reintroduce the idea of what we know the sound source is doing when it produces a sound.

Suggested Prompts:

- ➔ What do we know the sound source is doing when it produces sounds?
- ➔ What would that do the particles in the air or particles in a liquid it is up against (like the steel bearings in the fish tank)
- ➔ Let's imagine this sheet of paper is the sound source, and it is vibrating back and forth, what would that do to the neighboring particles in the medium?

Listen for *student responses* that refer the following:

The sound source is vibrating back and forth
It would bump into the particles that are in the medium it is up against.

Tell the person/particle nearest the sound source prepare to slowly simulate what would happen to them as the sound source vibrated. Holding the sheet of poster paper vertically, move it back and forth (like a door opening and closing). Ask what this would do when it touched a particle of the medium.

Listen for *student responses* that refer the following:

The particle would be pushed / hit.
The particle would move / fly away from the thing that hit it.

Have the person who was the particle that was hit then keep moving until they come up against

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another particle. Right before hitting into the next person have them stop and ask the class what will happen when this moving particle hits the next particle.

Listen for *student responses* that refer the following:

The next particle would move / fly away from the thing that hit it.
Maybe the particle that hit it would slow down or stop moving.

Ask the students that would be involved in the particle collision to show that transfer of energy using a high five. And then have the new particle that was "hit" start moving toward the next particle. Repeat this process a few times.

Suggested Prompts:

- ➔ What about this model works better than our first model?
- ➔ How were we passing the sound in this model? What thing in real life does that remind you of?
- ➔ What might we call that when we're passing a movement by pushing or pulling or hitting each other?
- ➔ Remember that sound is a vibration, what can we call it when I pass the vibration to the next particle?

Listen for *student responses* that refer the following:

This model has us moving a little bit, but not a lot.
This model doesn't make a lot of extra noise.
We were hitting each other.
That reminds me of when we bump into each other in the hallway.
That reminds me of when dominoes fall over.
That reminds me when you break the rack when you're playing pool.
We could call that bumping or colliding.
We could call that a collision force between the particles.
We could call that passing movement/vibration/energy to the next particle.

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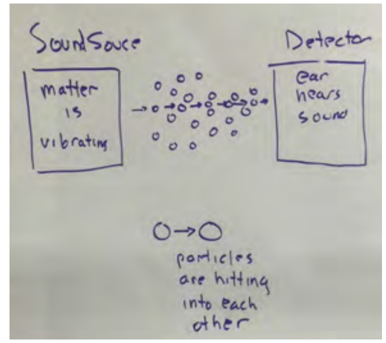
9. (10-15 min.) Come to Consensus on how these simulations can help us explain the results from our earlier investigation-when we removed the air from the container, and when we used water in place of air. By first drawing a consensus model together



Suggested Prompts: D

- ➔ Today we modeled what the system looks like with air particles in it, would we see similar interactions between particles if we simulated sound traveling through a liquid? Or a solid? How would those compare?
- ➔ How does this model help us understand why we couldn't hear any sound when we sucked the air out of the system?

Listen for *student responses* that refer the following:

Our model for Lesson 10 wouldn't have all the particles-it would just be empty.
With no particles, there's nothing to pass the sound from the source to our ear.
With water particles, there still would be particles to pass the sound from the source to our ear, but they would be spaced together more closely.
In any state of matter, particle collisions could pass the sound from the source to our ear.

---

10. (3 min.) Tell students that our goal is to use a computer program, next time in class to simulate and visualize some of the ideas that they will outline in in the Home-learning tonight. Assign the Next Steps as Home learning due the next time the class meets for science.

Alternate Activity

D These questions are also included in the student activity sheets, to support the option to assign them to students to work at in small groups if you prefer, before discussing ideas.

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Alignment With Standards

Building Toward Target NGSS PE

- **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.
- **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.]

Building Toward Common Core Standards ELA

Comprehension and Collaboration:
CCSS.ELA-LITERACY.SL.6.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- CCSS.ELA-LITERACY.SL.6.1.B Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed
- CCSS.ELA-LITERACY.SL.6.1.C Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

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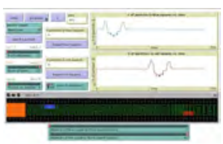
Lesson 13: What Exactly Is Traveling Across The Medium?

Middle School Unit: How Can I Hear So Many Different Sounds From Across The Room?

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,
MS-PS4-1,
MS-PS4-2,
MS-LS1-8
	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 result from changing the frequency and amplitude of vibrations at the sound source.*	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:
			    • 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.

These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.

Getting Ready: Materials Preparation

Materials For The Class

- PI of NetLogo Simulation Results to display
- Project and computer to display the image above onto a whiteboard.
- Whiteboard markers.

Materials For Each Student

- Lesson 13 - Student Activity Sheets
- A laptop or chomebook with a web browser to access the internet. Students should be able to save a downloaded file to the computer they are using (e.g. to google drive)

Preparation of Materials (15 min.)

- Test the Sound Across A Medium Introduction Video to make sure it plays on the computer you are using to project to the class.
- Make sure that you and students can get to this web site: http://goo.gl/mTPUZp and that student computers can download the model following the directions on the first page of their student activity sheets.

Getting Ready: Teacher Preparation

Background Knowledge

- NetLogo web (http://www.netlogoweb.org/) is freely available. It was developed the the Center for Connected Learning at Northwestern University.

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Linking Our Understanding to Scientific Terminology

- Compression Wave
- Wavelength

These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.

Learning Plan: What Exactly Is Traveling Across The Medium? (2 periods of 45 min each)

Day 1

1. (8 min) Begin with a Sharing Initial Ideas Discussion to have students share out their responses to the Next steps prompts from their home-learning in the previous lesson:

Suggested Prompts:

- ➔ In the home-learning you thought about the kind of objects, interactions, and visualization you would want to see included in such computer simulation that would help you understand more how across sound travels across a medium. Let's share some of those out… What sort of things would you want to be able to adjust about the sound source in that simulation?
- ➔ What sort of particle interactions would you need included in the simulation?
- ➔ What sort of things would you want to be able to visualize?

Listen for *student responses* A that refer to what we figured out last time, such as:

- ➔ *We wanted to be able to adjust the frequency and amplitude of the sound source*
- ➔ *We wanted to be able to see particles running into each other / colliding with each other.*
- ➔ *It would be nice the particles across the entire medium.*
- ➔ *It would be nice to be able to watch the sound move across the medium and pause it (freeze frame the simulation) like we did when we were simulating it with people as particles.*

Suggested Prompts:

- ➔ How might running a computer simulation that includes all the things you listed above help us better understand what exactly is traveling across the medium, when a sound moves from sound source to my ear or from a truck stereo to a window in a building across the parking lot.

Teacher Supports & Notes

Strategies for this Sharing Initial Ideas Discussion

A The goal of this discussion is to remind ourselves of what it is we wanted in the simulation that we will be using today and why, justifying what needs to be in the simulation based on what we know so far about sound.

This discussion will help student orient themselves to what will be in the simulation before they ever run it and will increase the sense of coherency for students, since it will feel like outlined the specifications for the simulation they wanted to be able to work with - making it feel like they had a hand in co-constructing it.

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Accept all *student responses*

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2. (7 min) Have students download the Sound Across A Medium model from this location: http://goo.gl/jEQOMa and save it to their desktop.

Play the Sound Across A Medium Introduction Video to the entire class to give them a general orientation to using NetLogo Web to show how to upload and run the model file.

Tell students that they will be conducting four investigations over the next couple of days. The procedures first two investigations can pursued independently today, but parts of the making sense and conclusion sections for the activities will be done with partners or the whole class. B

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3. (10 min) Have students complete the prediction questions for Investigation 1 on their student activity sheets.

Then have students complete the procedure and observation section for investigation 1. B

Check to see if students are getting the model running. Encourage people sitting near each other to check in with the elbow partners to make sure they can get the uploaded model running.

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4. (15 min) Have students independently complete the prediction question, and the procedure and observation sections for investigation 2.

Day 2

5. (7 min) Project the PI of NetLogo Simulation Results. Tell students that frame 1 is from the start of the simulation, frame 2 is later, and frame 3 is toward the end of the simulation run. Ask

Additional Guidance

B It is recommended that you set a timer to limit the time for each of these steps

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students to describe what these frames from the simulation run show us is happening to the matter in the medium after a sound source vibrates back and forth a couple of times.

Suggested Prompts:
- ➔ What are these brighter bands showing?
- ➔ What is between the bright bands?

Listen for *student responses* [A] that refer to what we figured out last time, such as:

- ➔ *The bright bands are where the particles are compressed together*
- ➔ *Between the bright bands are where the particles are more spread apart.*

Remind students that we discovered that all matter is springy and this includes gases like air, and that when you squish it springs back. Ask students to give example of objects filled with air that behave this way.

Listen for *student responses*, such as:

Basketballs, bike tires, air mattresses...

Remind that we know that the particles don't move all the way from the sound source to the window or our ear, but that they do move. Ask students what the motion looked like in the simulation when they are getting compressed together and when they are spreading apart.

Listen for *student responses*, such as:

- ➔ *They move back and forth*
  They go one direction and then back and then back again.

---

6. (5 min) Start co-constructing representation of these bands of denser and less densely packed particles together on the PI of NetLogo Simulation Results. Have students make a record this

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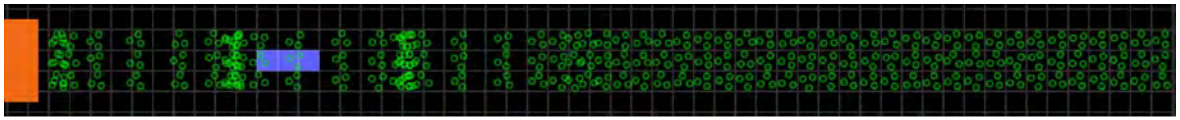
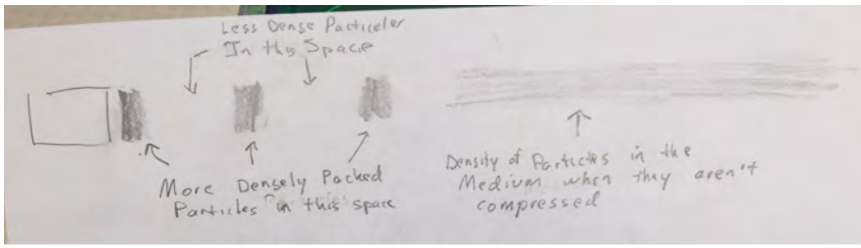
model representation too on their Conclusion section of their Student Activity Sheets.

Frame 1





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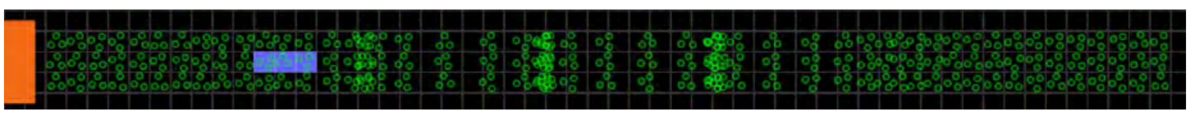
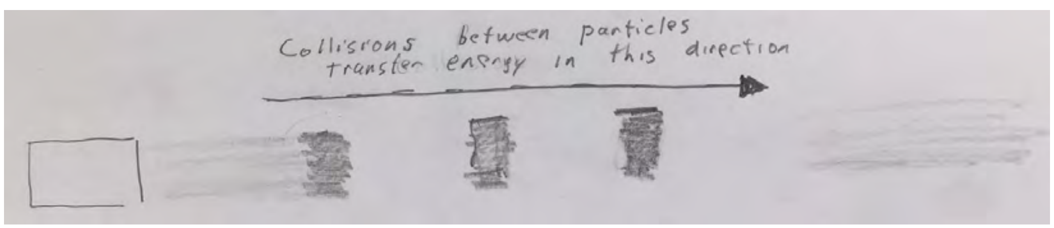
7. (5 min) In frame 2, add the arrow representation shown below. Remind students that we have always had an arrow representing the movement of sound. Now we know that that arrow represents the direction of energy transfer through collisions between particles in the medium.

Frame 2





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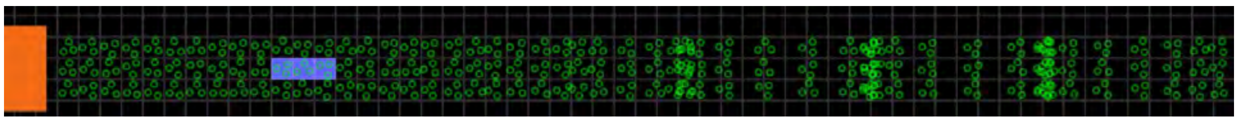
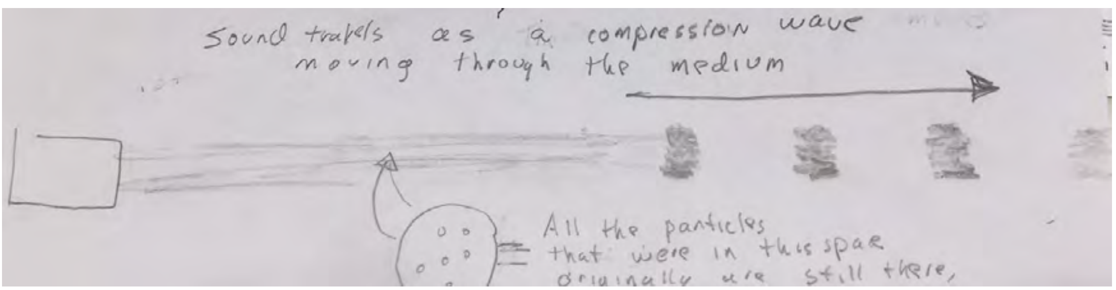
8. (7 min) In frame 3, emphasize that the arrow is showing the sound is moving, and it is moving due to a compression wave traveling through the matter, which is springy due to collisions between particles. Add a representation of the particles in the medium after the compression wave moves through - showing that all the particles in the matter still remind in their space after the wave has passed through them.

Frame 3





Point out that the distance between one compression bands and another doesn't change. Emphasize that this distance is another way that scientists describe these type of waves and it is referred to as the wave length. Tell students that this can be visualized as the distance from where the particle density is highest at one spot in the medium to the next spot where the particle density is highest.

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9. (15 min) Have students work with partners to complete the questions in the Getting Ready to Apply and Assess Your Understanding section of their Student Activity Sheets. C

Formative Assessment Opportunities

C Listen in on student conversations during this portion of the lesson to see if they are using ideas related to vibrations of the source source, collisions between water particles, energy transfer, and changes in that happen in particle density across the medium.

You may want to collect this last sheet of the student activity guides to give students feedback on their explanations

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Alignment With Standards

Building Toward Target NGSS PE

- **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.
- **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.]

Building Toward Common Core Standards ELA

Comprehension and Collaboration:
CCSS.ELA-LITERACY.SL.6.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- CCSS.ELA-LITERACY.SL.6.1.B Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed
- CCSS.ELA-LITERACY.SL.6.1.C Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

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Lesson 14: How does the matter in-between the sound source and my ear help the sound reach my ear? (or the window)

Middle School Unit: How Can I Hear So Many Different Sounds From Across The Room?

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) 50-60 min. **(Optional Embedded Assessment #2:)** *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** 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 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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Getting Ready: Materials Preparation

Materials For Each Student	Materials for each group	Materials for the teacher
• Lesson 14 - Student Activity Sheets (1) • Lesson 14: Home-learning	• None	• Use Lesson 14 - Key for Assessment to guide assessment of student understanding. • Posters and markers

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Learning Plan: How does the matter in-between the sound source and my ear help the sound reach my ear? (or the window) (50-60 min)

Teacher Supports & Notes

1. (5 min.) Revisit classroom Incremental Model from Lesson 13, which includes how particles collide, compress, and decompress to transfer a vibration (sound). We'll use those discoveries up to this point to better explain what's going on with our anchoring phenomenon.

[Incremental Model from Lesson 13]

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2. (15 min.) Go back to the interaction between the needle and the record-looking closely at the surface of the record showed us that there were lots of little bumps and grooves (project this image for students to see) which the needle dragged across. We think that the bumps and grooves were able to bend the needle-pushing it back and forth. Work with students to take stock and summarize progress to this point using a summary table:

Summary Table

What we saw:	What we figured out:
Needle moved in the grooves	• Vibrating matter makes sound • The needle is getting bounced around, it's vibrating → sound • The needle is springy: - When it bends a lot it makes a louder sound (amplitude) - When it bends more often, the pitch goes up (frequency)

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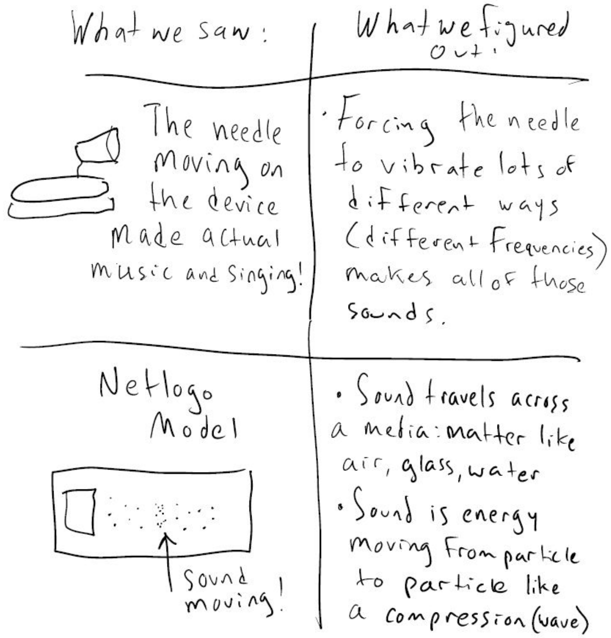
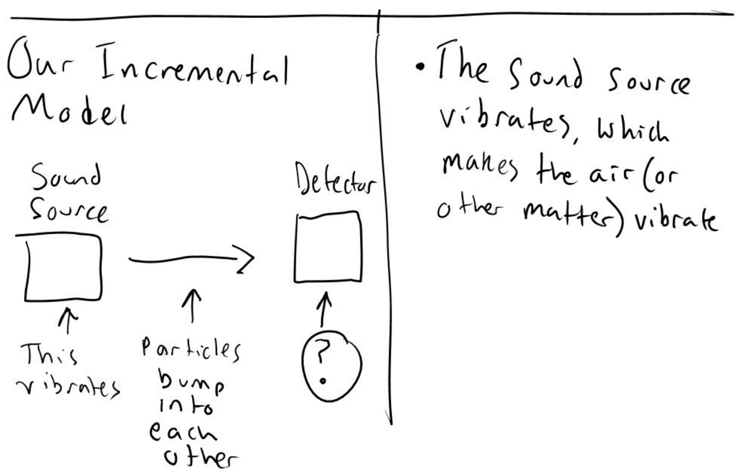


4. (5 min.) Revisit the Incremental Model to develop latest version (below) and to establish our next question: What is going on inside my ear? Use understanding gained from modeling the vibrating glass to establish that the Detector must be vibrating when the sound reaches it.



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5. (25-30 min.) After determining progress to this point, refer students back to the phenomenon of the truck speakers making the windows vibrate. Ask students to use the Lesson 14 Activity Sheet to model (using what we figured out in Lesson 13) to explain how and why this happens.

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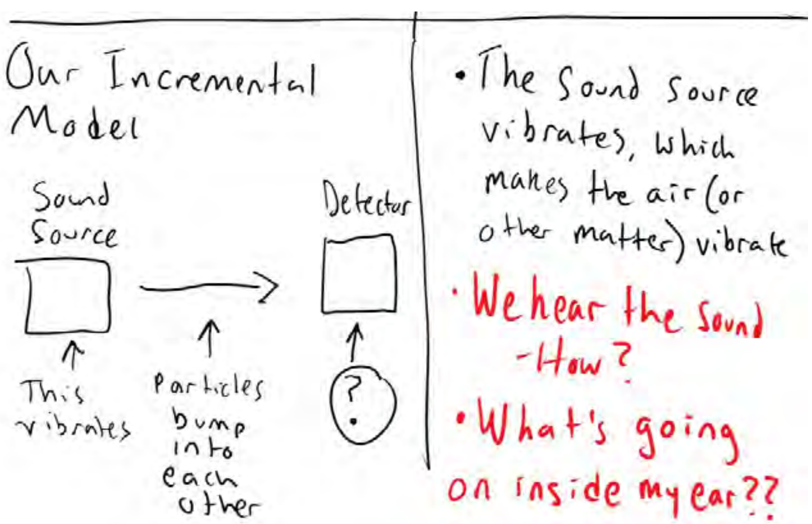
5. (5 min.) After students have the chance to share their understanding (or turn it in as a formative assessment), add a representation of those that to the Summary Table.

Suggested Prompts:

- We know that our ears are often the detector, and we know that we hear the sound-but we still have no idea how that works? What are some ideas that we have? Get your thoughts on paper in the Lesson 14 Student Activity Sheet. (Allow students time to model their predictions) So questions do we have now?

Listen for *student responses* that refer the following:

What happens when the particle compressions get to my ear?
How is my ear detecting the sound? How do I hear the sound when it gets to my ear?
Does my ear move when I hear the sound? Does the air moving in my ear make me hear?



Formative or Summative Assessment Opportunity

A Use this model as either a formative or summative assessment of student understanding for the 2nd of third bends in the unit.

Have students turn in their student activity sheets as the assessment, and then use the remaining page to complete the rest of this lesson.

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What is going on inside my ear when I hear something?

Suggested Prompts:

- ➔ Knowing that these are our questions, what could we do next to start to figure out what's happening with the detector, our ears?

Listen for *student responses* that refer the following:

We need to look at the detector
We need to look at our ears
We need to see inside our ears
We need to see the sound go in the ear
We need to see the sound hit the ear
We need to see if our ears vibrate

Assign the Lesson 14 home-learning to students to brainstorm ideas for how this might work.

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