

**Synopsis:** In this unit, students start by observing a perplexing phenomenon. When a sewing needle taped to a cone is dragged over the surface of a plastic disc that is spun underneath it, voices and musical notes can be heard coming from it. This leads students to start wondering about other sound related phenomena, which in turn leads to a wealth of new questions about: 1) What causes different sounds? 2) What is traveling from a sound source to our ears? 3) Wow do we hear and why do we hear things differently in different places? 4) How do electronic devices (digital sound sources) produce and detect sounds?

- By investigating things like loudness and pitch, students figure out a model of vibration that captures important ideas about changes in the frequency and amplitude of the vibrations that can explain these different characteristics of sounds. What they figure out from this helps answer their initial questions about what causes different sounds.
- By testing various types of materials and types of simulations, students figure out how sound travels from one location to another through matter. What they figure out from this helps answer their initial questions about what is traveling from a sound source to our ears.
- By investigating the internal structure of the ear and by designing and testing how different structures can redirect sounds, students figure out how sounds can be detected, reflected, absorbed, and transmitted. What they figure out from this helps answer their initial questions about how we hear and why we hear things differently in different places.
- By dissecting an electronic speaker and building and testing a speaker of their own design and by analyzing how Edison wax cylinders and vinyl records were produced, students figure out how analog and digital audio information can be encoded and played back. What they figure out from this helps answer their initial questions about how electronic devices (digital sound sources) produce and detect sounds.

| NGSS PERFORMANCE EXPECTATIONS BUNDLE              |          |   |
|---|----------|---|
| MS. Waves and Electromagnetic Radiation           |          |   |
| MS-PS4-1  | MS-PS4-2 | MS-PS4-3  |
| MS. Motion and Stability: Forces and Interactions |          | MS. Structure, Function, & Information Processing |
| MS-PS2-3 (partial)                                |          | MS-LS1-8 (partial)                                |
| MS. Energy  |          |   |
| MS-PS3-5 (partial)                                |          |   |



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- Alpha version of storyline piloted (Spring, 2016).
- Design team expanded (Summer, 2016).
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- Beta version of storyline developed and sent to Achieve (Jan., 2017).
- v1.0 field trials pilot (Spring, 2017).
- Editorial team expanded (Summer, 2017).
- v2.0 field trials pilot - Learning While Teaching (Fall, 2017).
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## Table of Contents

|  |           |
|--|-----------|
| <b>A. What is This Unit About? .....</b>   | <b>4</b>  |
| <b>B. What is a Storyline? .....</b>   | <b>4</b>  |
| <b>C. What NGSS Performance Expectations Does This Storyline Target?.....</b>                | <b>6</b>  |
| <b>D. How Long is This Unit and What DCIs and CCCs are Targeted in Each Part of It? ....</b> | <b>8</b>  |
| <b>E. What Do Students Investigate and Figure Out in Each Lesson?.....</b>                   | <b>10</b> |
| <b>F. What Unit Planning Resources Are There? .....</b>                                      | <b>12</b> |
| <b>G. What Lesson Planning Resources Are There?.....</b>                                     | <b>13</b> |
| <b>H. What Assessments Resources Are There?.....</b>   | <b>14</b> |
| <b>I. How Can Teachers Use Similar Instructional Routines Across Lessons?.....</b>           | <b>23</b> |
| <b>J. How Can Teachers Support Different Types of Discussions?.....</b>                      | <b>29</b> |
| <b>K. How Can Teachers Support the Development of Scientific Terms?.....</b>                 | <b>35</b> |
| <b>L. How Can Teachers Support Differentiated Instruction? .....</b>                         | <b>36</b> |



## A. What is This Unit About?

In this middle school unit on waves, students investigate how sounds occur, fueled by trying to account for a perplexing anchoring phenomenon, where music and voices are heard coming from a paper cup and needle as it is dragged over the surface of a vinyl disc. In this unit, teachers help students develop plans for a series of investigations through which they incrementally build a model of what causes sound, how sound travels, and how it is detected and encoded. This leads students to develop the idea of vibrations and sound waves in order to explain the patterns they observe across different parts of a system.

This unit illustrates how students can incrementally build a model over time, through investigations that are motivated by their initial questions rather than needing to learn about the related science ideas ahead of time before planning and conducting such investigations.

## B. What is a Storyline?

This unit is a storyline. A storyline is an instructional unit that is a coherent sequence of lessons, in which each step is driven by students' questions that arise from their interactions with phenomena. A student's goal across a storyline should always be to explain a phenomenon or solve a problem. At each step, students should make progress on the classroom's questions through science and engineering practices, to help figure out a piece of a science idea. Each piece they figure out should add to the developing explanation, model, or designed solution.

Each step may also generate new questions that lead to the next step in the storyline. Together, what students figure out helps explain the unit's phenomena or solve the problems they have identified. A storyline provides a coherent path toward building a disciplinary core idea and crosscutting concepts, piece by piece, anchored in students' own experiences and questions.

Often the reason a particular problem or idea is important is clear to the teacher, but not to the students. For example, the teacher knows how learning about the cell will help with important biological questions, but to the students, they are learning about cells because that's the title of the current chapter in the textbook. The teacher may know how a particular chemistry experiment will help understand something about conservation of matter, but to the students, they are doing the experiment because they are following the directions.

In a storyline, the coherence is designed to make sense from the students' perspective, not just the teacher's. When a storyline is coherent from the student perspective, on any given day, a visitor to the classroom should be able to walk over to a group of students and ask them:

- What are you working on?
- Why are you working on this?



Students should be able to answer by describing a question they are trying to figure out or a problem they are trying to solve, and not just say because the teacher told them to do this. And they should be able to explain how they helped the classroom community decide how they should go about it.

Figuring out is not a process you can do by jumping from topic to topic or from lab to lab. Practices are more than just technical skills, like learning to use a microscope or when to wear goggles. Practices refer to how a community works together, guided by common goals, norms, and language, to make progress. Science and engineering practices guide the work with phenomena and problems so students can develop, test, and refine science ideas.

So each storyline is a path in which all the students help manage the trajectory of their knowledge building. The class as a whole, which includes all students and their teacher, develop ideas together over time, motivated by questions about phenomena in the world, where each step is an attempt to address a question or a gap in the classes' current explanatory model. The storyline approach supports students' agency in sensemaking:

- WE figure out the science ideas.
- WE figure out where we are going at each step.
- WE figure out how to put the ideas together over time.

So, how will WE orchestrate our sensemaking? The answer is a storyline. The bottom line is that a storyline reflects a way to support sensemaking that is coherent from the students perspective.



## C. What Performance Expectations Does This Storyline Target?

### Targeted NGSS Performance Expectations:

**1-PS4-1.** Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate. [Clarification Statement: Examples of vibrating materials that make sound could include tuning forks and plucking a stretched string. Examples of how sound can make matter vibrate could include holding a piece of paper near a speaker making sound and holding an object near a vibrating tuning fork.]

**4-PS4-1.** Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move. [Clarification Statement: Examples of models could include diagrams, analogies, and physical models using wire to illustrate wavelength and amplitude of waves.]

**MS-PS4-1.** Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. [Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.]

**MS-PS4-2.** Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.]

**MS-PS4-3.** Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. [Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.]

**MS-LS1-8. (Partial)** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

**MS-PS3-5. (Partial)** Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.]

**MS-PS2-3. (Partial)** Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.]





These are the related science and engineering practices, disciplinary core ideas and cross-cutting concepts that the storyline targets:

| Science & Engineering Practice(s)  | Disciplinary Core Ideas - DCI(s)   | Cross-Cutting Concept(s) - CCC(s)   |
|--|--|---|
| <p><b>Asking Questions and Defining Problems</b></p> <ul style="list-style-type: none"> <li>Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. (MS-PS2-3)</li> </ul> <p><b>Developing and Using Models</b></p> <ul style="list-style-type: none"> <li>Develop and use a model to describe phenomena. (MS-PS4-2)</li> </ul> <p><b>Using Mathematics and Computational Thinking</b></p> <ul style="list-style-type: none"> <li>Use mathematical representations to describe and/or support scientific conclusions and design solutions. (MS-PS4-1)</li> </ul> <p><b>Obtaining, Evaluating, and Communicating Information</b></p> <ul style="list-style-type: none"> <li>Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings. (MS-PS4-3)</li> <li>Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. (MS-LS1-8)</li> </ul> <p><b>Connections to Nature of Science</b></p> <p><b>Scientific Knowledge is Based on Empirical Evidence</b></p> <ul style="list-style-type: none"> <li>Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS4-1)</li> </ul> | <p><b>PS4.A: Wave Properties</b></p> <ul style="list-style-type: none"> <li>Sound can make matter vibrate, and vibrating matter can make sound. (1-PS-4-1)</li> <li>Waves of the same type can differ in amplitude and wavelength. (4-PS4-1)</li> <li>A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1)</li> <li>A sound wave needs a medium through which it is transmitted. (MS-PS4-2)</li> </ul> <p><b>PS1.A: Structure and Properties of Matter</b></p> <ul style="list-style-type: none"> <li>Matter of any type can be subdivided into particles that are too small to be seen... (5-PS1-1)</li> </ul> <p><b>PS4.B: Electromagnetic Radiation</b></p> <ul style="list-style-type: none"> <li>However, because light can travel through space, it cannot be a matter wave, like sound or water waves. (MS-PS4-2)</li> <li>When light* shines on an object, it is reflected, absorbed, or transmitted through the object. (*referenced for sound in the evidence statement for MS-PS4-2)</li> </ul> <p><b>PS4.C: Information Technologies and Instrumentation</b></p> <ul style="list-style-type: none"> <li>Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (MS-PS4-3)</li> </ul> <p><b>PS1.B: Conservation of Energy and Energy Transfer</b></p> <ul style="list-style-type: none"> <li>When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5)</li> </ul> <p><b>LS1.D: Information Processing</b></p> <ul style="list-style-type: none"> <li>Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories. (MS-LS1-8)</li> </ul> <p><b>PS2.B: Types of Interactions</b></p> <ul style="list-style-type: none"> <li>Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3)</li> </ul> <p><b>Connections to the Preamble for PS4.A</b></p> <ul style="list-style-type: none"> <li>Sound is a pressure wave in air or any other material medium.</li> <li>The human ear and brain working together are very good at detecting and decoding patterns of information in sound (e.g., speech and music) and distinguishing them from random noise.</li> <li>When a wave meets the surface between two different materials or conditions (e.g., air to water), part of the wave is reflected at that surface and another part continues on.</li> </ul> <p><b>Connections to Chapter 9 of the Framework (Integrating the three dimensions)</b></p> <ul style="list-style-type: none"> <li>The role of forces between particles also begins to be discussed in grade 6—topics include the recognition that particles in a solid are held together by the forces of mutual attraction and repulsion (which act like springs) and that there are forces between particles in a gas that cause them to change their paths when they collide.</li> </ul> | <p><b>Patterns</b></p> <ul style="list-style-type: none"> <li>Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena. (4-PS-1)</li> <li>Graphs and charts can be used to identify patterns in data. (MS-PS4-1)</li> </ul> <p><b>Structure and Function</b></p> <ul style="list-style-type: none"> <li>Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS4-2)</li> <li>Structures can be designed to serve particular functions. (MS-PS4-3)</li> </ul> <p><b>Cause and Effect</b></p> <ul style="list-style-type: none"> <li>Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3 and MS-LS1-8)</li> </ul> <p><b>Energy and Matter</b></p> <ul style="list-style-type: none"> <li>The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS3-5)</li> </ul> <p><b>Connections to Engineering, Technology, and Applications of Science</b></p> <ul style="list-style-type: none"> <li>Influence of Science, Engineering, and Technology on Society and the Natural World Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. (MS-PS4-3)</li> </ul> <p><b>Connections to Nature of Science - Science is a Human Endeavor</b></p> <ul style="list-style-type: none"> <li>Advances in technology influence the progress of science and science has influenced advances in technology. (MS-PS4-3)</li> </ul> |



## D. How Long is This Unit and What DCIs and CCCs are Targeted in Each Part of It?

The complete unit is 37.5 periods long. This includes four embedded assessments. Each period is assumed to be 40-45 minutes in length.

This unit is broken into four different Bends. A Bend is an interconnected series of lessons that explores a set of investigations motivated by a related set of student questions. Each Bend targets different parts of the PEs and related DCIs.

This page and the next describe which Bends target which set of Disciplinary Core Ideas (DCIs) and which Bends target which performance expectations.

There are multiple options for shorter implementations of a smaller portion of the storyline. These options are described below.

| Bend 1                               |                    | Bend 2                 |                    | Bend 3                   |                    | Bend 4                                |                    |
|--------------------------------------|--------------------|------------------------|--------------------|--------------------------|--------------------|---------------------------------------|--------------------|
| How do different objects make sound? |                    | How does sound travel? |                    | How can we detect sound? |                    | How do speakers and microphones work? |                    |
| Lesson Number                        | # of class periods | Lesson Number          | # of class periods | Lesson Number            | # of class periods | Lesson Number                         | # of class periods |
| 1                                    | 3.5                | 8                      | 1                  | 14                       | 1                  | 21                                    | 1                  |
| 2                                    | 1.5                | 9                      | 1                  | 15 <sup>C</sup>          | 2                  | 22                                    | 1                  |
| 3*                                   | 1.5                | 10                     | 1                  | 16                       | 2                  | 23*                                   | 2                  |
| 4 <sup>A</sup>                       | 1                  | 11 <sup>B</sup>        | 1                  | 17                       | 2                  |                                       |                    |
| 5                                    | 1                  | 12                     | 2                  | 18                       | 1                  |                                       |                    |
| 6                                    | 1                  | 13*                    | 2                  | 19                       | 1                  |                                       |                    |
| 7*                                   | 3                  |                        |                    | 20*                      | 3                  |                                       |                    |
| total                                | 12.5               | total                  | 9                  | total                    | 10-12              | total                                 | 4                  |

\* Embedded summative assessment included in this lesson

<sup>A</sup> If students have completed a contact forces unit that developed the idea that all solids are elastic up to a point, this will take less time. See Teacher Background knowledge section in the Teacher Guide for Lesson 4.

<sup>B</sup> If students have completed a contact forces unit that developed the idea that all solids are elastic up to a point, this will take less time. See Teacher Background knowledge section in the Teacher Guide for this lesson.

<sup>C</sup> Lesson 15 is math intensive. The math concepts targeted in this lesson (and the related PE) are aligned to the Common Core math standards for 8th grade.

Options and Total length for each option (without compacting lessons 4 or 11):

- **Option A: Do all lessons in Bends 1 and 2 only.** Total length: 21.5 periods.
- **Option B: Do all lessons in Bends 1, 2, and 3, but without Lesson 15\*.** Total length: 31.5 periods
- **Option C: Do all lessons in Bends 1, 2, and 3.** Total length: 33.5 periods.
- **Option D: Do all lessons in Bends 1, 2, 3 and 4.** Total length: 37.5 periods.

This table explains which performance expectations will be met with each option:

| Targeted Performance Expectations:  | Option A: | Option B: | Option C: | Option D: |
|---|-----------|-----------|-----------|-----------|
| <b>1-PS4-1.</b> Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.  | full      | full      | full      | full      |
| <b>4-PS4-1.</b> Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.  | full      | full      | full      | full      |
| <b>MS-PS4-1.</b> 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.                                    | partial   | partial   | full      | full      |
| <b>MS-PS4-2.</b> Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.  | none      | full      | full      | full      |
| <b>MS-PS4-3.</b> 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. | none      | none      | none      | full      |
| <b>MS-LS1-8. (Partial)</b> Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.                  | none      | partial   | partial   | partial   |
| <b>MS-PS3-5. (Partial)</b> 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.                   | partial   | partial   | partial   | partial   |





**MS-PS2-3. (Partial)** Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

none

none

none

partial

Each of the Four Bends Addresses A Different Portion of the DCIs:

Bend 1

Bend 2

Bend 3

Bend 4

#### Disciplinary Core Ideas - DCI(s)

##### PS4.A: Wave Properties

- Sound can make matter vibrate, and vibrating matter can make sound. (1-PS-4-1)
- Waves of the same type can differ in amplitude and wavelength. (4-PS4-1)
- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1)
- A sound wave needs a medium through which it is transmitted. (MS-PS4-2)

##### LS1.D: Information Processing

- Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories. (MS-LS1-8)

##### PS1.A: Structure and Properties of Matter

- Matter of any type can be subdivided into particles that are too small to be seen... (5-PS1-1)

##### PS4.B: Electromagnetic Radiation

- However, because light can travel through space, it cannot be a matter wave, like sound or water waves. (MS-PS4-2)
- When light\* shines on an object, it is reflected, absorbed, or transmitted through the object. (\*sound is also referenced in the evidence statements for MS-PS4-2 for these wave like properties in its interaction with matter)

##### PS4.C: Information Technologies and Instrumentation

- Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (MS-PS4-3)

##### PS3.B: Conservation of Energy and Energy Transfer

- When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5)

##### PS2.B: Types of Interactions

- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3)

#### Connections to the Preamble for PS4.A

- Sound is a pressure wave in air or any other material medium.
- The human ear and brain working together are very good at detecting and decoding patterns of information in sound (e.g., speech and music) and distinguishing them from random noise.
- When a wave meets the surface between two different materials or conditions (e.g., air to water), part of the wave is reflected at that surface and another part continues on.

| Each of the bends uses different combinations of cross-cutting concepts.<br>These cross-cutting concepts are listed below:                                   | bend |     |     |     |
|--|------|-----|-----|-----|
|  | 1    | 2   | 3   | 4   |
| Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena.                            | yes  |     |     |     |
| Graphs and charts can be used to identify patterns in data.  | yes  |     | yes |     |
| Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. | yes  |     | yes | yes |
| Cause and effect relationships may be used to predict phenomena in natural or designed systems.  | yes  | yes | yes | yes |
| The transfer of energy can be tracked as energy flows through a designed or natural system.  |      |     | yes | yes |
| Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations.   | yes  | yes | yes |     |
| Advances in technology influence the progress of science and science has influenced advances in technology.  | yes  |     | yes | yes |



## E. What Do Students Investigate and Figure Out in Each Lesson?

The diagram below outlines the sequence of each lesson across the storyline. A larger four page version of this resource (called the skeleton) is available at <http://www.nextgenstorylines.org/how-can-hear-so-many-different-sounds>.





## Sample Driving Question Board

The image below shows an example of the questions that students posted to The Driving Question Board (DQB) at the end of the first lesson of this storyline. The questions are from four classes of sixth grade students. The types of questions that middle school students form are **very similar** across the multiple pilots we have conducted in grades 6th through 8th across the country.

The color coding overlay on top of the photo, shows which questions the students will be able to answer by the end of the corresponding bend of the storyline. Being able to answer many of questions that are initially raised is very satisfying milestone in a classroom community that uses the driving question board (DQB) as a representation of their joint mission statement.

Students may add new questions to the DQB over the course of the unit, so make sure to mark which questions are the initial questions on the DQB after lesson 1, so your class can take stock of which of the initial questions they have answered by the end of the unit.

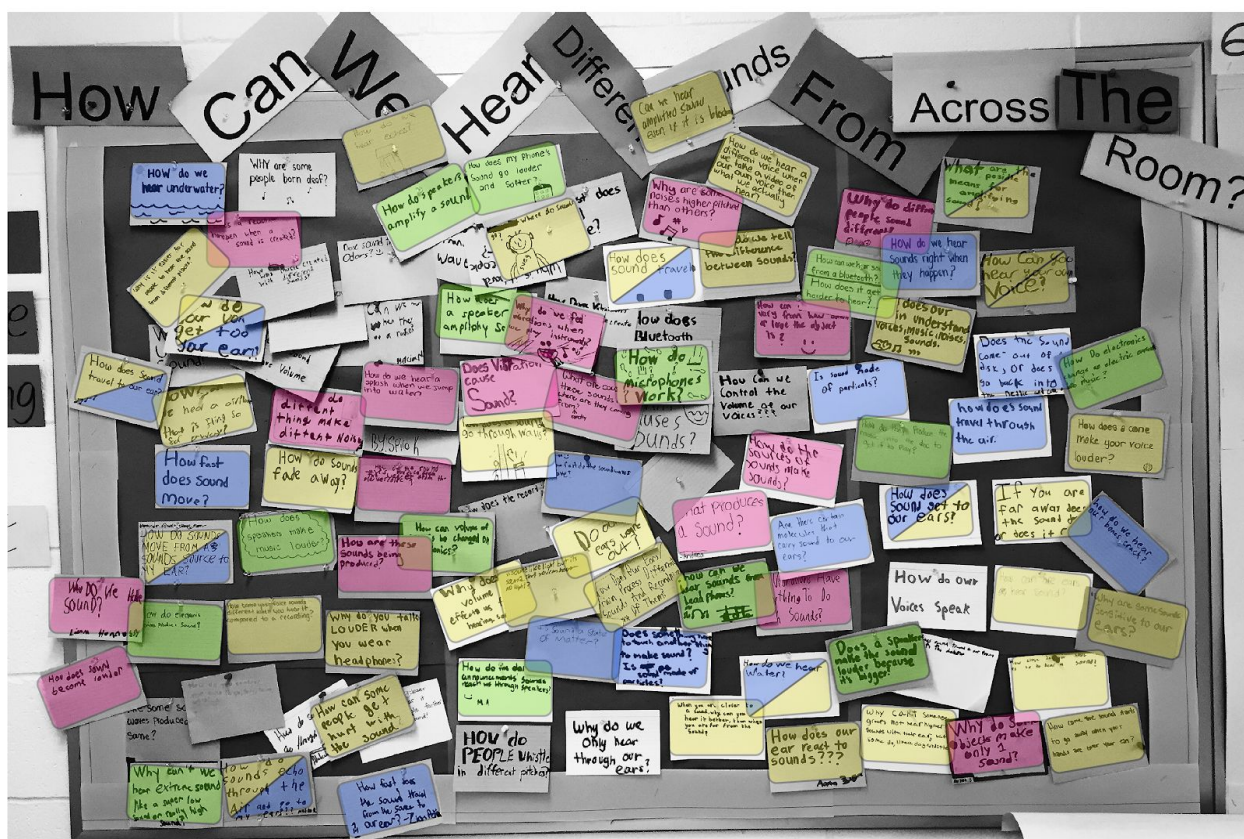
These Four Colors Correspond to a Set of Connected Investigations (a bend)  
That Help Student Develop an Answer to This Question:

bend 1

bend 2

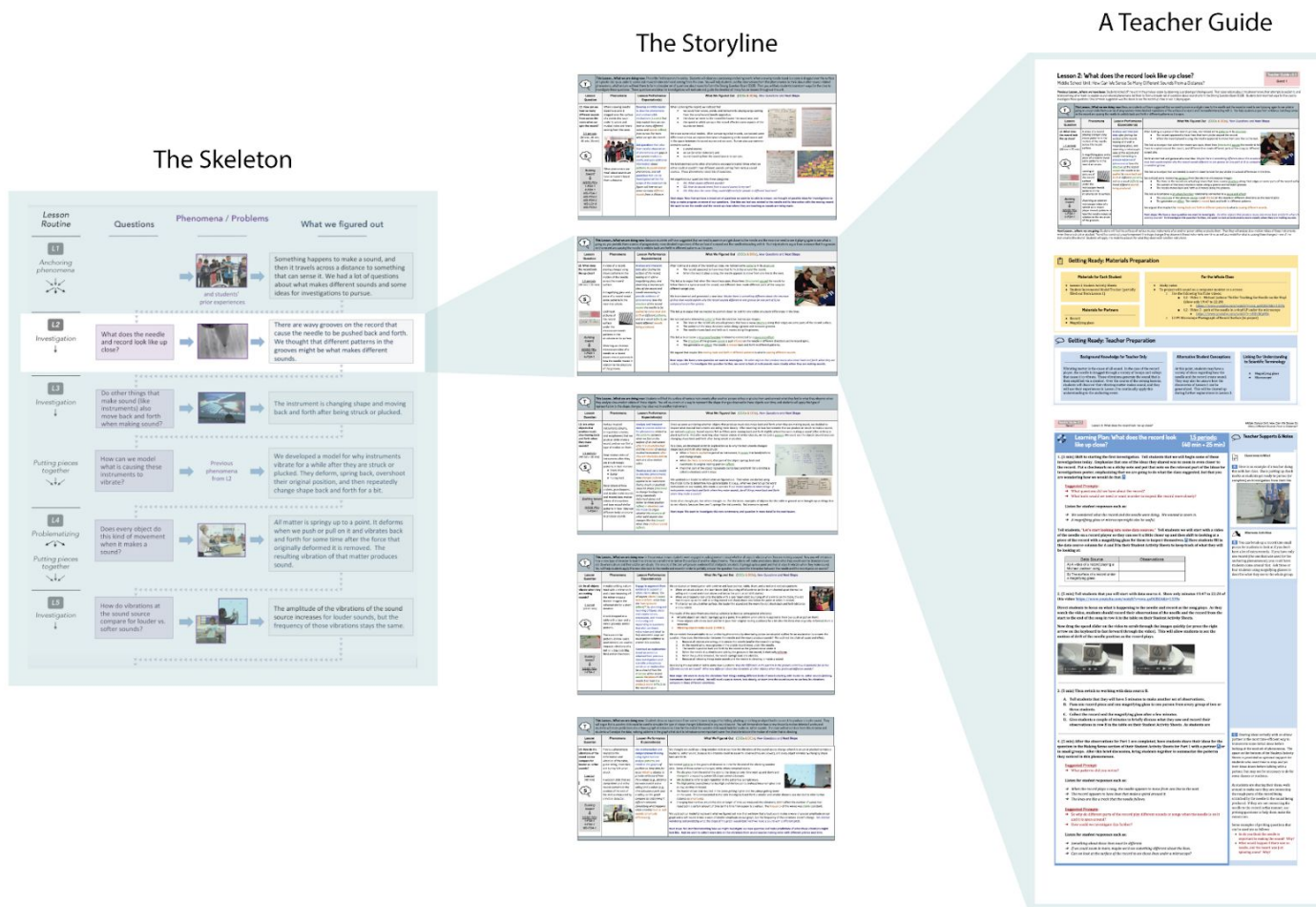
bend 3

bend 4



## F. What Unit Planning Resources are Available?

There are three main unit planning resources available. They are the skeleton, the storyline, and the teacher guides. As suggested in the diagram below, each of these resources provides progressively finer detail about what is in a particular lesson in the unit.



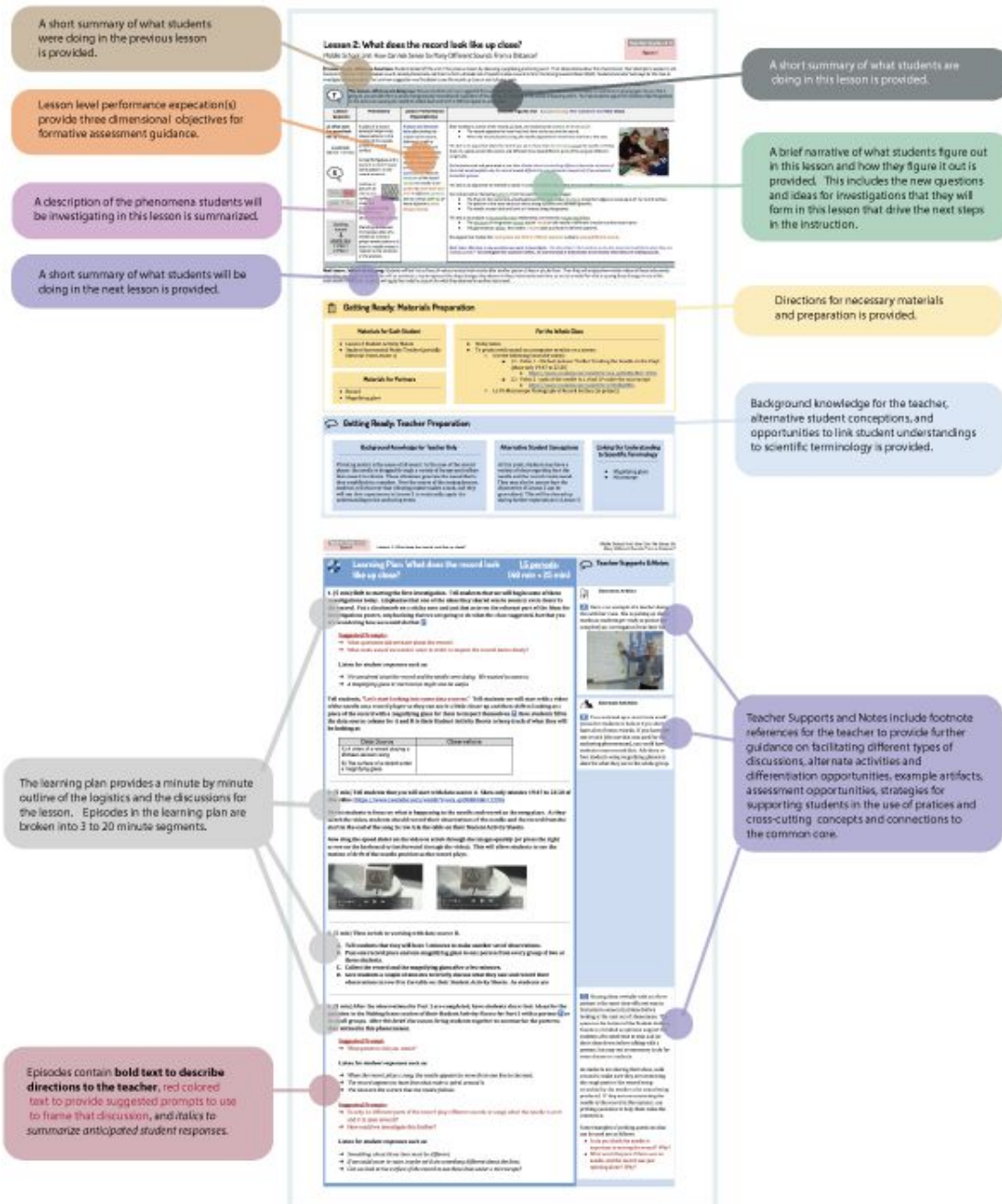
- The skeleton includes the question that students will investigate in each lesson and a photo/diagram of one of the related phenomena they will investigate in that lesson. It also includes a two to four sentence summary of what students figure out for that lesson. In the diagram above, this portion of the skeleton shows this for the first five lessons of the unit.
- The storyline provides a more detailed description of what students will investigate in each lesson, with each lesson summarized in its own table. Each table is 1-2 pages in length, and is referred to as the roadmap for that corresponding lesson. Each roadmap includes lesson level, performance expectations, connections to the previous lesson and the next, and a more detailed narrative of what the class is doing in that lesson. In the diagram above, the first five roadmaps in the storyline are shown.
- Every roadmap has a corresponding teacher guide. The first few pages of the teacher guide include the roadmap for that lesson, background information for the teacher and a learning plan. The learning plan provides a minute by minute guide to



help the teacher coordinate and facilitate the learning activities. Additional details about these and other supports included in each lesson plan are summarized on the next page.

## G. What Lesson Planning Resources are Available?

Each Teacher Guide for every lesson has a similar structure. This structure is outlined in the example shown below.





Each lesson may include additional resources, such as student activity sheets, data packets, video clips, readings, home learning assignments, and projected images (PIs). All related resources for the lesson will be referenced in the Materials Preparation section of the Teacher Guide.

## H. What Assessments Resources Are There?

### Pre-Assessment

Lesson 1 of the unit provides an embedded pre-assessment. The pre-assessment targets the two lesson performance expectations (LPEs) identified in the roadmap of this lesson. The table below provides a summary of those LPEs and what students are asked to do that provides evidence of meeting them.

| Lesson Performance Expectation in Lesson 1   | What is the format of this assessment?  |
|--|---|
| <b>Develop an initial model to describe phenomena and unobservable mechanisms (causes) that help explain how we can hear so many different voices and sounds (effect) from across the room when we spin the record.</b>  | At the end of day 1 students are asked to draw and label a model to help explain how they were you able to hear the different sounds you heard from across the room (from the record player), including a zoomed in view of where the needle touches the record and the air in the room. This is completed on the student activity sheets.  |
| <b>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.</b> | At the end of day 2 students are asked to form at least two questions about sound related phenomena.<br><br>At the end of day 3 students are asked to list/draw some ideas for possible investigations the class could conduct in order to help answer some of the questions posted to the driving question board.<br><br>Both of these are completed on the student activity sheets. |

Initial student models will help you determine if students are readily using these two ideas from prior grade bands in their models:

- 1) The sound source (either the needle or the record) is vibrating back and forth.
- 2) The medium through which the sound is traveling (air) is made of particles and empty space between them.

We have rarely seen these ideas in student models. If most of your students do show idea 1), then you will be able to do a compressed version of lesson 3, focusing just on developing a model of the slow motion videos of the instruments. If most of your students show idea 2), then lesson 12, can be reduced to a 5-10 minute review.

Examples of typical models that students develop in lesson 1 are shown on the next page.

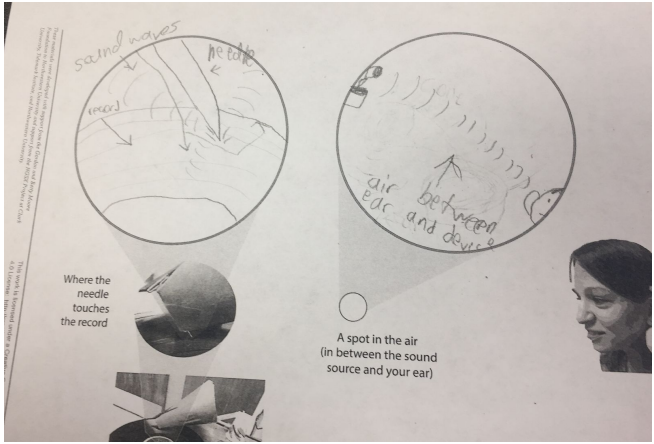
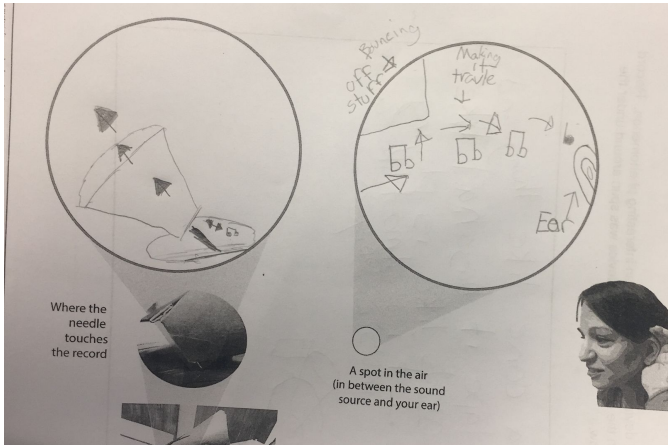
An optional pre-assessment is provided for the unit. One tradeoff in giving the pre-assessment before lesson 1, is that it may undermine the sense of mystery and wonder that are typically a big part of what the teacher is cultivating in that lesson to help students form the driving question board. It also might lead to students asking question in that lesson that are targeted at the pre-test questions, rather than ones that come from their own experiences and curiosity. One possibility is to use the pre-test right after lesson 1 and before lesson 2. If you use the pre-test, you may want to:

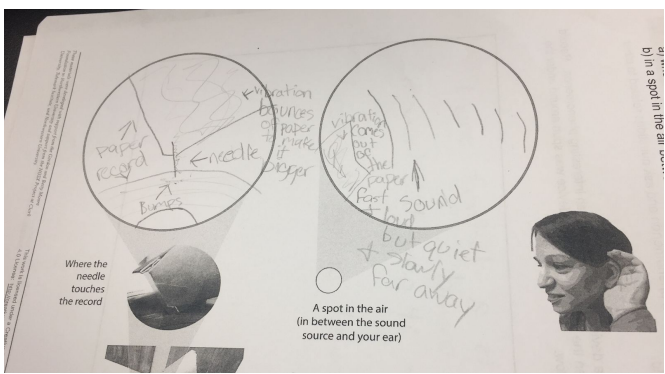
- Use part of the questions rather than all (the entire set of questions will likely take over an hour to complete)
- Have students pick 3 of questions to answer (their choice)





**Lesson 1- Initial Models: Here is typical range of initial models that students develop**

|   | At the <u>sound source</u>  | In the <u>medium</u>  |
|---|---|---|
|    | <ul style="list-style-type: none"> <li>Something is happening at the point of contact between the needle and the record (motion lines)</li> </ul> | <ul style="list-style-type: none"> <li>Sound waves are lines/bands (similar to wifi symbols) originating from this point</li> </ul>                                       |
|  | <ul style="list-style-type: none"> <li>Nothing shown happening at the point of contact between the needle and the record</li> </ul>               | <ul style="list-style-type: none"> <li>Something (notes) is moving out of the cone and across the room to the ear</li> <li>Those sounds can bounce off objects</li> </ul> |

|   |  |  |
|---|--|--|
|  | <ul style="list-style-type: none"> <li>• Vibrations originate near where the needle touches the record</li> <li>• Vibrations bounce off the cone to make it bigger and vibrations come out of the paper</li> </ul> | <ul style="list-style-type: none"> <li>• Sound “waves” are lines/bands leaving from there (similar to wifi symbols)</li> </ul> |
|---|--|--|

### Lesson Level Formative Assessments in Every Lesson

The summary shown above demonstrates how some of the work students are doing within that lesson can provide a key measure of students’ progress toward meeting the LPE for that lesson. This alignment is not limited to lesson 1. Every lesson has one or more LLEs listed in the roadmap. These are the recommended area of focus for formative assessment in that lesson.

Student activity sheets and/or Home Learning assignments provide the context for many of the embedded formative assessment prompts that provide evidence of whether students are meeting these LLEs. Some models that students produce or discussions they participate in provide the context for other LLEs.

The table on the next page summarizes opportunities in each lesson for assessing every LLE. Most LLEs are recommended as *potential* formative assessments. Assessing every LLE listed can be logistically difficult. Strategically picking which LLEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher’s discretion.

Five embedded summative assessment opportunities are also identified in this table. Further details about these is provided below this next table.

The structure of every LLE is designed to be a three-dimensional learning, combining elements of science and engineering practices, pieces of disciplinary core ideas and cross cutting concepts. The font used in the LLE indicates the source/alignment of each piece of the text used in the statement:

- **Blue bold font:** Science and Engineering Practice
- **Regular blue font:** Quoted text from the relevant Appendix F Practices Matrix
- *Italicized font:* Specific storyline context (phenomena/question)
- **Green font:** Alignment to a cross-cutting concept(s)
- **Orange font:** Alignment to the Disciplinary Core Ideas (or pieces of these DCIs)

| Lesson | Lesson Performance Expectations (LPEs)   | What is a good opportunity for assessing student progress toward meeting these?   |
|--------|--|---|
| 2      | <b>Analyze and interpret data</b> after 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 of (phenomena) how the structure of the record causes the needle to be pushed to move back and forth in different patterns, and as a result (effect), we heard different sounds being produced.  | Student responses to Q2 provided in their student activity sheets provide an effective context to collect evidence of student progress toward meeting this LPE.   |
| 3      | <b>Analyze and interpret data</b> to provide evidence for phenomena related to the patterns between what we feel on the surface of an instrument after it is struck/plucked and the motion of various musical instruments after they are struck/plucked as seen in a slow-motion video.<br><br><b>Develop and use a model</b> to describe (phenomena) how changes in forces applied to an instrument (being struck or plucked) cause its shape (structure) to change leading it to being repeatedly deformed above and below its initial position (effect) = vibration; use the model to argue whether the structure of other solid objects also changes like this (cause) when they produce sounds (effect).  | Student responses to Q2 provided in their student activity sheets provide an effective context to collect evidence of student progress toward meeting this LPE. But the second LPE, rather than this first one, is the primary focus of this lesson.<br><br>The models on page 3 and 4 of their student activity sheets provide an effective context to collect evidence of student progress toward meeting this LPE. The first model students make will be co-constructed as a class. The second model is independently completed. <b>This model is considered a Summative Assessment.</b>   |
| 4      | <b>Engage in argument from evidence</b> to support or refute 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 and posing and responding to questions that elicit pertinent elaboration and detail to help determine ways we could gather evidence to answer this question.<br><br><b>Construct an explanation</b> 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.  | Q2 and Q3 in the student activity sheets target the first LPE. The written responses provides a draft of ideas for students to share in discussion. The related participation in the discussion (small or large group) around the responses to Q2 and Q3 provide an effective context to collect evidence of student progress toward meeting this LPE.<br><br>Though the second LPE is the main punchline of the lesson, this explanation is co-constructed as a class in Q4 of the student activity sheets, and therefore not considered as useful as a formative assessment of individual student understanding.  |
| 5      | <b>Use mathematical and computational thinking</b> using digital tools to analyze patterns and trends in the graphs of position vs. time data for large vibrating objects to provide evidence of how the y-values (e.g., distance between a peak and a valley) and x-values (e.g., time between a peak and a valley) on the graph compare for deforming it different amounts (simulating what happens when creating loud vs. soft sounds [amplitude differences]).   | Most of the mathematical thinking done in the student activity sheets is co-constructed in the class. The individual responses to Q3, Q4, Q5, and Q6 in the Student Reading 5 provide an effective context to collect evidence of student progress toward meeting this LPE. Assessing the response to one or more of these questions at the start of lesson 6 as an entrance ticket is a helpful intermediate check before starting that lesson, which develops this graphical analysis skill further. Lesson 7 has multiple questions in the summative assessment related to this LPE  |
| 6      | <b>Analyze and interpret data</b> to determine a causal relationship between the length of a tine/bar and the pitch of the note produced (effect) by a music box or xylophone.<br><br><b>Use mathematical and computational thinking</b> 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 of how the y-values (e.g., distance between a peak and valley) and x-values (e.g., time between a peak and a valley) on a graph compare for different pitch sounds.<br><br><b>Develop a Model:</b> 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). | Student responses to Q2 and Q3 in the student activity sheets target the first LPE. Q5 and the conclusions in Incremental Model target the third LPE. The first of these LPEs though isn’t the main punchline of the lesson, and the third is partially co-constructed as a class, and so is not considered as useful as a formative assessment of individual students.<br><br>The second LPE is the recommended formative assessment target. But, again, most of the mathematical thinking done in the student activity sheets is also co-constructed in the class. Any or all of the individual responses in the Student Graph Analysis 6 is the recommended source of evidence of student progress toward meeting this LPE.<br><br>Assessing the response to one or more of these questions at the start of lesson 7 as an entrance ticket is a helpful intermediate check before starting that lesson, which develops this graphical analysis skill further. Lesson 7 has multiple questions in the summative assessment related to meeting this LPE. |



| Lesson | Lesson Performance Expectations (LPEs)  | What is a good opportunity for assessing student progress toward meeting these?   |
|--------|---|---|
| 7      | <p><b>Engage in Argument from Evidence</b> by respectfully providing and receiving critiques about each other's claims, explanations, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail to help explain how the variation in the <i>patterns in the structure</i> of the grooves on the record could <i>force (cause)</i> the needle to vibrate at <i>different frequencies and with different amplitudes</i>, resulting in it <i>(effect)</i> producing different sounds as you spin it.</p> <p><i>The embedded assessment also targets a subset of the Lesson Performance Expectations from lessons 2 through 6.</i></p>  | <p>The making sense section of the student activity sheets outlines the expectations for students to participate in this sense making discussion in day 2. Preparation and participation in the related discussion provide an effective context to collect evidence of student progress toward meeting this LPE.</p> <p><i>The embedded assessment is administered individually on day 3 of this lesson. It targets the primary LPEs from lesson 3, 5, and 6. Student responses to these are considered a Summative Assessment.</i></p>   |
| 8      | <p><b>Develop and use a model</b> to describe unobservable mechanisms at work in the space (traveling) between a sound source (a stereo speaker in a truck) and another object at a distance (a window in a building across the parking lot) that help explain what is causing the window to move (effect).</p>   | <p>The group/partner models constructed for the gallery walk provide an effective context to collect evidence of student progress toward meeting this LPE. These models could be considered a second "initial model" (similar to those produced in lesson 1) of what is happening in the air between the sound source and something far away the sound travels to.</p>  |
| 9      | <p><b>Plan and Carry Out an Investigation:</b> Conduct an investigation and revise the experimental design to produce data to serve as the basis for evidence to <i>test whether air was moving from the sound source to the sensor</i> (systems and system models).</p>  | <p>Both LPEs listed here are targeted in both lesson 9 and 10. It is recommended that you pick either the first or the second LPE to focus your formative assessment on, but not both in a single lesson. You could however focus on one of these LPE for lesson 9 and the other one for lesson 10.</p>   |
| 10     | <p><b>Engage in Argument from Evidence:</b> Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute <i>that the air is not being moved (cause) all the way from the sound source to my ears when I hear the sound or when the window moves (effect).</i></p>  | <p>If you focus on the first, then some combination of the responses for A, B, C, and/or D for one or more of the investigations provide an effective context to collect evidence of student progress toward meeting this LPE.</p> <p>If you focus on the second, then student contributions to partner talk and whole group discussions across these investigations provide an effective context to collect evidence of student progress toward meeting this LPE.</p>  |
| 11     | <p><b>Develop and use a model</b> to describe unobservable parts (particles) of the system and how they would <i>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.</i></p>   | <p>There are multiple ways to collect evidence of student progress toward meeting this LPE: Q3 in the student activity sheets is an individual response to a related question assigned in the home learning. Q4 and Q5 are partner based discussion questions targeted at this LPE. And Q6, Q7, and Q8 are individual responses targeted at this LPE.</p>   |
| 12     | <p><b>Use mathematical and computational thinking</b> to generate data for unobservable mechanisms (propagation of sound waves across a medium to investigate and describe the patterns in the <i>motion (energy)</i> of each single <i>particle (matter)</i> 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 <i>frequency and amplitude of vibrations at the sound source.</i></p>   | <p>Students' observation results recorded in the student activity sheets for investigation 2 and the response to Q5 provides an effective context to collect evidence of student progress toward meeting this LPE.</p>  |
| 13     | <p><b>Develop a model</b> to describe phenomena using unobservable mechanisms for how <i>banging on a drum causes vibrations on it that lead it to produce sound, which causes particles of matter in the surrounding medium to be compressed and expanded together, which then collide with neighbors to transfer energy across the medium to result in (effect) making salt on plastic wrap stretched over a bowl far away move.</i></p> <p><b>Develop and use a model</b> to describe phenomena using unobservable mechanisms for how a stereo speaker playing music could <i>cause vibrations that produce sound (effect), which causes particles of matter in the surrounding medium to be compressed and expanded together, which then collide with neighbors to transfer energy across the medium to result in (effect) making a window far away move.</i></p> | <p>The first LPE is targeted through a co-constructed model the class develops together. As part of that co-construction, students develop a gotta-have-it-check list that they will apply to their individual models for the second LPE.</p> <p>The second LPE is targeted through a take home summative assessment (a revision to the lesson 12 home learning model). A more scaffolded version of this assessment is also available (Lesson 13 - Alternate Student Assessment #2). Use either as evidence for meeting this LPE. <b>Student responses to this is considered a Summative Assessment.</b></p> |
| 14     | <p><b>Obtain and communicate information</b> integrated from written text and video into visual displays showing how the <i>structures in the ear interact with each other to transfer vibrations (cause and effect) from the eardrum to fluid in the cochlea and to a series of sensory cells along this structure that then vibrate (more or less) in response to vibrations of particular frequencies, thereby sending signals along different nerve cells to the brain in response to different pitch sounds.</i></p>   | <p>Student responses to Page 2 and 3 in the student activity sheets provides an effective context to collect evidence of student progress toward meeting this LPE.</p>  |



| Lesson | Lesson Performance Expectations (LPEs)  | What is a good opportunity for assessing student progress toward meeting these?  |
|--------|---|--|
| 15     | <p><b>Plan and Carry Out an Investigation:</b> Identify what tools are needed to do the gathering, how measurements will be recorded, and how much data are needed to determine <i>what transfers more energy—waves with greater amplitude or waves with greater frequency.</i></p> <p><b>Use Mathematical and Computational Thinking:</b> Apply mathematical concepts and processes to scientific questions about <i>what transfers more energy—waves with greater amplitude or waves with greater frequency.</i></p>  | <p>Student responses to Q4 through Q8 in the student activity sheets provides an effective context to collect evidence of student progress toward meeting this first LPE.</p> <p>Student responses to Q9 through Q12 in the student activity sheets provides an effective context to collect evidence of student progress toward meeting this second LPE. This LPE requires recognizing linear vs. non-linear relationships and scale factors. Because this is related to a CCMS in 8th grade, it is recommended you only assess this LPE with grade 8 students.</p> |
| 16     | <p><b>Plan and Carry Out an Investigation</b> identifying what tools are needed to do the gathering, how measurements will be recorded, and how much data are needed to determine <i>patterns in how the distance from a sound source affects the amplitude and frequency of a sound detected at a microphone.</i></p> <p><b>Develop and use a model</b> to show the relationships among variables (<i>patterns of particle density and energy/amplitude of a sound wave</i>) including those that are not observable but predict observable phenomena.</p>   | <p>Student responses to Page 2 and 3 in the student activity sheets provides an effective context to collect evidence of student progress toward meeting this first LPE.</p> <p>Student responses to Page 4 of the student activity sheets and Q8 provides an effective context to collect evidence of student progress toward meeting this second LPE.</p>  |
| 17     | <p><b>Design a Solution:</b> Apply scientific ideas to design, construct, and test the design of an object (a structure) that <i>amplifies the volume of a sound from a sound source at a given distance and evaluate how it functions.</i></p> <p><b>Develop and use a model</b> to describe unobservable mechanisms to explain <i>how it's possible that certain shaped tubes and cones (structures) make a sound louder than without the tube or cone (function).</i></p>  | <p>Student responses to Q1 and Q2 in the student activity sheets provides an effective context to collect evidence of student progress toward meeting this first LPE.</p> <p>Student responses to Q3 in the student activity sheets provides an effective context to collect evidence of student progress toward meeting this second LPE.</p>  |
| 18     | <p><b>Developing and Using Models:</b> Collaboratively develop a model based on evidence that shows the relationships between how much energy reaches a barrier, how much goes through it, and how much is reflected for frequent and regularly occurring events (sound pressure waves).</p>  | <p>Student responses to Q2 through Q5 in the student activity sheets provides an effective context to collect evidence of student progress toward meeting this LPE.</p>  |
| 19     | <p><b>Engaging in Argument from Evidence:</b> Use oral arguments supported by empirical evidence and scientific reasoning to revise a model for a phenomenon (<i>when matter moves [or is bent] back and forth, some of the energy of that motion is absorbed by the matter and converted to thermal energy).</i></p>   | <p>Student responses to Q2 and Q3 provides partial evidence for meeting this first LPE. The related participation in the discussion (small or large group) around the responses to these question provides an effective context to collect evidence of student progress toward meeting this LPE.</p>   |
| 20     | <p><b>Develop and revise a model</b> to show the relationships between the components of the system (in the anchoring event) and their interactions, including <i>how sound is generated, how it travels, and how it is detected to describe observable and unobservable phenomena.</i></p> <p><b>Construct an Explanation</b> applying scientific ideas, principles and evidence to construct and revise an explanation for real world phenomena and events pertaining to how sounds get made, travel (energy), and get sensed.</p> <p><i>The embedded assessment also targets a subset of the Lesson Performance Expectations from lessons 6, 13, 14, 15, 16, 17, 18, and 19.</i></p> | <p>Page 2 and 3 in the student activity sheets and the group models produced for the gallery walk provides an effective context to collect evidence of student progress toward meeting this first LPE.</p> <p><i>The embedded assessment is administered individually on day 3 of this lesson. It targets the second LPE and the primary LPEs from lessons 6, 13, 14, 15, 16, 17, 18, and 19. Student responses to these are considered a Summative Assessment.</i></p>  |
| 21     | <p><b>Conduct an investigation</b> to produce data to serve as the basis for evidence to answer a scientific question 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 volume and pitch.</p>   | <p>Student responses to Q4 and Q5 on the student activity sheets provides an effective context to collect evidence of student progress toward meeting this LPE.</p>  |
| 22     | <p><b>Design a Solution:</b> Apply scientific ideas to design, construct, and test the design of different objects (structures) to determine which produces better sound quality (function) when hooked up to a coil of wire and a magnet when plugged into an electronic music device to play back music stored on the digital device.</p>   | <p>The observation table on page 4 of the student activity sheets provides an effective context to collect evidence of student progress toward meeting this LPE.</p>   |
| 23     | <p><b>Obtain, Evaluate, and Communicate information:</b> Critically read scientific texts (historical descriptions) adapted for classroom use and video to determine the structures and their related functions in the earliest devices for making analog recordings of sound (designed world).</p> <p><i>An optional embedded assessment also targets a subset of the Lesson Performance Expectations from lessons 2-22.</i></p>   | <p>Student responses to Q1 and Q2 on the student activity sheets provides an effective context to collect evidence of student progress toward meeting this LPE.</p> <p><i>The optional embedded assessment can be administered individually on day 2 of this lesson. It targets a subset of the Lesson Performance Expectations from lessons 2-22. Student responses to these are considered a Summative Assessment.</i></p>   |



## Using Entrance and Exit Tickets as Formative Assessments

Entrance and exit tickets are excellent opportunities to formatively assess student understanding. Almost every lesson start and ends with engaging students in the navigation routine (see section **I. How Can Teachers Use Similar Instructional Routines Across Lessons?**)

These materials are designed to put the work of reflecting on what we figured out and where we should go next as much on the students as much as possible in both of these parts of the lessons. Prompts for discussions the teacher can facilitate at these points are embedded in the Teacher Guides. But in every case where those prompts are included, those prompts could be used as an entrance and exit ticket. In fact, when time is limited, collecting student responses to these prompts, and then reading through them and using those responses at the start of the next lesson, can to jump start the discussion.

In general, asking students these three questions in an exit ticket can help assess (and reinforce) the ideas that students are figuring out:

- What did we figure out in this lesson?
- What new question does this raise for us?
- What ideas do you have for how we might go about investigating this next time?

In general, asking students these three questions in an exit ticket can help assess (and reinforce) the ideas that students are figuring out:

- What did we figure out last time?
- What new question did this raise for us?
- What ideas do you have for how we might go about investigating this today?





## Summative Assessment Descriptions

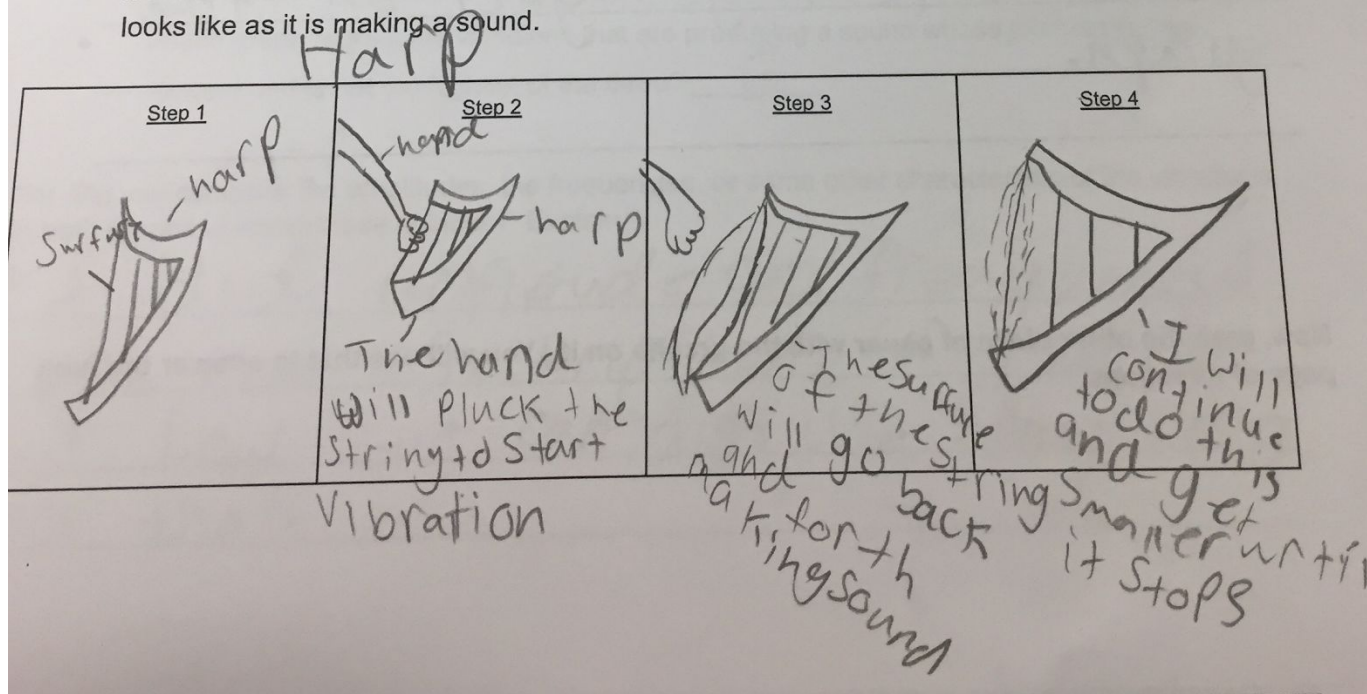
The five summative assessment opportunities were identified in the table above are described in greater detail in the table below, along with a description of related teacher keys, exemplars, and rubrics. Teachers can use the provided rubrics as a way to provide feedback to the students as they progress to mastery for each component and interaction in their models.

| Lesson # | Description of the summative assessment opportunity  | Description of related teacher keys, exemplars, and rubrics   |
|----------|--|---|
| 3        | Students independently develop a model to describe (phenomena) how changes in forces applied to an instrument (being struck or plucked) cause its shape (structure) to change leading it to being repeatedly deformed above and below its initial position (effect) = vibration.   | Example student models are provided in the teacher guide for this lesson along with key elements of the model and rubric.   |
| 7        | Students independently answer a bank of related prompts targeted at explaining sound related phenomena, including: <ul style="list-style-type: none"> <li>Develop a model similar to the one developed in lesson 4 but for a different instrument.</li> <li>Analyze graphs to determine how vibrations from different sound sources compare in terms of frequency, amplitude, pitch, and loudness.</li> <li>Use mathematical thinking to compare rates of vibration (frequency) between two instruments.</li> </ul>  | An answer key and rubric are provided for this assessment.  |
| 13       | Students independently develop and use a model to describe phenomena using unobservable mechanisms for how a stereo speaker playing music could cause vibrations that produce sound (effect), which causes particles of matter in the surrounding medium to be compressed and expanded together, which then collide with neighbors to transfer energy across the medium to result in (effect) making a window far away move.   | Example student models are provided in the teacher guide for this lesson along with key elements (a gotta-have-it checklist) of what should be a part of the model. A rubric using the gotta-have-it checklist is included. |
| 20       | Students independently answer a bank of related prompts targeted at explaining sound related phenomena, including a subset of the following: <ul style="list-style-type: none"> <li>Develop a model and use it to explain how dropping a rock on the bottom of a pool produces a sound and how sound travels underwater.</li> <li>Develop a model and use it to explain that music would sound louder the closer a person stands to the stereo speaker at a dance, but quieter the further they move away from it.</li> <li>Construct an explanation for why each of these types of exposure contribute to hearing loss: Exposure to sounds that are too loud, exposure to sounds for too long of a time, and why exposure to higher pitch sounds can lead to hearing loss more quickly than exposure to lower pitch sounds of the same volume.</li> <li>Describe how the pattern of motion of the two different bars on a xylophone would compare after they are both struck (one that produces a high pitch note vs. one that produces a low pitch note).</li> <li>Construct an explanation for how is it possible that a boy can hear music coming from a radio outside of his van, even if he is within a completely enclosed space surrounded by solid material (the van) and why the music is quieter with the windows in his van rolled up than it is with the windows rolled down. Develop a model and use it to explain why being inside the tunnel makes the music sound louder to the boy in the van than when the car and van were both outside of it.</li> <li>Explain why adjusting the volume and/or the pitch that a song is played in would affect the battery life of a cell phone that is playing that song.</li> </ul> | An answer key is provided for this assessment using student exemplars when available.   |
| 23       | Optional: Students independently answer one or more of the following: <ul style="list-style-type: none"> <li>How is music recorded on an Edison cylinder?</li> <li>How is it played back?</li> <li>Why would it be easier to hear the music standing in front of the cone as it is being played back than to the side of it?</li> <li>Why would it be easier to hear the music standing in front of the cone as it is being played back if you were inside a room than if you were outside, even if you were the same distance from the cone?</li> </ul>   | No answer key is provided. Teachers should identify the elements from the Incremental Model Tracker that students should use in each response.  |



**Lesson #3 -Example of an individual model a student produced**

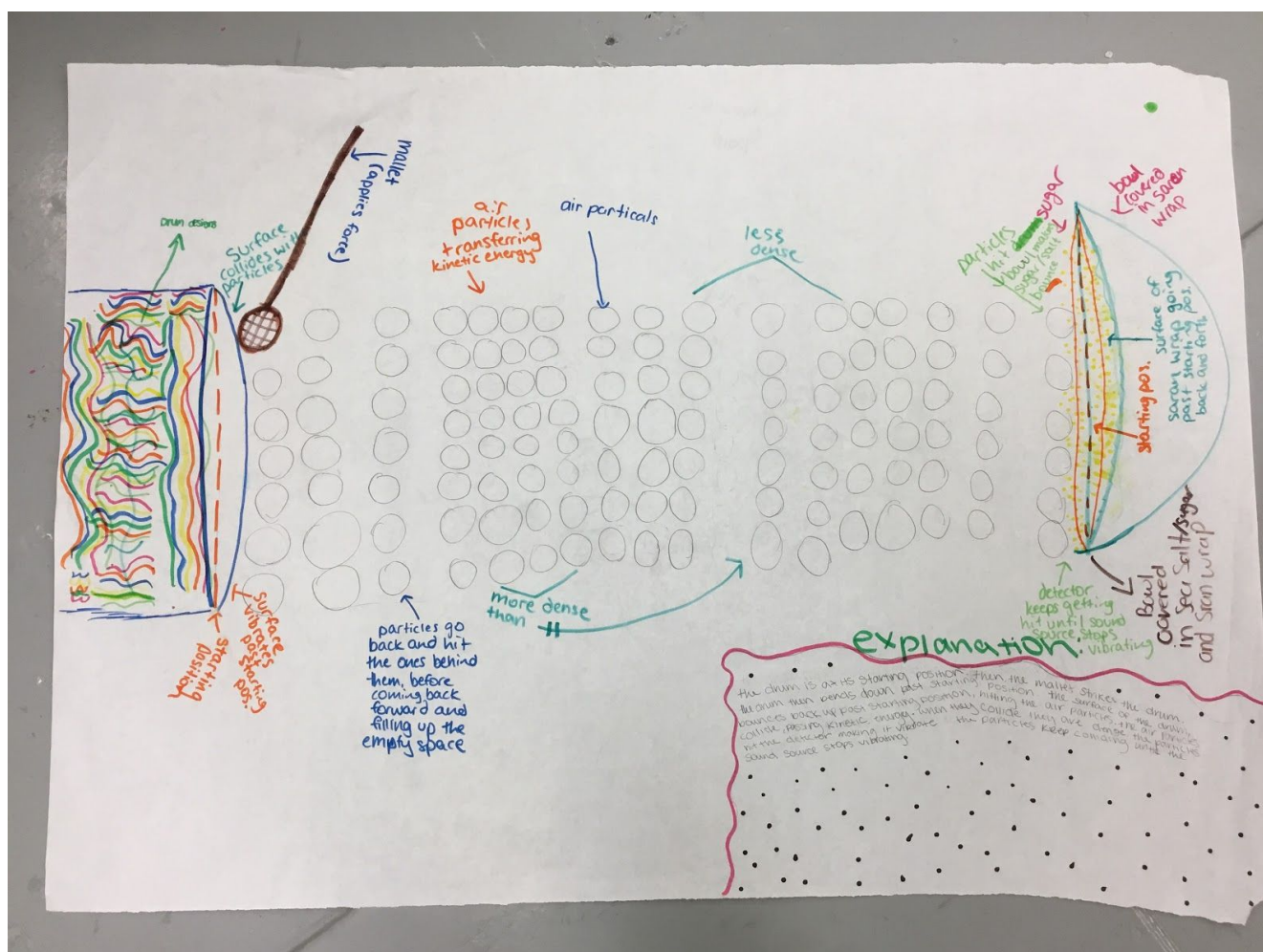
4. **Draw and label** a step-by-step **model** that shows and describes what the sound source is doing when it makes a sound. Step #1 should show what the sound source looks like before it makes a sound. The remaining steps should show, step by step, what the sound source looks like as it is making a sound.



The model shows the use of three important science ideas developed by the end of lesson 4:

- An external force will deform the sound source (change its shape)
- When released, the position/shape of the string (the sound source changes shape back and overshoots its original position) and continues to overshoot back and forth.
- This makes the sound; when this motion stops, the sound stops.

**Lesson 13:** Here is an example of a small group model two-thirds of way through the unit, “Why does striking a drum make salt on a plastic wrap on a bowl far away move?”



The model shows the use of three important science ideas developed by the end of lesson 13:

Shows what is happening at the sound source

- An external force will deform the sound source (change its shape)
- There is elasticity in the drum surface (it deforms back and forth past its original starting position)

Shows how the sound source causes changes in the surrounding medium

- Deformation causes the particles in the surrounding medium to start moving
- Particles from near the source don't move all the way from the source to the detector
- Particles go back and forth and hit neighbors
- Collisions transfer energy across the medium

Shows how the medium causes motion in the detector

- Particle motion (back and forth) near the detector causes the “detector” to move (the plastic wrap on the bowl which makes the salt dance)



## I. How Can Teachers Use Similar Instructional Routines Across Lessons?

Embedded in our curriculum materials are five instructional routines that are used to support three-dimensional learning throughout this unit and can be applied to other units of instruction. These routines are not meant to be interpreted as a step-by-step guide, but rather as dynamic elements used in NGSS Storylines to achieve the goals of three-dimensional learning outlined in *A Framework for K-12 Science Education* and with the Next Generation Science Standards. Here we attempt to summarize and make the design rationale of storylines explicit using each of the five routines. Use the far left column in the [Storyline Skeleton](#) to identify where in the unit each routine is used.

### Anchoring Phenomenon Routine

Explore Anchoring  
Phenomenon



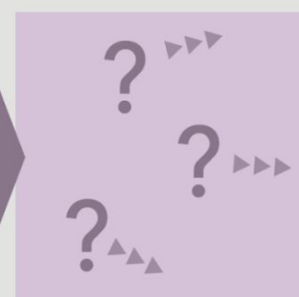
Attempt to  
Make Sense



Identify Related  
Phenomena



Develop Questions  
& Next Steps



There are four main parts of the Anchoring Phenomenon (AP) Routine, which occur at the start of every unit:

**Explore Anchoring Phenomenon:** Every instructional unit should start with some puzzling phenomenon that students experience. In this section, students should explore that phenomenon in some way. The question the class is working on is *What do we notice?* For example, students might make observations, look for patterns, or create a timeline of events that occurred. The purpose of this section is for students to recognize the interesting events going on and to publicly, as a learning community, acknowledge aspects of the phenomenon that require key pieces of target DCIs to explain.

**Attempt to Make Sense:** Students should try to come up with an explanation, model or some other reasoning to explain why or how the phenomenon under investigation is happening. Oftentimes people view this attempt to make sense of the phenomenon as pointless. For example, they may think that we know the students don't understand what's going on, so why take the time for them to try and come up with a reason to explain the phenomenon when it's going to be wrong? The intention of this section isn't to come up with the "right" answer. The purpose is to start to stake out the territory of what they don't know yet so that later we can up come with a plan to figure out those pieces. It's important that each student tries individually to attempt to make sense of the phenomenon and then go public with his or her ideas. Diversity in our sense-making ideas here is very productive! It helps create the sense that we are all not on the same page, and that there is stuff here that begs to be figured out. The role of the teacher in this stage is two-fold: 1. To help students get their thinking down on the page, regardless of if it's right or wrong and 2. To push students to come up with a mechanistic explanation about what's going on. Press students to go deeper if they think they know the answer. More likely than not, even students who use correct vocabulary to explain what they think is going on cannot really tell you what those words mean in a mechanistic way.





**Identify Related Phenomena:** The goal of NGSS storylines isn't just to solve a single mystery about one phenomenon. The goal is to build up disciplinary core ideas and cross-cutting concepts that can be applied to a range of events in our world. It's important to frame brainstorming-related phenomenon around the aspects of the phenomena that lead to the target pieces of the disciplinary core ideas. The purpose of having students generate related phenomena is to broaden out the scope of what the class is really interested in figuring out and for students to have a personal connection and investment to the events being explored in class. In fact, if students are not able to come up with related phenomena, then that might be a sign that the anchoring phenomenon needs to be adjusted because kids just won't care or relate to what the class is working on.

**Develop Questions and Next Steps:** In this section, the class makes a joint list of questions and action items to accomplish their mission of figuring out the driving question of the unit. What's unique about three-dimensional learning is the opportunity for students to be involved in the thought process and decision-making about what the class should be figuring out and how the class should be figuring it out. It is important for each student to participate in generating a question to be explored and for those questions to be made public so that the class as a whole retains ownership of those questions. This may take on various forms such as a "Driving Question Board" or a "Notice and Wonder" chart. Similarly, students should be involved in thinking about ways to go about answering one or more of the questions from the class. This early on in the unit it is not important that the ideas for investigations have a step-by-step procedure. They don't have to be what is considered an "experiment". Rather, the point is that students are identifying actionable ways to figure out answers to their questions. For example, maybe the class thinks a good way to follow up on one of their questions is to look up what experts have to say or gather secondhand data. Also, the goal isn't to come up with the perfect question or solution, anything goes right now! The questions and next steps that are kept on a public class record should be kept alive! Questions and next steps should be revised, revisited and checked off as the unit progresses.

Here is a tool that can be used for this instructional routine: [Anchoring Phenomena Routine Analysis Tool](#)

## Navigation Routine



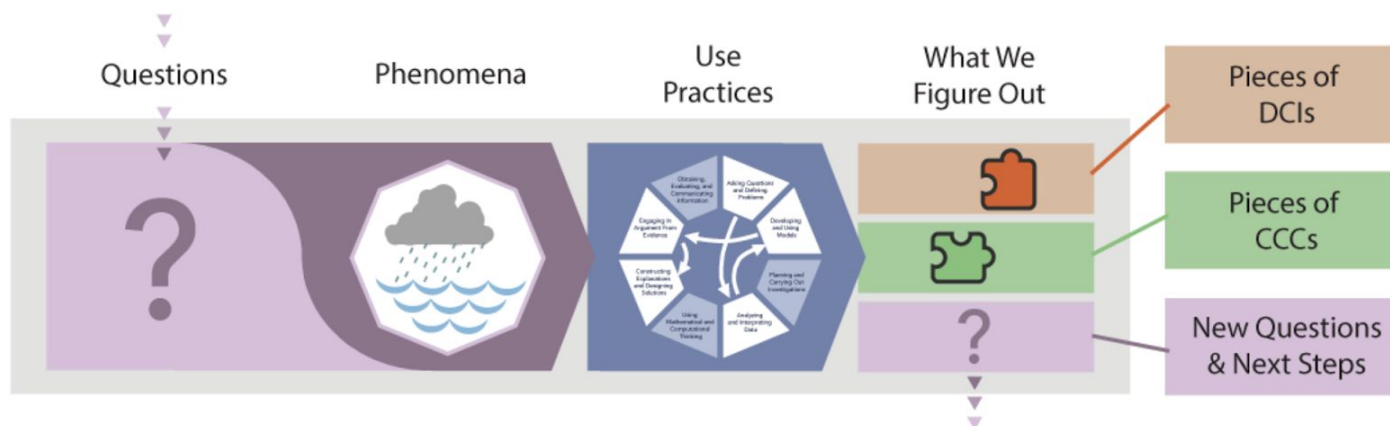
There are two main parts of the Navigation Routine, which occur between every lesson in the unit. Think about the idea of navigation. When you are on your way somewhere and actively navigating, you have to constantly address two types of questions. First, where are we now? And second, where should we go next? These two questions happen at the beginning and end of each lesson, as well as at major decision points that may arise during lessons.

**Looking Back:** Each lesson begins and ends with reflection or looking back. The class asks, "What brought us to this point?" At the start of each lesson, the learning community needs to look back and remind themselves: Where are we in our mission? What have we accomplished? What's the main thing we need to work on now? What was our question? Oftentimes instructional materials will prompt teachers or students to recall where the class left off. While this is part of the Looking Back element in the Navigation Routine, there is an important difference. Although the teacher may have to start the conversation, the work of reflecting should be done by the students as much as possible. And the purpose of reflecting isn't just to recap, it's to prime the pump so the class can think about, "Now knowing where we are, what makes sense to do next?" (Looking Forward).



**Looking Forward:** After the class has a chance to look back, each lesson begins and ends with planning or looking forward. The class asks, “Where do we need to go next?” When the class looks forward, the students together with their teacher may identify a new question or direction to pursue. Rarely in instructional materials are students prompted to take part in articulating a logical next step to pursue. However, involving students in this work is critical for helping them develop into problem-solvers and positioning students as partners in figuring out how and why the world works.

## Investigation Routine



Questions around phenomena led the class to engage in science practices to make sense of the phenomenon, and then develop the science ideas as part of the explanation. This is the basic structure of the work of three-dimensional learning. We refer to this as the investigation routine.

**Questions / Phenomena:** Notice there is a yin/yang symbol between the question and phenomena segments. This is because the question and phenomena are tightly coupled. There is a column of arrows above the question block because often times the question comes from the previous lesson and that creates a need to engage in new phenomena. Or perhaps exploring new phenomena motivates the class to think of a new question. You can think of each step in the storyline as a step forward in the knowledge building, starting with a question arising from a phenomenon.

**Use Practices:** Students use science practices such as designing investigations, analyzing data, modeling, and argumentation to make progress on their explanation. The bulk of the class’s time and energy is spent in this space - using NGSS practices to make sense of a puzzling phenomenon and question. Kids should be doing the heavy lifting of figuring out.

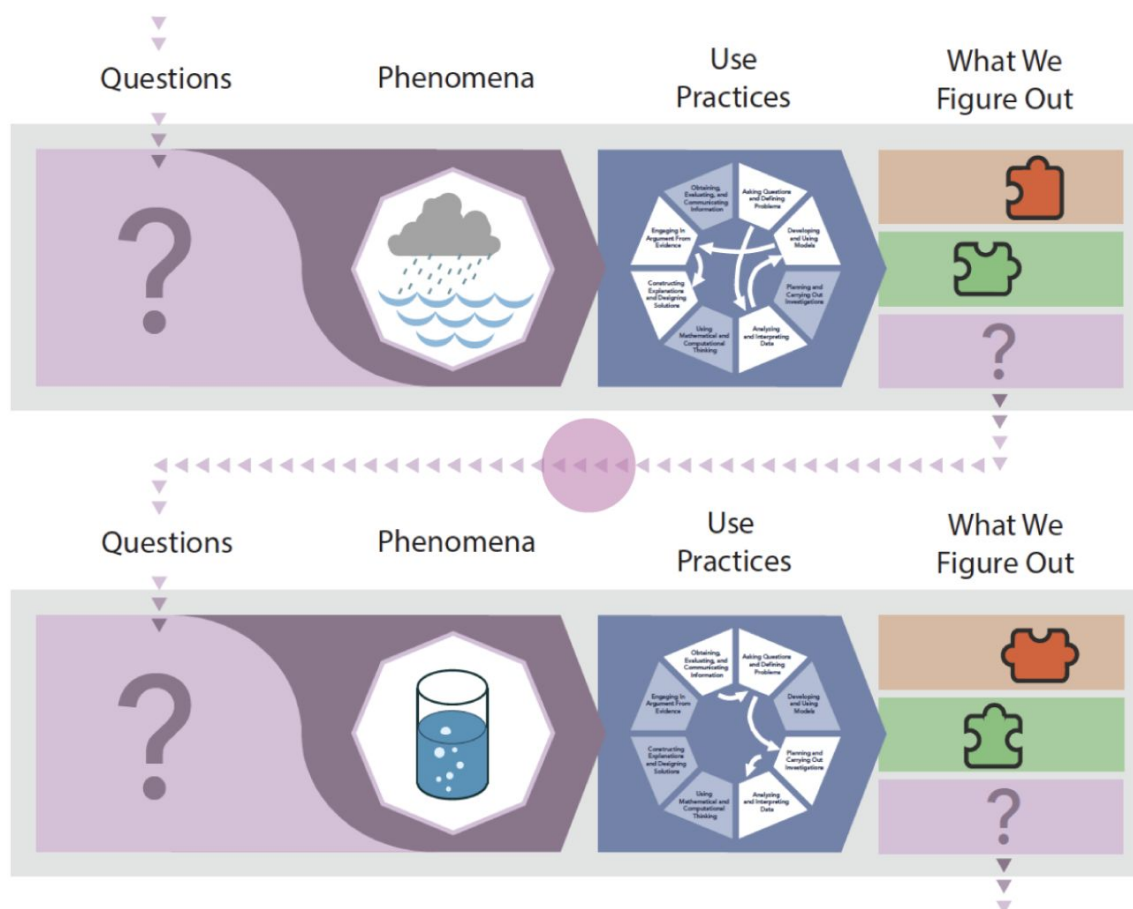
**What We Figure Out:** At each step they assemble another piece of the puzzle. It might be a piece of a disciplinary core idea, such as the idea that a vibrating object can make sound. They may also be extending their ideas of crosscutting concepts such as matter and energy. Notice that students didn’t learn about the science ideas first, and then engage in practices to use those science ideas to explain a phenomenon; it was the reverse.

## Connected Investigations

Two intertwined routines, the Navigation and Investigation Routines, form Connected Investigations.

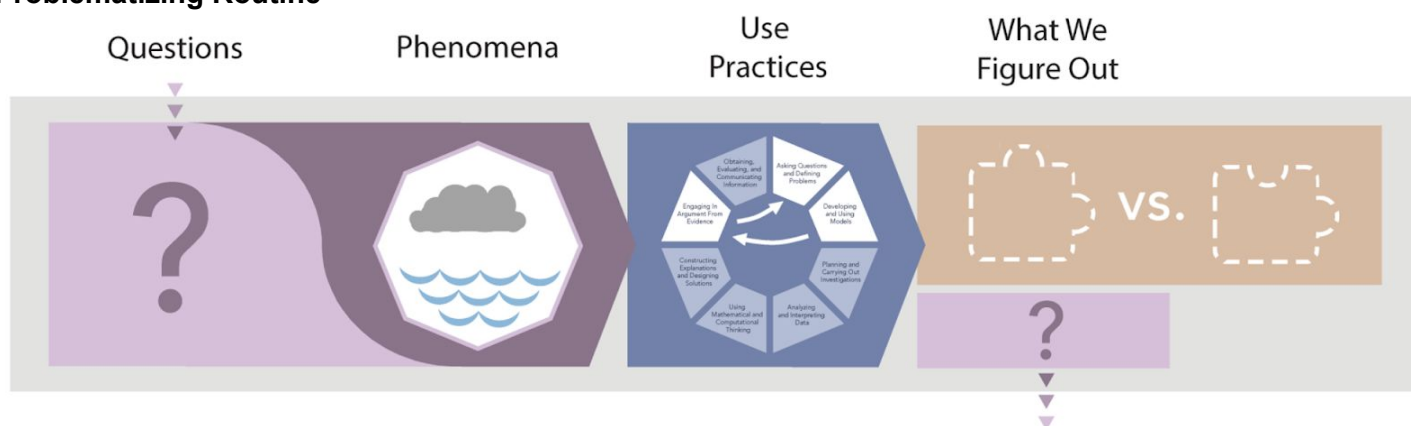






The navigation routine provides the connection between each investigation and helps the class take stock of where they are and where they agree they want to head next. In other words, it helps the class bring a new question into focus and set a new trajectory for the next investigation. Both Navigation and Investigation routines coupled together, are in service of supporting two types of coherence: WE figure out the pieces of the science ideas and WE decide our next steps. So together they are really supporting Connected Investigations. Here is a tool that can be used to look for Navigation and Investigation Routines: [Connected Investigations Analysis Tool](#).

### Problematizing Routine



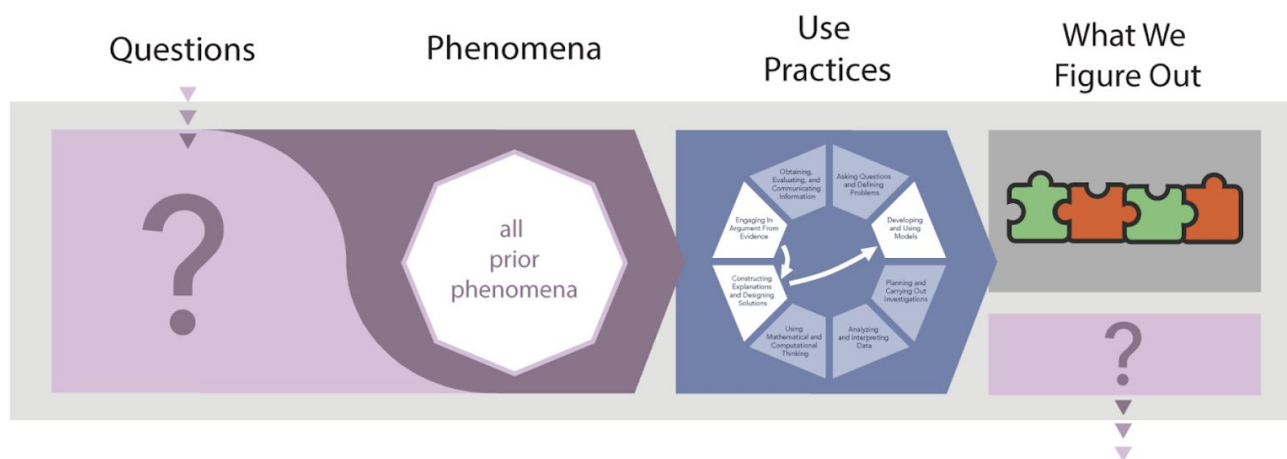
The teacher seeds, cultivates, and capitalizes on an emerging disagreement that reveals a potential problem with their current model to get students to focus on an important question that could extend their model. There are three elements of this routine.

**Foreground a new question or phenomena:** The teacher helps orient the learning community to a new puzzle for the class to consider that it is intentionally designed to elicit disagreement or competing explanations. The role of the teacher in this piece is to draw attention to and press the class for whether a particular key science idea they had developed could be pushed beyond what they had considered so far. This type of move is really important for NGSS. What makes a science idea a disciplinary core idea is that it can be used to explain a broad range of phenomena. Once we make some progress in explaining phenomena, we need to try to extend or break the model; we intentionally throw a wrench in the class' progress.

**Argue for competing ideas:** In this section, the learning community attempts to really dig into this new puzzle and argue for their predictions or explanations. When students tried to use their model in a new context, they brought some competing ideas to the table. The role of the teacher here is to help the students to go public with their competing ideas and help the class realize they do not have consensus.

**Determine a way to resolve this question:** Third, students needed to figure out what they needed to work on next, and start to think about how to resolve this question. While we don't need students to articulate the detailed design of every investigation, in a coherent storyline we want the students to know why we are conducting a particular investigation and be a part of that thought process.

### Putting Pieces Together Routine



Students take the pieces of ideas they have developed across multiple lessons and figure out how they can be connected together to account for the phenomenon they have been working on.

**Take Stock:** The first element focuses on taking stock of the main punchlines the class has figured out so far. This could take different forms. Students might highlight the important discoveries they made in their science notebooks. They might fill out a summary chart of what the class figured out with regard to the question that framed each lesson. Or they might refer back to a series of posters of scientific principles that the class has been adding to lesson by lesson to keep track of their discoveries over time. The purpose of this step is to get all the pieces of the puzzle out on the table.

**Put Pieces Together:** The second element of the routine involves coming to a consensus on how to put these ideas together to explain a phenomenon or design a solution. During this process, the class develops a public representation of the ideas as we are putting them together, such as a diagrammatic model, a table showing commonalities across a series of cases, or a written explanation.



**Apply This to Another Phenomenon (Optional):** Sometimes the class is ready to go further, and we see a third element of this routine emerge. After the class comes to a consensus on a public representation of how the pieces fit together, and they feel confident about their model, they may attempt to generalize the ideas they just put together by applying them to explain new phenomena or solve a new problem.

Here is a tool that can be used to look for the Problematising and Putting Pieces Together Routines: [Problematising and Putting Pieces Together Routines Analysis Tool](#).

## J. How Can Teachers Support Different Types of Discussions?

Ideas for this resource are developed from the Next Generation Science Exemplar program and from research on fostering productive academic talk in science. Productive talk is the glue that connects practices to one another, practices to DCIs and crosscutting concepts, and also the way that the class makes sense of what they are figuring out.

There are four basic types of discussion that can facilitate science learning in ways that are consistent with the vision of *A Framework for K-12 Science Education* and with the Next Generation Science Standards:

[Generating and Prioritizing Questions Discussion](#)

[Initial Ideas Discussion](#)

[Building Understandings Discussion](#)

[Consensus Building Discussion](#)

These different discussions serve different purposes, and they are useful in different phases of a lesson or unit centered around an anchoring phenomenon or engineering design challenge. We have indicated which phases of a lesson or unit when different types of discussion might be valuable, but any type of discussion might be useful, depending on what students are thinking and wondering about at the time. When planning for a classroom discussion, it is also important to think about how all students can contribute ideas and to create opportunities for individual and small group “think time.”

### Generating and Prioritizing Questions Discussion

#### Purposes

- To identify questions students need to answer in order to solve an engineering design challenge or to develop a complete explanatory model of a science phenomenon
- To identify questions that students need to answer to refine their understanding of a problem
- To identify questions that students want to investigate in order to develop a piece of understanding related to a phenomenon
- To help motivate the next row(s) in an NGSS storyline
- To support students in developing a grasp of the practice of asking questions and defining problems
- To identify questions that come from students’ personal experience and interests that relate to the challenge or phenomenon

#### Some Unit Phases When Useful

- At the beginning of a unit
- At the conclusion of a “bend” in the storyline



### Some Lesson Phases When Useful

- “What questions do we still have?”
- “Where should we go next?”

### Steps in A Possible Discussion Routine

1. Elicit Questions
2. Clarify Meanings of Questions
3. Discuss Significance of Questions
4. Prioritize the Questions

### Potential Talk Moves for this Discussion

#### *For Eliciting Initial Questions*

- What questions do we need to answer to solve the design challenge just presented?
- If we want to explain this phenomenon, what questions will we need to know the answers to?
- What questions do we have after being introduced to this phenomenon?
- What questions do we need to ask the client/partner to refine our understanding of the problem they are trying to solve?
- What questions should we try and answer with this investigation? How will answering those questions help us figure out something about the phenomenon?
- What questions should we try and answer with this test of our design solution? How will answering those questions help us figure out something we need to know, to solve the design challenge?

#### *For Prioritizing Questions*

- Which questions that we came up with are similar? What makes them similar?
- Which questions should we answer first? Why do those questions come first?
- We can't answer all of these questions at once, so which ones should we prioritize? Why are those questions important to answer; that is, ones that might help us make progress on a larger set of related questions?

### Making Participation Equitable

In eliciting questions, the goal is to get as many ideas on the table as possible, so group work is a better option. Consider asking students to “write and pass” a sheet of paper around their group until they have at least 10 things. That way, all students get a chance to contribute, to see others’ ideas, and to add their thinking in a low-stakes way.

Then, use groups to prioritize questions for the class investigations. Have groups pass their written list to another group, who circle the two “most pressing questions” on the list. As they do this, you can circulate and find the top four or five questions -- this is your final student-generated list of driving questions.

### **Initial Ideas Discussion**

#### Purposes

- To provide a supportive opportunity for students to make some sense of what may be not yet fully-formed ideas (either their own or those of others)
- To support students in making tentative connections between questions being asked and the participants’ experience and everyday ideas about observing a phenomenon



Some Unit Phases When Useful

- At the beginning of a unit
- At the beginning of a new “bend” in a storyline

Some Lesson Phases When Useful

- “What are some ideas about how we can answer what we’re wondering about?”
- “What sources of data or equipment might we need to investigate this question?”

Steps in a Possible Discussion Routine

1. Provide a way for all students to surface their ideas (think-pair-share is one strategy)
2. Give people a chance to clarify one another’s ideas and to ask about why people think their ideas are good ones
3. Ask a student to summarize the initial ideas that the class has
4. Ask students how they might test or further explore their ideas

Potential Talk Moves for this Discussion*When eliciting initial ideas:*

- What are your ideas about how to explain this phenomenon?
- What’s your “first draft” thinking about how to solve this design challenge?
- Let’s see what we think about this phenomenon using our own past experience as a guide and what we’ve learned in class this year.
- What experiences do you have that might help you think about this phenomenon?

*When clarifying ideas and pressing for reasoning:*

- Can you say more about that?
- Where does that idea come from?
- Is that something you’ve heard, observed, or experienced before?
- What do you mean when you say the word “\_\_\_\_\_”?
- Can anyone add onto this idea?
- Who has a different way of thinking about this topic?
- Can you think of an instance when that was not the case?

*When asking a student to summarize initial ideas:*

- Who can summarize some of the ideas we’ve heard today?
- Is this a complete summary? Can someone add what’s missing?
- Does the summary capture our ideas accurately?

*When asking students for how to investigate their initial ideas:*

- What are some ways we could test our initial thinking?
- What ideas are we unsure about that we need to know more before we can be confident in them?

Making Participation Equitable

Think about what kinds of support your students might need to be able to *ask each other* these kinds of clarifying and summarizing questions without being critical or evaluative. You might try using the [metaphor of a coach](#) to introduce these think-pair-share routines. You could try telling students, “This is about helping your partner practice as a scientist and



supporting them in their thinking, so you're going to ask questions, encourage them, and for now, your ideas will stay on the sideline. Then we'll switch and you'll get a chance to share your ideas as you are coached by your partner."

Tip: Have sentence starters ready for students so that they know what they might ask to push their partner further, but *also* have sentence starters ready to slow down the fast explainers, such as "Wait - you said that really fast. Can you say that again?"

## Building Understandings Discussion

### Purposes

- To help students make their reasoning with evidence public so that other students can connect with it, critique it, and build on it if possible
- To provide the teacher and students with an opportunity to clarify which understandings emphasized in the storyline have been developed and which need further development

### Some Unit Phases When Useful

- After a series of lessons where some piece of understanding should have been built
- Toward the end of a "bend" in the storyline

### Some Lesson Phases When Useful

- "What did we figure out last time? What did we wonder about?"
- "What have we figured out today? What questions do we still have?"

### Steps in A Possible Discussion Routine

1. Invite a student or group of students to share their current explanatory model or design solution with the class
2. Invite others to ask questions about the model/solution, suggest additions to it, and critique the model/solution
3. Invite a second student or group to share their model/solution, and then invite response and critique
4. Ask students about how the models/solutions compare in terms of similarities and differences
5. Invite the class to consider what might need to be revised in models/solutions, based on the models seen and the evidence so far

### Potential Talk Moves for this Discussion

#### When inviting a group to share:

- What are some of the key components of your model/solution?
- How does this model explain the evidence we have so far about this phenomenon?
- How does this solution fit the criteria we identified for a possible solution?
- Is there any evidence you know of that's not accounted for in your model/solution?
- Did you consider other models/solutions? If so, what were they?
- For second group and after: How is your model/solution different from or similar to ones presented earlier?

#### When inviting others to critique a model/solution:

- What questions do you have for this group about their model/solution?
- Can you clarify \_\_\_\_\_ aspect of your model/solution?
- So let me see if I understand this aspect of your model/solution here. Are you saying...?





- What do the rest of you think of that idea?
- Is there anything you can add to this model/solution?
- How well does this model fit the evidence we've gathered so far?
- How well does this solution meet the criteria we identified for the solution?
- What could the group do to improve the model/solution?

*When inviting students to compare models/solutions and consider revisions:*

- How does group A's solution connect to group B's?
- How do these models/solutions help us make sense of and contribute to our question at hand?
- What might a model/solution look like that puts the things we think best reflects all the evidence we have so far?
- Is there any evidence that we have that none of our models/solutions can account for?

### Making Participation Equitable

Consider lower-stakes ways for students to have these discussions, such as in a gallery walk where one person stays by the model to invite critique with the questions above and the other students ask pressing questions. During critique-based interactions, it is important to emphasize "making our ideas stronger," not "showing we have the best ideas." You can also encourage students to take a "coaching" stance here; their role is to ask questions that support others' ideas, and encourage students to speak up when something needs to be repeated.

### **Consensus Building Discussion**

#### Purposes

- To press toward a common (class-level) explanation or model, resolving (if possible) disagreements, different perspectives, or partial understandings
- To support public revision of earlier ideas, as new ideas are shared and as they learn information that makes visible the limitations of previous understandings held by individuals or even the class as a whole

#### Some Unit Phases When Useful

- After a series of lessons where multiple pieces of understanding should have been built
- At the end of a "bend" in the storyline

#### Some Lesson Phases When Useful

*"What have we figured out today? What questions do we still have?"*

#### Steps in a Possible Discussion Routine

1. Ask students to take stock of where the class has been and what they've figured out, offering conjectures or pieces of a model, explanation, or solution
2. Ask students to offer proposals for a synthetic model, explanation, or solution
3. Ask students to support or challenge proposals, and say what evidence is the basis for their support or critique
4. Ask students to propose a modification to the model based on input from the class

#### Potential Talk Moves for this Discussion

*During stock-taking:*



- What are some things we think we can say at this point about our anchoring phenomenon that are supported by evidence?
- Could you clarify the link you are making between your explanation and the evidence?
- Could someone restate our question (or our charge)? What are we building consensus about?

*When inviting proposals for a synthetic model/explanation/solution:*

- How are these explanations similar? How are they different?
- Both groups seem to be using the same term but in a different way, could someone explain the difference?
- Could someone restate our question (or our charge)? What are we building consensus about?

*When inviting support or critique:*

- Who feels like their idea is not quite represented here?
- Would anyone have put this point a different way?
- What ideas are we in agreement about?
- Both groups seem to be using different language to explain the same idea, is that what you are hearing?
- Are there still areas of confusion or discontent?
- Are there still places where we disagree? Can we clarify these?

*When inviting modifications to models/explanations/solutions:*

- How could we modify what we have, so that we account for the evidence we agree is important to consider?
- What modifications might you make to clarify confusion or address the discontent that this group feels?
- Is there more evidence or clarification needed before we can come to agreement? What is that?

### Making Participation Equitable

Many students are not comfortable being the “only one” who voices a disagreement, a discontent, or a potentially wrong idea, so ask students to think-pair-share and to carefully listen to their partners’ ideas. Then ask students to think about what they heard their partners saying, and ask the room if *their partners’* ideas are represented in the class discussion. This supports all students to share, to listen, to be heard, and to be represented.



## K. How Can Teachers Support the Development of Scientific Terms?

Some instructional approaches emphasize the role of introducing key vocabulary before learning about the concepts they are connected to in a lesson.

That is not an approach we support through our storylines. While we agree that developing scientific terminology is one important goal for students, it should not undermine the heavy lift we want to engage students in. In each lesson we want students engaging in practices around a question that they feel a genuine need/drive to figure out. Front loading vocabulary gives away the punchline for that lesson.

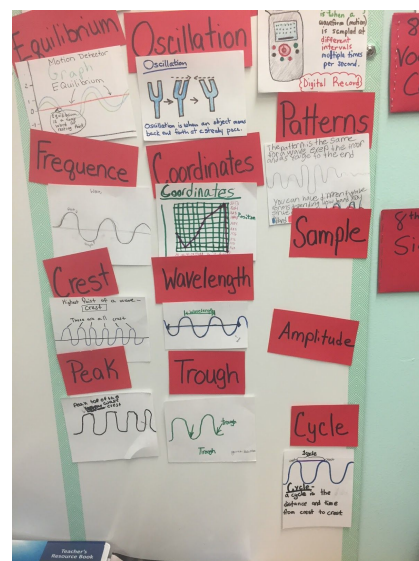
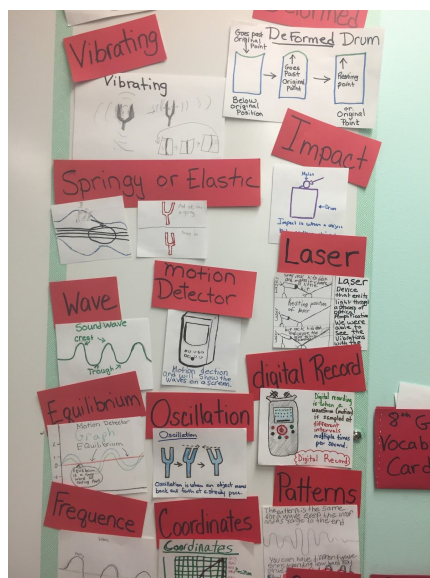
Once ALL students have developed a conceptual understanding of an idea in a lesson, introducing a relevant scientific term as shorthand way to reference that idea makes complete sense. It is simply a matter of timing.

Here is an example. In lesson 5 students will notice the graph of the vibrations produced by the object exhibits two interesting characteristics. After a few rounds of trying to describe patterns (individually, with a partner, and then in a whole group), this will lead students to start talking about two features of these patterns that can be compared and measured. One can be described in terms of the distance from the y-value of a high point on the graph. The other can be described in terms how often that pattern repeats. It is at this point, after the class has worked with these ideas for a bit and wrestled with what words best describe each feature, that the teacher can point out that it seems a bit cumbersome to keep referring to these features to describe the graphs in such a way, and that there are two terms that are used to refer to these features. One is amplitude and one frequency. At this point, it makes sense to consolidate students' ideas by showing how these two terms correspond to the patterns they observed. From this point on, using these terms to represent these features of such graph makes total sense.

This sort of “just in time” academic vocabulary building doesn’t undermine the sense-making of students, nor defeat the goal of figuring out important science ideas in each lesson. We want to give them a rich opportunity and experience to wrestle with developing these important science ideas before introducing vocabulary to represent an abbreviated description of those ideas.

Key scientific terminology to connect “just in time” as a lesson unfolds is identified in every Teacher Guide. Teacher Tooltips in the Learning Plan describe when to introduce many of these words.

As new scientific terminology is developed with the class, it is recommended you build a word wall of these ideas. Keeping a visual model next to each word can help students recall the concept the word is associated with. A set of student-built word cards for a teachers word wall is shown to the right.



## L. How Can Teachers Support Differentiated Instruction?

Differentiation strategies are built into individual lessons in the Teacher Supports section of the Learning Plan. An example strategy from lesson 1 is shown below.

In order to capture initial questions and ideas for investigation, take stock of any questions and ideas students may have at this time. You may want to record these questions on the chart paper titled, "Initial Questions." These early ideas for investigation can be recorded on the chart paper titled, "Initial Ideas for Investigation." This can be done simultaneously with the observations if they come up naturally or after going public with their observations. <sup>E</sup>

### Suggested Prompts:

- Oooh! This has got me thinking—are there any questions you are thinking of right now or is there anything you would like to investigate further?
- Turn and talk for 1 minute to the person next to you about any questions that person might be thinking about. Then I'll record them on our chart paper.
- Turn and talk for 1 minute to the person next to you about any ideas that person might have regarding anything we could investigate further to help answer our questions. Is there anything you would like to try out with the record player? I'll record those ideas on chart paper.

### Listen for student responses such as:

- *Yeah! We want to get our hands on the record player.*
- *Why does the music sound like chipmunks? Are those shiny things on the record lines? Someone said they are grooves—are they grooves or bumps? Does the needle "hop" to the next song? How does it get to the next song?*
- *Let's see the record up close. Watch a slow-mo video of the needle on the record. Spin the record backwards. Listen to other records. Put the needle on other parts of the record. Play a song or the whole record all the way through and watch the record.*



### Differentiation Support

<sup>E</sup> Sometimes teachers report that their class does not bring up checking out the record more closely after this initial exploration of the record player phenomenon. So in order to capture this idea on a public record, we suggest asking for initial ideas for investigations now. Even though students *really* might want to do all these other investigations right now, don't allow them to do so—keep their curiosity peaked. This may seem counterintuitive, but if you allow them to satisfy all their curiosity upfront, they might lose momentum and not engage with the subsequent materials with the same interest or vigor.

Every lesson provides opportunities for students to articulate new questions and ideas for investigations that the class should pursue at the end of the lesson. Though the Teacher Guides for subsequent lessons provide ideas for how to investigate the questions that are most commonly raised by students, using novel ideas that students raise for ways to investigate these questions increases students' sense of agency, as well as providing opportunities to extend investigation design to the level that students can articulate.

Here are some examples we have seen in previous pilots of this storyline:

- At the end of lesson 3, a student decided to collect evidence to help resolve the emerging controversy about whether the table vibrates when struck, by slow motion video taping the motion of her kitchen table after she hit it and brought it back to class.
- In lesson 4, some students suggested slow motion video taping the motion of the laser dot (e.g. using a smartphone) after striking the drum or table.
- In lesson 6 and 7, many students suggest running the motion detector for a longer period of time (e.g. 10 seconds) to see if the patterns they notice in the vibrations between conditions remains constant.
- In lesson 9, some students suggested double ziplock bagging the phone or submerging the container it is in underwater to make sure it was airtight.
- In lesson 10, some students suggested putting their head underwater rather than the sound source underwater. Others suggested using smoke or dust as a air movement indicator.
- In lesson 11, some students suggested using marbles rather than people as "particles" in the medium to simulate the domino effect of energy transfer via particle collisions.



At the end of most lessons, the teacher guide prompts the teacher to have the class co-construct a summary of the big ideas that they figured out in their Incremental Model Tracker. This resource serves as a useful “single stop” location for students to look to review the big ideas they will use in future assessments. A Incremental Model Tracker key is provided for the teacher for the entire unit.

A similar tool, “The gotta-have-it checklist,” is introduced in lesson 13. Students use this set of co-constructed criteria to revise their individual assessments in lesson 13.

Encourage students to return to referencing either of these resources during summative assessments. Or for students who you want to challenge, encourage them to do these assessments first without this reference.

Some lessons provide different options for student home learning assignments. For example in lesson 7, three possible assignments are provided in the materials for each student in the Teacher Guide (shown to the right). Two are geared at some experimentation and some reading, while one is geared at only reading.

In such lessons, giving students an option of what assignment they wish to do is a way to support self-selected differentiation.

Section D of this document outlines different options for implementing different portions of this storyline. Some options support implementations that will skip lessons from bend 3 and 4. You could save those investigations as alternate activities for students who master a particular assessment or want to conduct an independent investigation. For example, students who master the assessment in lesson 7 could begin work on the speaker lessons (20 and 21), while you work with other students that you want to review the results of the assessment with and/or remediate.

Lastly, consider using unanswered questions from the driving question as opportunities for students to pursue additional research about any of those topics they self select, after the storyline is complete.

#### Materials for Each Student

- Lesson 7 Student Activity Sheets
- Lesson 7 Record Surface Student Handout (1)
- Incremental Model Tracker sheets (partially filled out from previous lessons)
- Wooden or plastic coffee stirrer OR straws OR an unbent [paperclip](#) (1)
- Lesson 7 Assessment #1 (1)

Differentiated options for students for after the assessment:

- Supplemental Investigation 7A (1) and 6 wooden coffee stirrers
- Supplemental Investigation 7B (1) and a balloon. (If you use latex balloons, check for latex allergies first)
- A reading on how humans produce sounds:  
<http://www.npr.org/templates/story/story.php?storyId=129083762>

