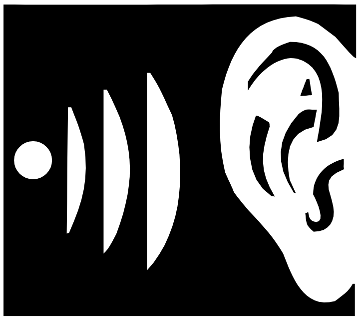

# Sound Energy Unit
# Grade 4

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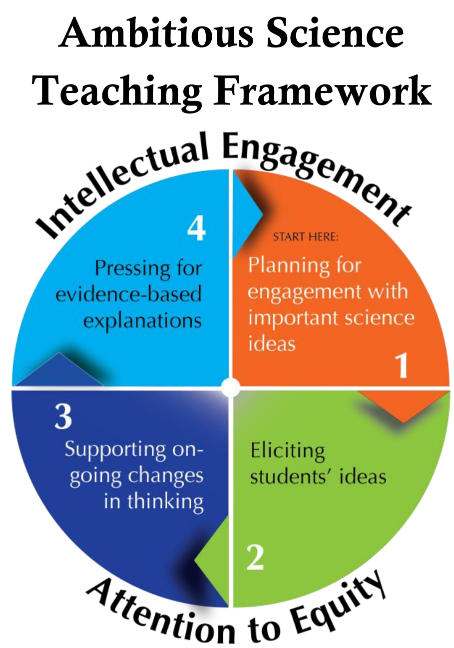
Unit Synopsis:

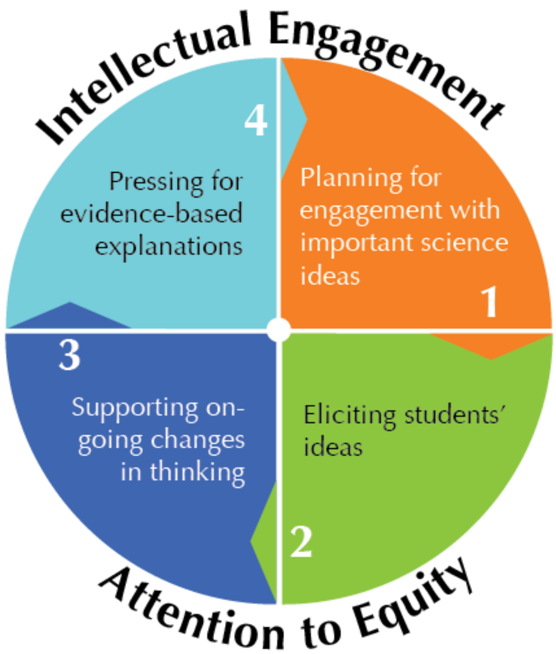
After watching a video clip of a singer shattering a glass with his voice, students will gather evidence from a range of activities to explain how the singer is able to do this. The scientific explanation behind this event includes big science ideas around energy transfer and transformation and requires an understanding of the particulate nature of matter (to some degree). Throughout the unit, students should have opportunities to create and revise their own models of this glass-shattering event in light of new evidence from activities. Ultimately, the model and explanation students create is for the glass-shattering event; however, students should also apply what they understand about sound energy to other phenomenon relevant to their own lives. (Examples may include: loud airplanes flying over their neighborhoods, how guitars or other instruments work, or hearing loud music through walls from their sibling's/neighbor's room.)




*Unit Note: The Next Generation Science Standards (NGSS) expect students to understand properties of sound energy such as wavelength, pitch, amplitude, and frequency in grade 4. Some districts currently have a sound unit located in other grade levels. This unit was written with grade 4 NGSS standards in mind, but also pulls from grades 5 and 6 NGSS, creating a unit for upper elementary grades. Also, math connections with common core come from grades 5 and 6.*

# Ambitious Science Teaching

We provide here a vision of ambitious teaching—teaching that is effective, rigorous and equitable. But more than that, we provide a framework of research-based teaching practices that are consistent with this vision and a wide range of tools that can transform how students learn in your classroom. The vision, practice, and tools will furnish a common language about teaching for a group of science educators committed to the improvement of teaching. You will be able to identify "what we will get better at" and how to get started.




Ambitious teaching aims to support students of all racial, ethnic, and social class backgrounds in deeply understanding science ideas, participating in the talk of the discipline, and solving authentic problems. This teaching comes to life through four sets of teaching practices that are used together during units of instruction. These practices are powerful for several reasons. They have consistently been shown through research to support student engagement and learning. They can each be used regularly with any kind of science topic. And finally, because there are only four sets of practices, we can develop tools that help both teachers and students participate in them, anyone familiar with the practices can provide feedback to other educators working with the same basic repertoire, teachers can create productive variations of the practices, and everyone in the science education community can share a common language about the continual improvement of teaching.

The four Ambitious and Equitable Science Teaching Practices are summarized in the below.

| Practices | What does it LOOK like? |
|---|---|
| Planning for engagement with important science ideas | • Planning a unit that connects a topic to a phenomena that it explains (Chemical Reactions – Bike Rusting, Photosynthesis – Seed Becoming a Tree)<br>• Teaching a topic within a real-world context |
| Eliciting students' ideas | • Asking students to explain HOW and WHY they think a phenomena happens (How did the bike change? Why did it change? What is happening at the unobservable level?) |
| Supporting on-going changes in thinking | • Using ALL activities/lessons to explain the phenomena.<br>• Giving students opportunities to revise their thinking based on what they're learning |
| Pressing for evidence-based explanations | • Allowing students to create a final model or explanation about the phenomena<br>• Pressing students to connect evidence to their explanation |

Many teachers want to know what their classrooms should look like and sound like—they want to understand how to interact with their students about science ideas and students' ideas. This is especially true now that the *Next Generation Science Standards* are being used in many states.
As a result of the last 30 years of classroom research, we know enough about effective instruction to describe in clear terms what kinds of teaching practices have been associated with student engagement and learning. This research tells us that there are many ways that teachers can design and implement effective instruction, but that there are common underlying characteristics to all these examples of teaching that can be analyzed, described, and learned by professionals. These practices embody a new form of "adaptive expertise" that EVERY science educator can work towards. Expert teaching can become the norm, not reserved for a select few. Ambitious teaching is framed in terms of practices that any teacher can learn and get better at over time. What would we see if we entered classroom of a science educator using ambitious teaching? To give you a sense of what ambitious teaching looks like, we have described below some features common to all science classrooms where ambitious teaching is being implemented (listed on right). These features address everyday problems with learning and engagement that teachers face (listed on left).

| **Common problems in supporting student engagement and learning** | **What you'd see in a science classroom where ambitious teaching is the aim** |
|---|---|
| The problem: *Students don't see how science ideas fit together.* Each day is perceived by students to be the exploration of ideas that are unconnected with previous concepts and experiences. | At the beginning of the unit, students are focused on developing an evidence-based explanation for a complex event, or process. Students know that throughout unit, most of the activities, readings and conversations will contribute to this explanation. |
| The problem: *An oversimplified view of what it means "to know."* Science ideas perceived to be straightforward and learnable within a lesson—either you get it or you don't." | An idea is never taught once and for all, but revisited multiple times. Students' science explanations are treated as partial understandings that have to be revisited over time to become more refined and coherent. |
| The problem: *Lack of student engagement.* Students' experiences and interests not elicited or seen as relevant. Student ideas treated as "correct" or "incorrect." | Students' ideas and everyday experiences are elicited and treated as resources for reasoning; students' partial understandings are honored as a place to start. They are made public and built upon. |
| The problem: *Students reluctant to participate in science conversations.* Teachers dominate the talk, ask primarily for right answers, get brief responses from students. | Teachers use a varied repertoire of discourse moves to facilitate student talk. Guides and scaffolds for talk help students feel comfortable interacting with peers. |
| The problem: *Some students have little support for accomplishing tasks that would otherwise be within their grasp.* Little or no guidance for students' intellectual work. Giving "clear directions" is seen as enough to ensure participation in activities. | There is scaffolding that allows students to participate in science-specific forms of talk, in group work, and in science practices. |
| The problem: *Invisibility of student ideas and reasoning.* Teacher does not know what students think—their heads are a black box. Cannot then work on students' ideas. Students cannot take advantage of the ideas or ways of reasoning by their peers. | Students' thinking made visible through various public representations (tentative science models, lists of hypotheses, question they have, etc.). The teacher can see how students think and how that thinking could change over time. Students benefit from seeing and hearing the reasoning of others. |
| The problem: *Illusion of rigor.* Students reproduce textbook explanations, lean on vocabulary as a substitute for understanding. Talk of evidence and claims are rare. | The teacher presses for complete, gapless explanations for unique real-life events or processes, and press for the use of evidence to support claims. |

As you will see, ambitious teaching is not a "method," and the teaching practices are not scrip
set of principled practices that must be adapted to your classroom needs. Coaches and other teachers can work with you to do this ambitious work.

If viewing digitally, click here to return to page 1.

# TEACHER BACKGROUND


# Science Content Primer & Explanation of Phenomenon

Read through the explanation provided in the next few pages. Jot down questions or uncertainties. Consult internet resources to answer your questions, ask colleagues, and work together as a team to grow your own understandings of the science content and the phenomenon itself. This knowledge primes you to better listen and respond to student ideas in productive ways. Please feel free to revisit this explanation throughout the unit to revise and improve your own understanding of the science content.

# WHY WAS THE SINGER ABLE TO SHATTER THE GLASS?

**Teacher Notes about Science Content**

The explanation below provides some background knowledge and explanation of key science ideas that students need to understand and connect in order to explain this phenomenon. The more teachers understand the science behind the phenomenon, the more teachers can productively facilitate classroom science discussions to build on and wrestle with these key science ideas. There are more details about how to introduce the unit to students in the lesson guides. This overview is to help familiarize teachers with the science content knowledge required of this unit.

**Phenomena**: Singer shatters glass with his voice.

- "Jaime Vendera How to Shatter a Glass you're your Voice" (46 seconds) https://www.youtube.com/watch?v=10lWpHyN0Ok
- "Breaking Glass with Sound – Trevor Cox" (1 min, 04 sec; no sound in video but the glass is next to an amplifier and the video captures the slow motion) https://www.youtube.com/watch?v=dU0OqVDl7kc
- OPTIONAL: Clio SP AudioBreak Glass (only play part with speakers vibrating car windshield) https://www.youtube.com/watch?v=9VK4IAAFrPo

**Essential question**: Why was the singer able to shatter the glass?

**Key Science Ideas**:

1. **Energy transferred through matter.**
   a. Matter is made of particles.
   b. Particles can bump into each other to transfer energy.
   c. Sound energy decreases over distance as it is transferred through matter

2. **Energy can be transformed or changed from one form to another.**
   a. Types/forms of energy: chemical, mechanical, sound, light, heat, electricity.
   b. For the "singer shattering the glass" story, mechanical energy is transformed into sound energy and then back to mechanical energy as the energy goes from inside the singer, through the air, and into the glass.

3. **There is a relationship between energy, forces, and matter.**
   a. Sound can make matter vibrate and vibrating objects make* sound.
   b. The stronger the force that starts the vibration, the louder we hear the sound.

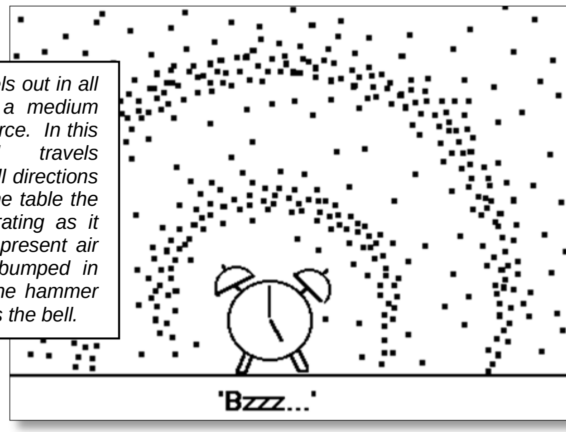
4. **Sound waves have regular patterns of motion.** *They can differ in:*
   *a. Volume which is represented by the amplitude (height of wave)*
   b. *Pitch which is represented by frequency (how many peaks per second)*
   *c. Wavelength(the distance between peaks)*

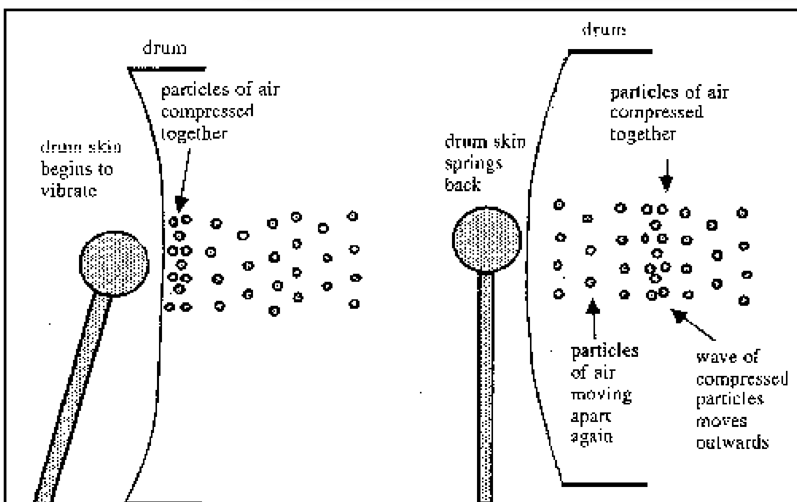
** Sound is a form of energy. Energy is never produced, created, made or conversely destroyed. Energy is only transferred and transformed. Students may use the terms "make" instead of "transform". Vibrating objects do "produce" sound that we can hear but really the vibrating object is transferring mechanical energy (motion of vibration) into sound energy by jostling molecules which transfer that energy through the air to our ears.*

# TEACHER EXPLANATION OF PHENOMENON:

The explanation about this glass-shattering phenomenon is all about transfer and transformation of energy. Sound energy is closely related to mechanical energy (energy of motion). When an object vibrates, such as vocal chords, the vibrations push the surrounding molecules in every direction. A medium is composed of molecules and can be solid, liquid, or gas. A medium is necessary for sound energy to be moved from one place to another because the sound travels by pushing molecules into each other in all directions emanating from the source, sort of like dominoes.

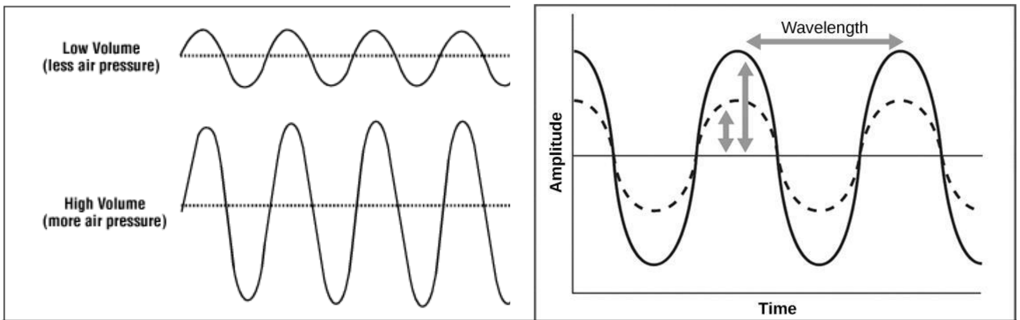
*Sound energy travels out in all directions through a medium from the sound source. In this example, sound travels through the air in all directions and also through the table the alarm clock is vibrating as it rings. The dots represent air particles that get bumped in waves each time the hammer in the alarm bell hits the bell.*



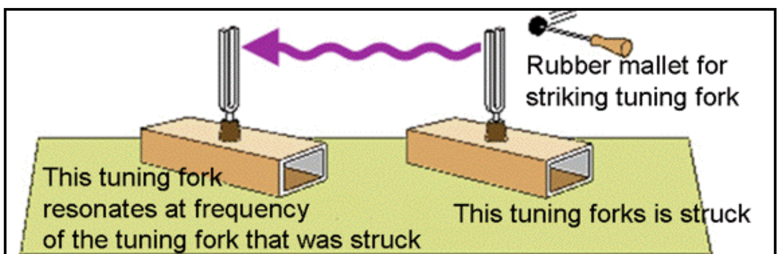

*How drums transform mechanical energy (hitting with the mallet) into sound energy by jiggling surrounding air molecules. As the drum flexes back-and-forth as it vibrates, it pushes air molecules and then does not, resulting in a pattern of compressions.*

Sound has specific properties, like pitch and volume. Higher pitch sounds have higher frequency. This means that the vibration goes back-and-forth faster and therefore is pushing surrounding molecules in pulses at a high rate over time. If the sound also has high volume, then the vibration pushes the molecules harder. For low pitch, the sound wave has lower frequency. This means that the vibration is moving molecules at a slower rate (more time between pushes). Again, more volume is a push with more energy and the amplitude of the wave (vibration) will be larger but the rate of vibration will stay the same if it is the same pitch.



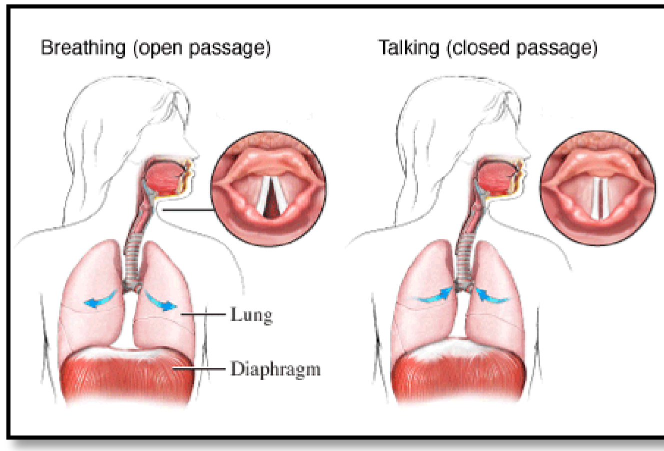

*LEFT: These sounds have the same pitch (wavelength measured from crest to crest is equal) but different volume (amplitude, or height of wavelength).Volume is related to force. The top sound has less pressure when traveling through air than the sound on the bottom. RIGHT: Diagram labeling the amplitude (height of the wave) which is related to volume and the wavelength (from crest to crest) which is related to pitch.*

At first the singer flicks the glass to hear the resonant pitch the glass makes. This is the pitch he must match in order to get the glass to vibrate. (If you listen closely at the beginning of the video, when the singer pauses to take a breath you can hear the glass 'humming' but it hasn't yet shattered. So he's at the right pitch but either not loud enough or not close enough.) The diagram below shows how the vibration of one tuning fork can make another identical tuning fork begin to vibrate (just like the singer can make the glass vibrate if he hits the right pitch.)

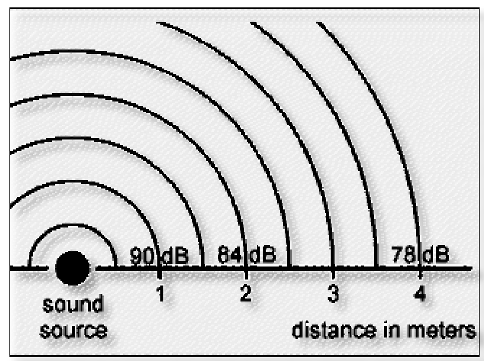



*Two identical tuning forks can exemplify the idea of resonant frequencies affecting objects over a distance. Each tuning fork is identical. When one is struck, vibrations of the tuning fork transform mechanical energy to sound energy. This sound energy bumps the surrounding air molecules in all directions. Those that bump into the other identical tuning fork make that fork start vibrating and making sound. To see this as a demonstration watch "Grandpa John Resonance" on YouTube* https://www.youtube.com/watch?v=hiHOqMOJTH4

The singer uses muscles to make his vocal chords vibrate. The vibrating vocal chords jiggle air molecules that are inside our trachea (wind pipe). The push is not constant, but pulsing (compression wave). These vibrations travel through air. Air molecules do not move across the distance between his larynx and the glass but rather they push against neighboring air molecules. This domino effect eventually pushes air molecules against our ears drums. We hear these vibrations as sound. Our eardrums vibrate at the same rate as the original vibration so we can hear him (and feel if loud enough) singing the note.




The singer must be loud and close to the glass. Sound energy dissipates over a distance. A loud volume will jiggle the air molecules with more force (or air pressure) than a soft volume. If that volume is close to the glass, then the glass "feels" the pressure directly as opposed to if the singer stood 4 meters away from the glass and sang – dispersing the pressure over a distance as sound energy travels out in all directions. Then as the singer increases his volume, the wine glass really vibrates. The glass is flexing and wobbling. Air molecules are always bumping against the inside and outside of the glass. However adding sound energy to the system makes the molecules bump harder and more frequently than normal.

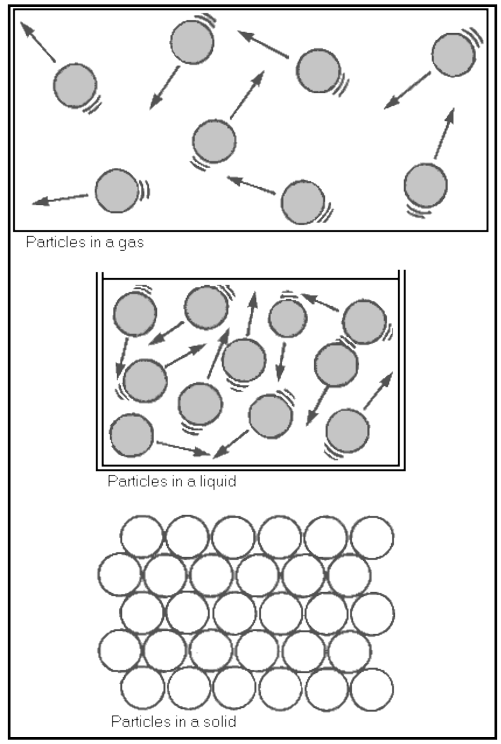



The singer must also sing at the "right" pitch for the glass. When the singer hits the particular note, the wine glass begins to vibrate, too. The singer listens to hear if the glass is making noise, too (resonating). You can find this note by tapping the glass or running your finger around the edge. The closer the singer is to this pitch, the more the glass vibrates.

The glass flexes because air molecules bump into the outside of it with more force than usual (extra force comes from sound wave). The glass will stay together through a little bit of wobbling, but over time the flexing back and forth will break the glass. So the shape of the glass is important. The wine glass is thin and round. The tiny stem does not absorb a lot of the vibrations. A thicker glass could absorb the sound vibrations and would not wobble or flex as much so it wouldn't break.

Also, the glass also has to be empty. The empty glass will flex and wobble at a certain pitch. However, if there were water in the glass, the water would help the glass keep its shape. The water would push on the sides of the glass and keep them from wobbling or breaking. The sound would travel through the water, too.

Sound is a form of energy. Sound energy is all about vibrating air, water, wood, whatever material the vibration/mechanical motion is near. Sound energy travels most efficiently through solids and least quickly through gases because of how the particles are arranged in each material. This connects to the phenomenon since sound travels through the air and then into/through the glass material (solid).



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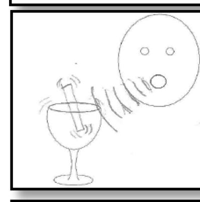
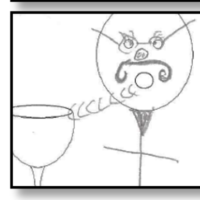
# HOW STUDENTS MODEL THE TRANSFER OF SOUND ENERGY

**THERE ARE SEVERAL REPRESENTATION STUDENTS TYPICALLY USE WHEN REPRESENTING SOUND.**
The information presented here is a blend of prior experiences teaching using this sound phenomenon with research about how students conceptualize sound energy (Eshach & Schwartz, 2006; Wittman, Steinberg, & Redish, 2003).

## SOUND CRESCENTS



Sound crescents are semi-circular shaped and repeated to show sound spreading out over a distance, which does happen. They typically show sound going in a particular direction (as opposed to sound circles/spheres that emanate in all directions from the source), but can be drawn emanating in all directions. Sound crescents do not show exactly how the sound energy is transferred (particles) but it does show spreading out.

***How could 'sound crescents' be used as a representation help students understand sound?***

- Represent volume by making crescents thicker/thinner
- Represent pitch by spacing crescents equally apart, closer spacing indicates higher pitch (and more pulses) and farther spacing indicates lower pitch (and fewer pulses/waves)
-

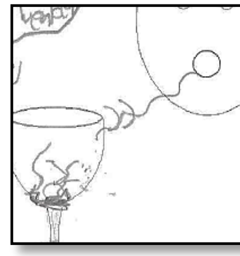
## SOUND THREADS

Sound threads are typically used to show how sound travels in a particular direction and the number of threads may represent the intensity or volume of the sound. The top drawings show student initial models about how the singer's voice traveled to the glass. The student's drawing (bottom) of "sound threads" in the stethoscope, traveling from the patient's heart to the doctor's ears is interesting because the student used the sound crescent idea to describe the sound in the air, but he uses the "thread" concept in the stethoscope context.


***How could 'sound threads' be used as a representation help students understand sound?***

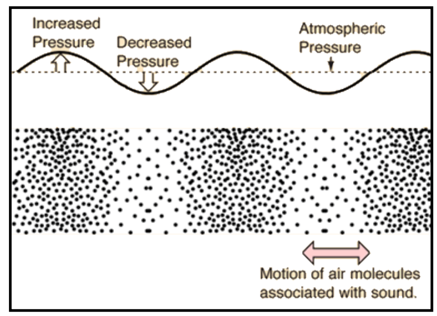
- Represent volume (and the related idea of force) by using multiple threads for louder sounds and fewer numbers of threads for quieter sounds (and less force)
- Representing pitch is possible (change thread thickness so that a high pitch could be thinner and a low pitch could be thicker); however, this representation does not show frequency of the wavelength (or frequency of bumps) which is a key idea to understanding pitch. So 'sound threads' may not be the best representation of sound if students are trying to model the effects of changing pitch.

## Sound Waves



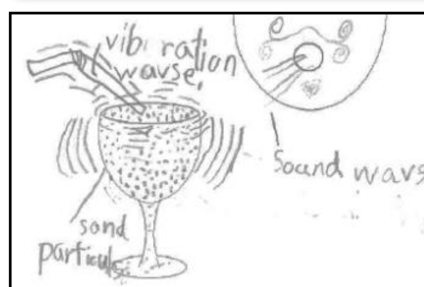
Sound waves are typically used to show how sound can travel in a particular direction and can be used to capture pitch and volume. Sound waves also typically show sound as unidirectional and targeted – so if students are thinking about how sound travels over a distance in all directions, the sound wave representation may not be as helpful as the sound crescents.
How could 'sound waves' be used as a representation help students understand sound?
The spacing of crests and troughs can represent pitch. The closer together the waves are the higher the pitch.
The amplitude or height can represent volume. If a wave is drawn across a distance, then the amplitude may be drawn as decreasing to show how volume decreases at a distance.

## Productive Discussion about model conventions




There is no 'best representation' that captures and models each property of sound. Each representation can be shaped through interactions with teachers and other students to foreground particular properties of sound energy such as volume, direction, dissipation over distance, pitch, frequency, etc. Some are better at representing some properties of sound than others which provides grounds for fruitful conversations with students about what ideas they think are most important to represent about sound energy in different contexts.

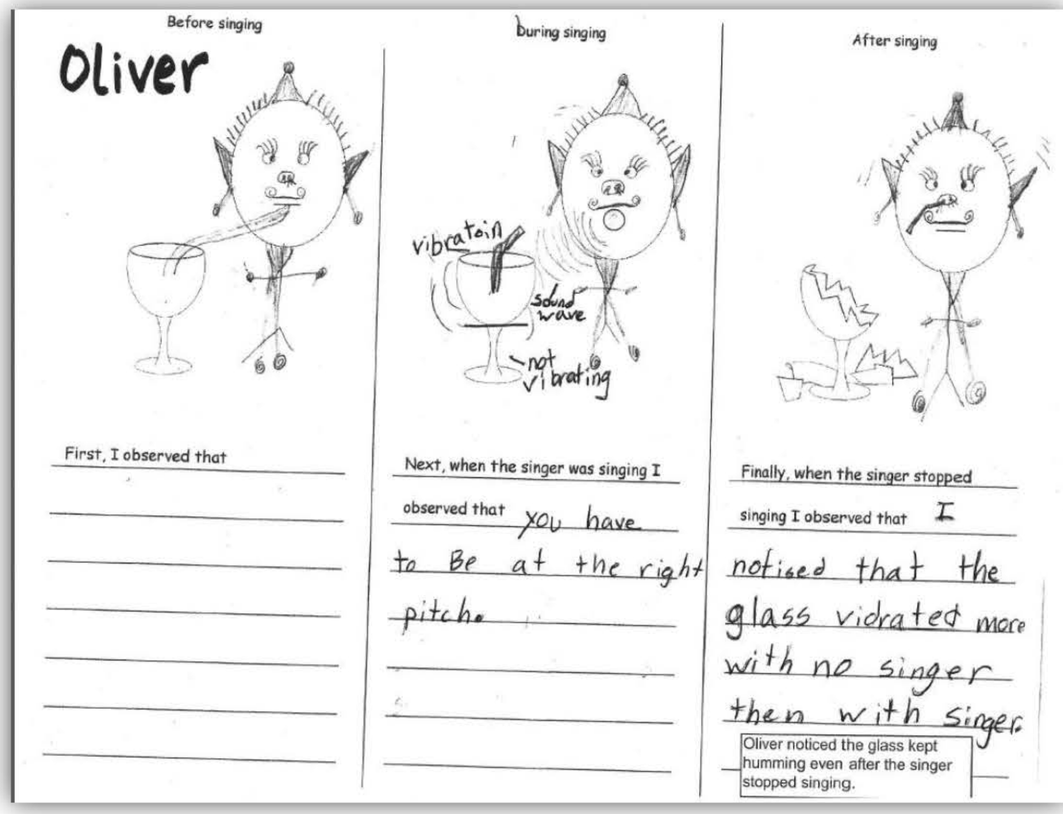

Between contexts students may switch between representations (without even knowing they do it) which can also be a place for productive discussion.
An additional modelling option may be introduced to help students think about how sound travels through different states of matter by attending to particle motion (top right). This diagram maps the sound wave representation on to a particle wave representation to show compressions.

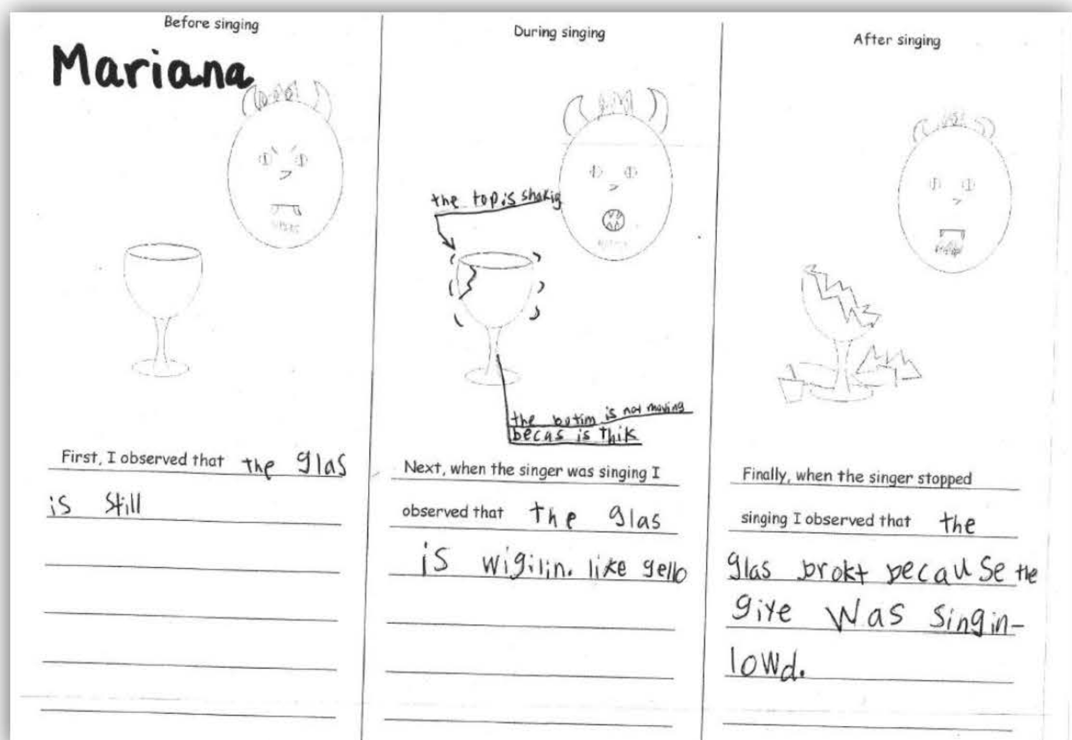


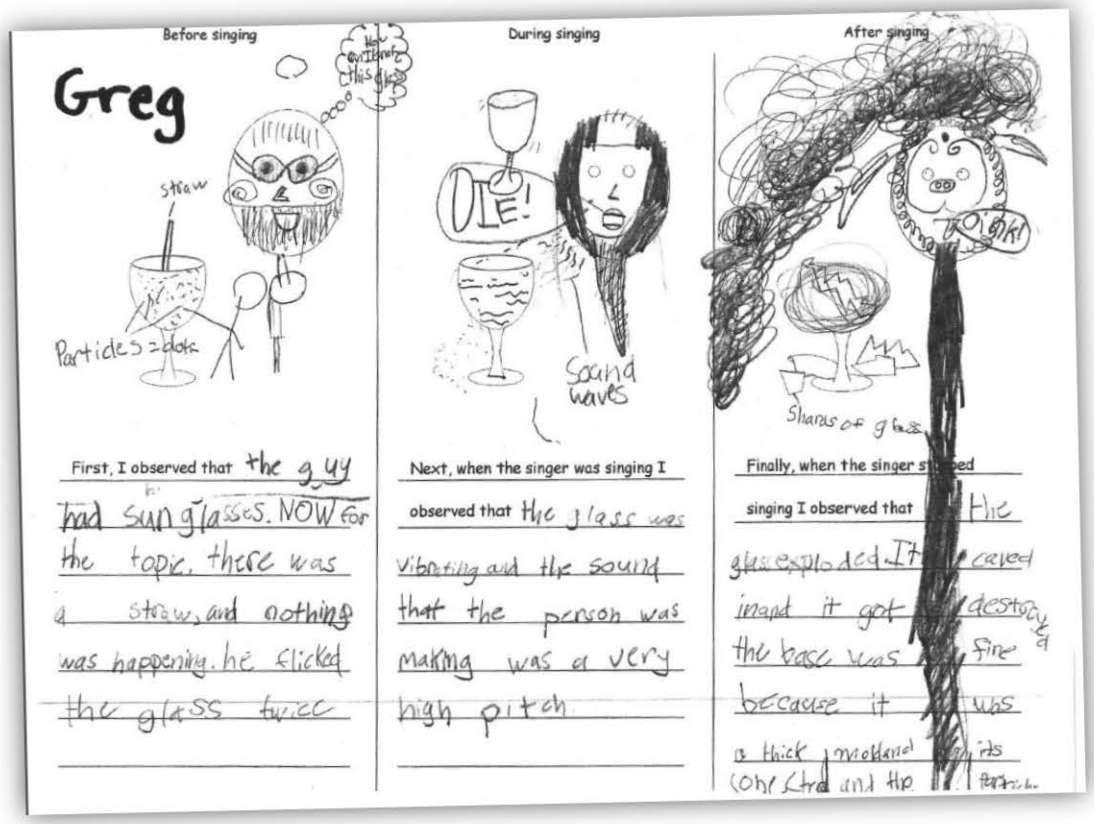

Students may attend to particles on their own prior to instruction using their prior knowledge that matter is made of particles and solids, liquids, and gases have different particle arrangements. But what will be new is helping students represent how sound energy can transfer through matter and into different materials. Students attend to particles in their initial models (right, middle and bottom).

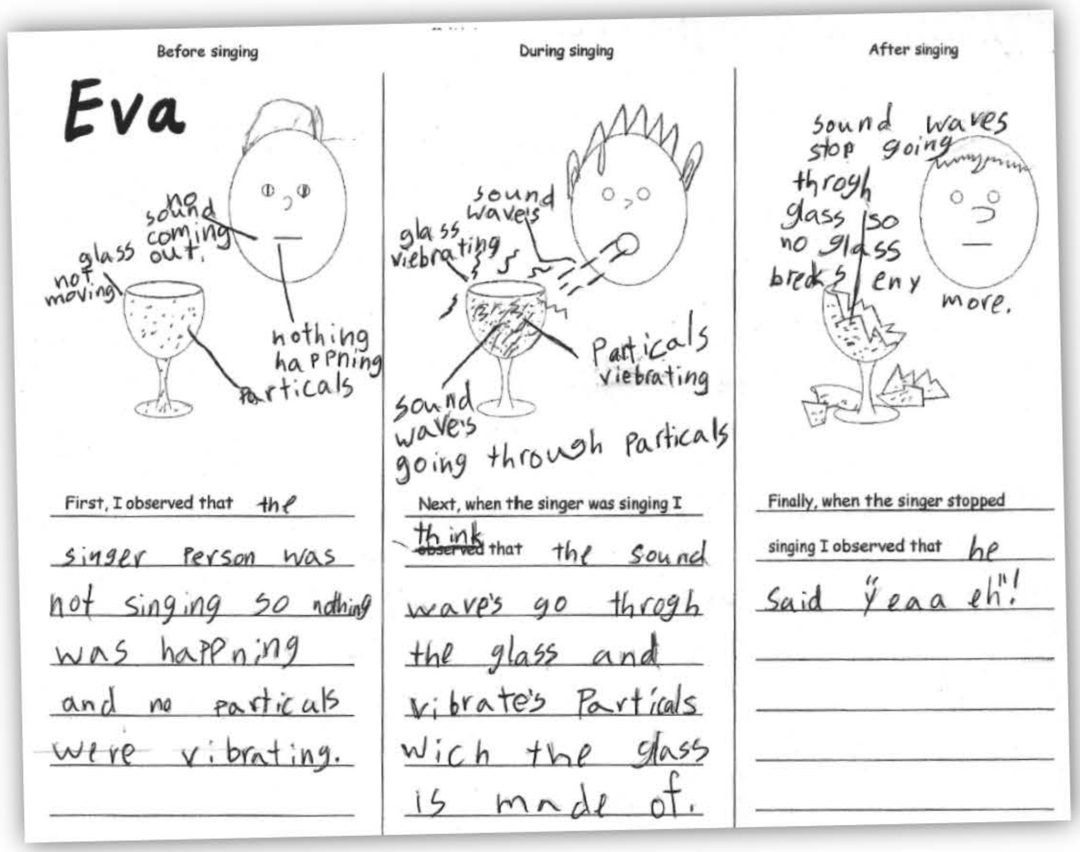
**Examining Student Work Samples:** Some examples of students' initial models and students' mid-unit model revisions follow. Look at what ideas students are representing and also how they are choosing to represent sound.

# INITIAL MODELS

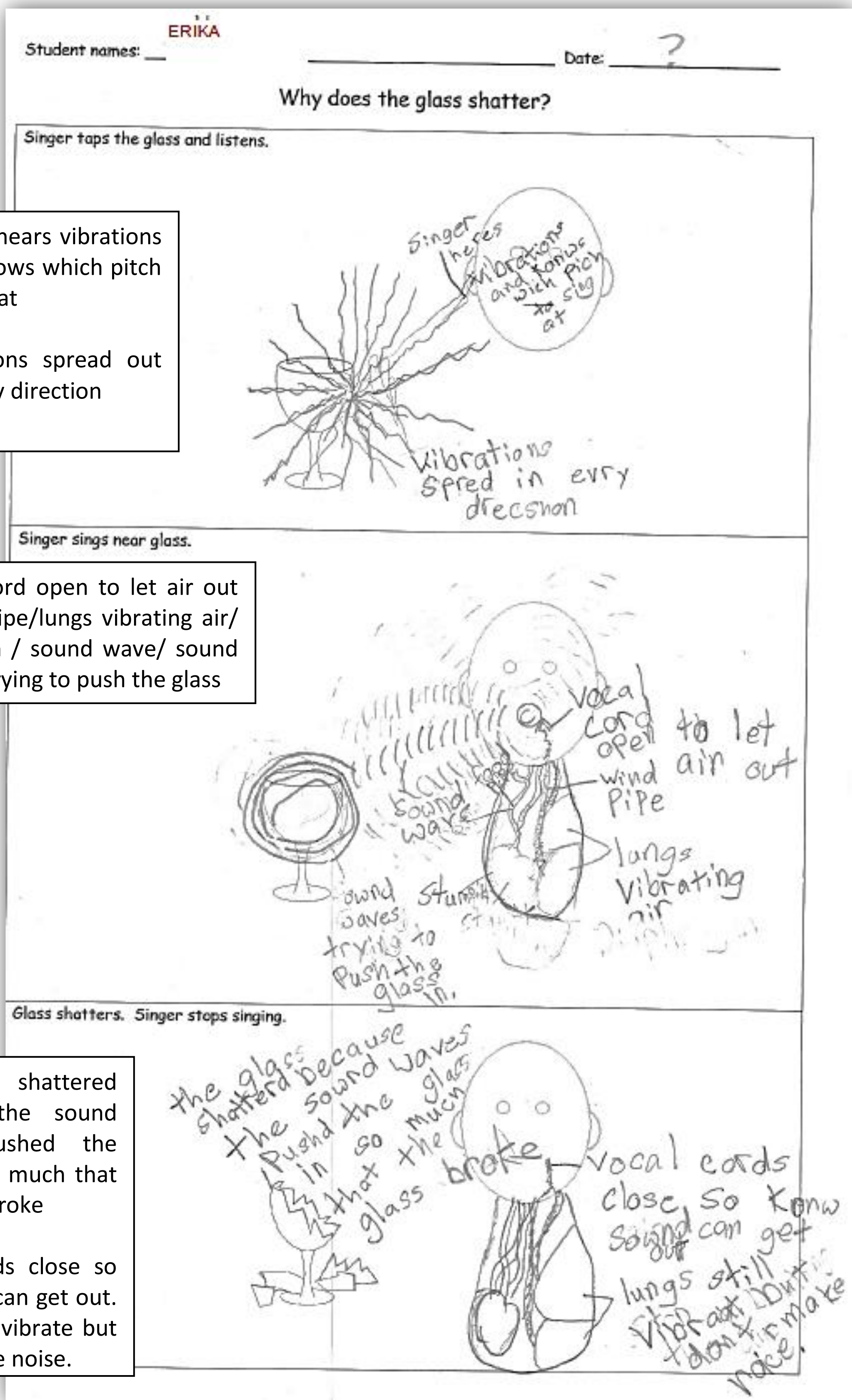



Before singing
During singing
After singing
Greg
How do I break this glass
straw
Particles = dots
DIE!
Sound waves
Oink!
Shards of glass
First, I observed that the guy had sunglasses. NOW for the topic, there was a straw, and nothing was happening. he flicked the glass twice
Next, when the singer was singing I observed that the glass was vibrating and the sound that the person was making was a very high pitch
Finally, when the singer stopped singing I observed that the glass exploded. It caved in and it got destroyed the base was fine because it was thick


Before singing
During singing
After singing
Eva
no sound coming out.
glass not moving
nothing happning
particals
sound waves
glass viebrating
Particals viebrating
sound waves going through particals
sound waves stop going throgh glass so no glass breks eny more.
First, I observed that the singer person was not singing so nothing was happning and no particals were vibrating.
Next, when the singer was singing I think ~~observed~~ that the sound wave's go throgh the glass and vibrate's Particals wich the glass is made of.
Finally, when the singer stopped singing I observed that he Said "yeaa eh"!

# INDIVIDUAL MODEL REVISIONS




Singer hears vibrations and knows which pitch to sing at

Vibrations spread out in every direction

Vocal cord open to let air out /wind pipe/lungs vibrating air/ stomach / sound wave/ sound waves trying to push the glass

The glass shattered because the sound waves pushed the glass in so much that the glass broke

Vocal cords close so no sound can get out. Lungs still vibrate but don't make noise.

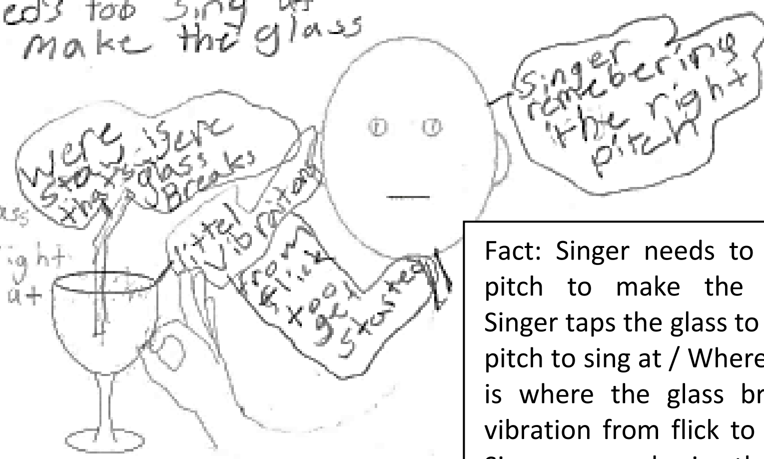
Student names: OLIVER Date: 5/29/12

## Why does the glass shatter?

~~Singer taps the glass and listens.~~

fact: singer need's tob sing at right pitch too make the glass Break.

singer taps glass too find the right pitch too sing at

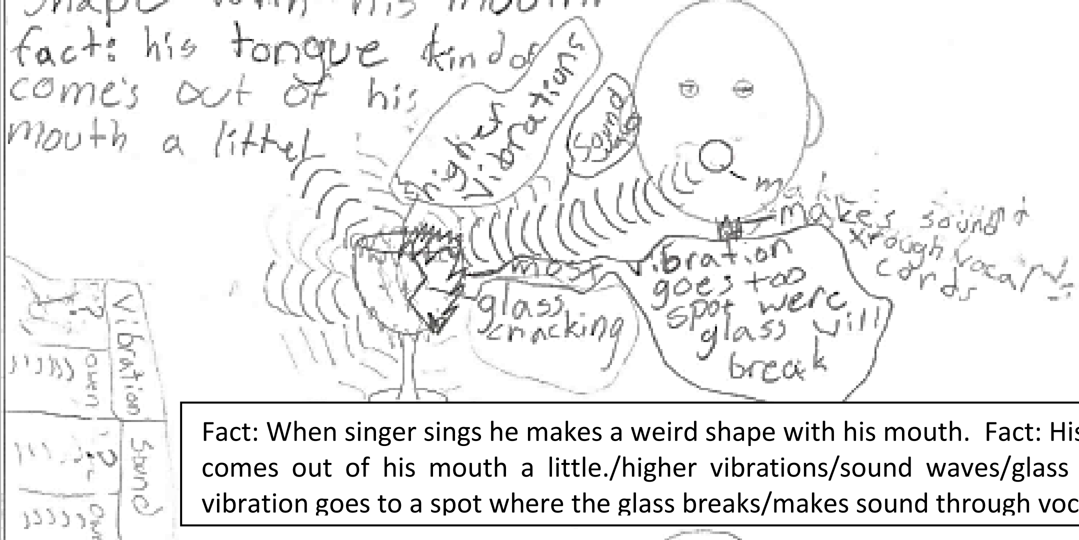



Fact: Singer needs to sing at right pitch to make the glass break. Singer taps the glass to find the right pitch to sing at / Where straw is that is where the glass breaks / Little vibration from flick to get started / Singer remembering the right pitch

~~Singer sings near glass.~~

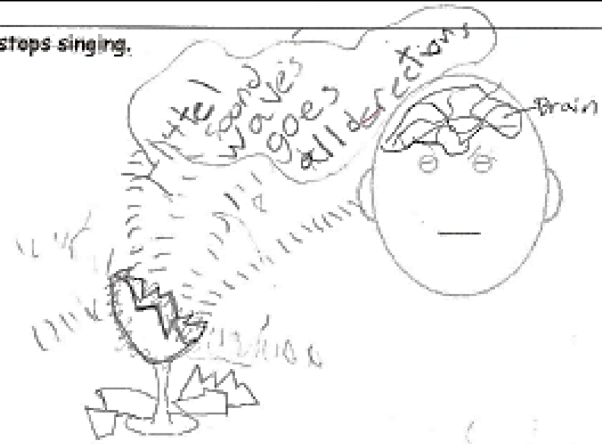
fact! when singer sing's he make's a wierd shape with his mouth.

fact: his tongue kind of come's out of his mouth a littel

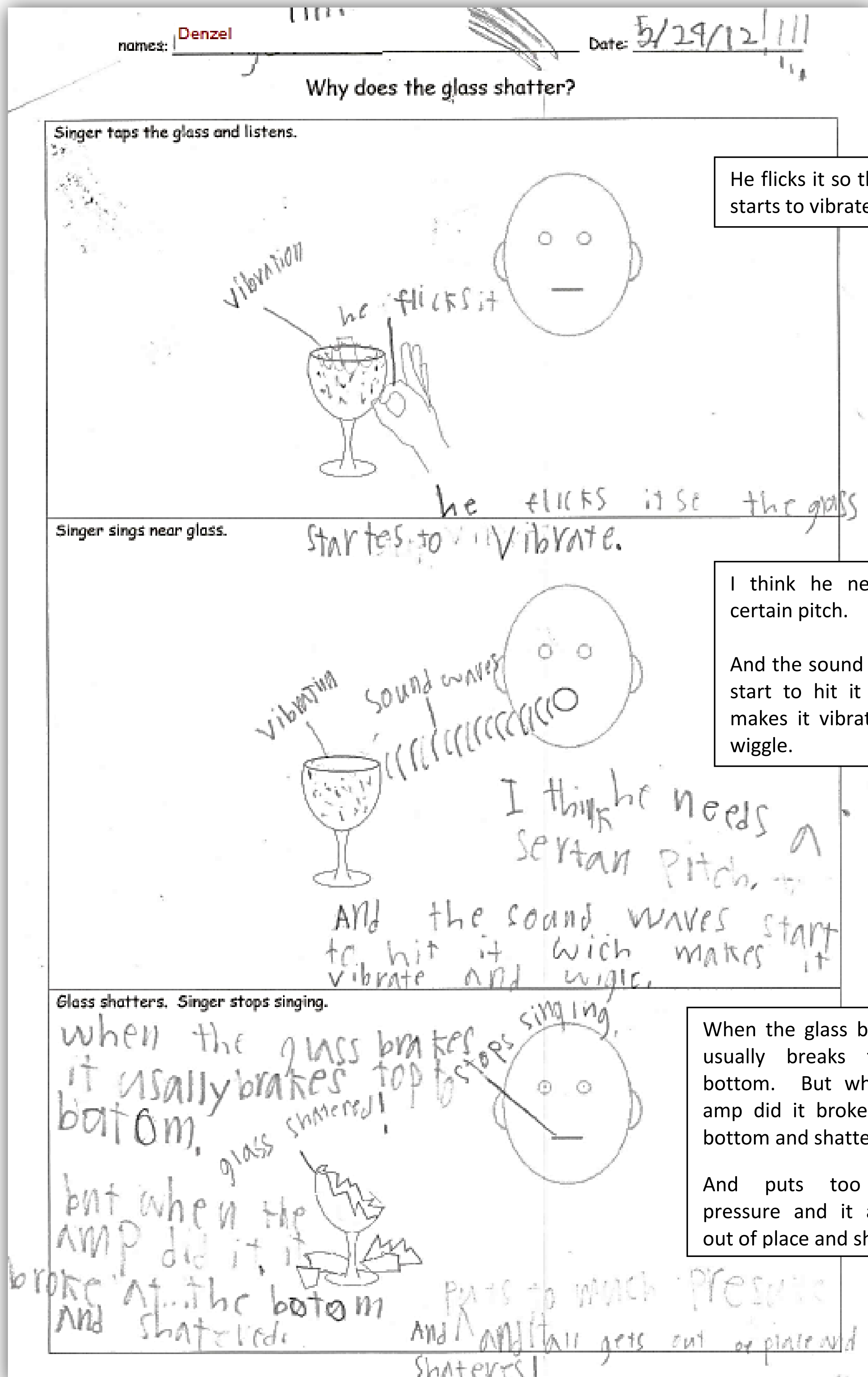



Fact: When singer sings he makes a weird shape with his mouth. Fact: His tongue kind of comes out of his mouth a little./higher vibrations/sound waves/glass cracking/ Most vibration goes to a spot where the glass breaks/makes sound through vocal cords

Glass shatters. ~~Singer stops singing.~~




Little sound waves goes all directions / brain



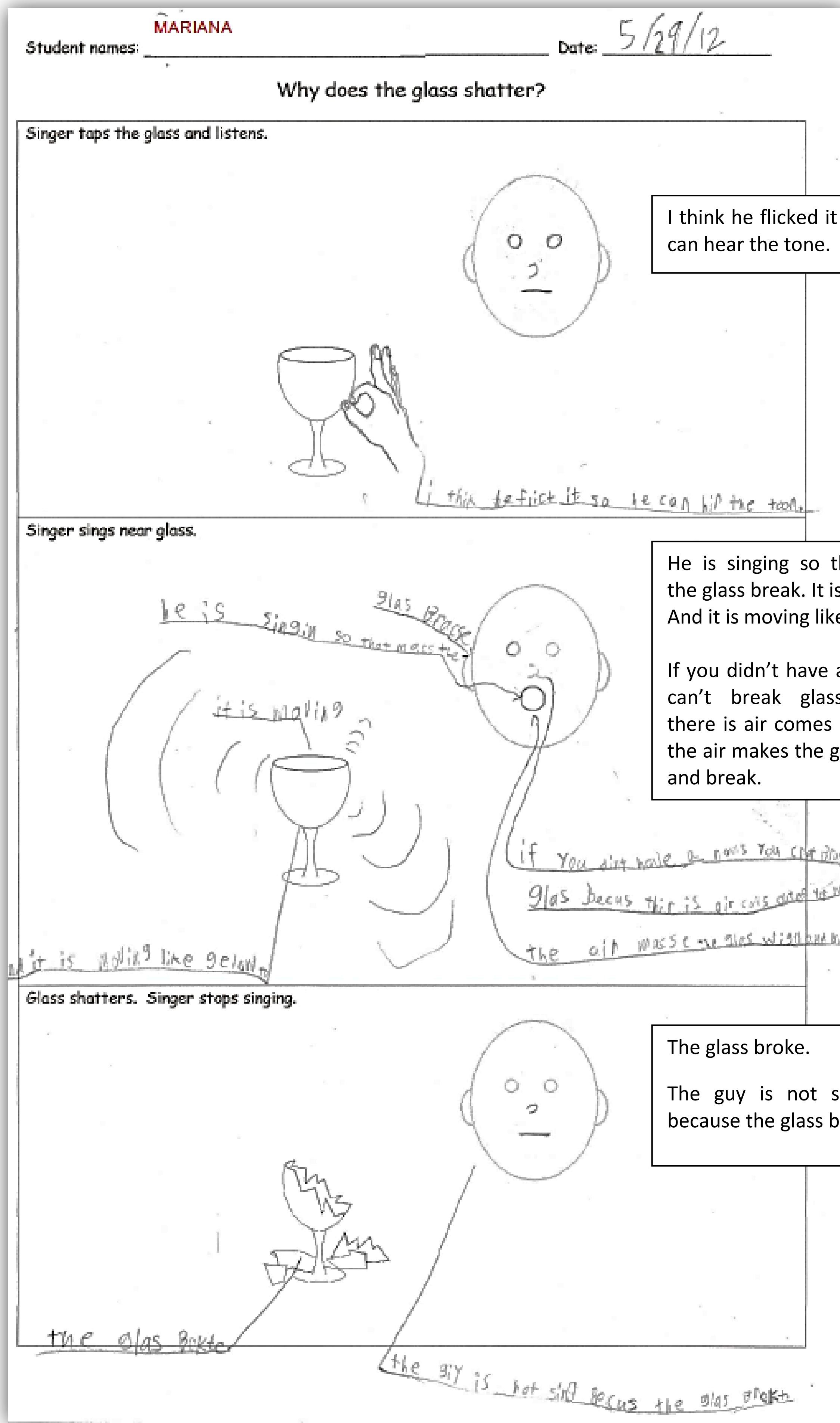

He flicks it so the glass starts to vibrate.

I think he needs a certain pitch.

And the sound waves start to hit it which makes it vibrate and wiggle.

When the glass breaks it usually breaks top to bottom. But when the amp did it broke at the bottom and shattered.

And puts too much pressure and it all gets out of place and shatters.


MARIANA

Student names: ______________________ Date: 5/29/12

**Why does the glass shatter?**

Singer taps the glass and listens.

i think he flict it so he can hir the toon.

I think he flicked it so he can hear the tone.

Singer sings near glass.

he is singin so that macs the

glas broke

it is moving

it is moving like gelow

He is singing so that makes the glass break. It is moving. And it is moving like jello.

If you didn't have a nose you can't break glass because there is air comes out of you the air makes the glass wiggle and break.

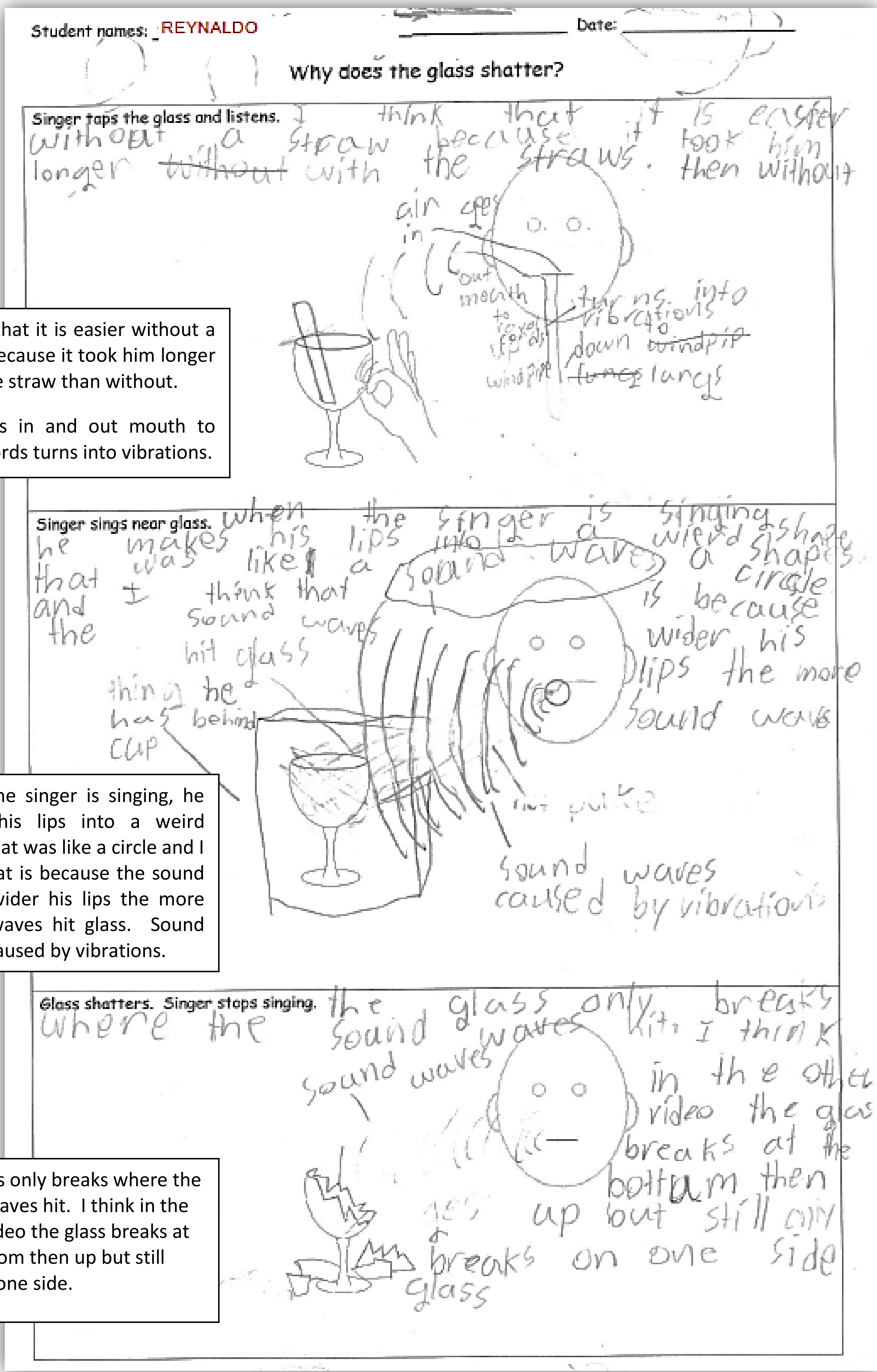
Glass shatters. Singer stops singing.

the glas Brokte

the giy is not sing becus the glas brokt

The glass broke.

The guy is not singing because the glass broke.




I think that it is easier without a straw because it took him longer with the straw than without.

Air goes in and out mouth to vocal cords turns into vibrations.

When the singer is singing, he makes his lips into a weird shape that was like a circle and I think that is because the sound waves wider his lips the more sound waves hit glass. Sound waves caused by vibrations.

The glass only breaks where the sound waves hit. I think in the other video the glass breaks at the bottom then up but still only on one side.

## EXAMINING STUDENT WORK SAMPLES

How did each student represent sound? Do you think there is a particular reason?
Did sound representation shift from initial models to model revisions?

When you filled in the initial model scaffold, how did you represent sound? Did you see other teachers representing sound a different way?

Space for Notes, Questions, Comments:

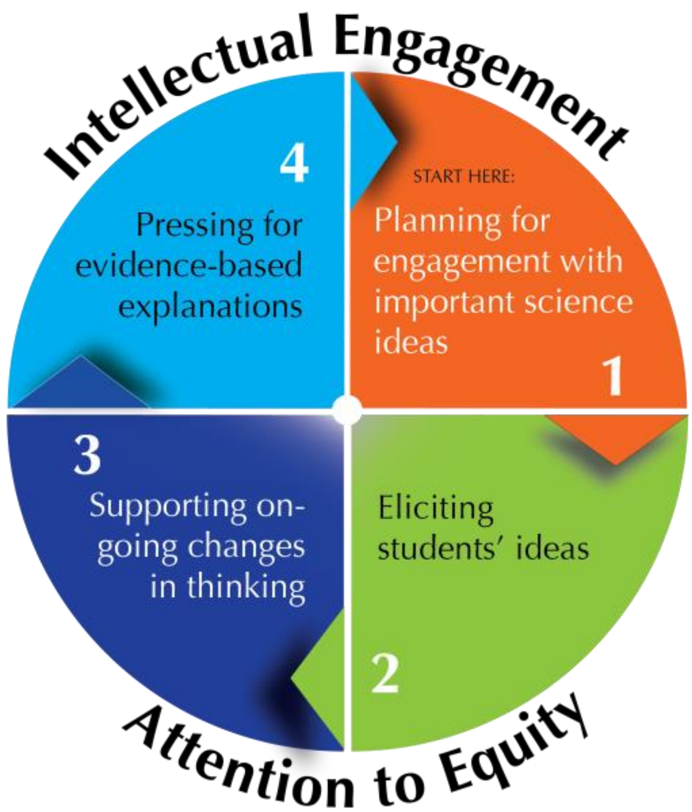


If viewing digitally, click here to return to page 1.

# Curriculum Guide

# Lessons & Activity Guides

## Ambitious Science Teaching Framework




This curriculum guide follows the four core teaching practices of the Ambitious Science Teaching Framework. This model-based inquiry approach to science teaching leverages students' existing personal experiences and current understanding about causal mechanisms in their world to revise their own explanations of specific, contextualized scientific phenomena.

For more information about this teaching framework, visit this website http://www.tools4teachingscience.org

# SOUND ENERGY UNIT ACTIVITY PLANNER

## HOW WILL THESE ACTIVITIES HELP STUDENTS MAKE SENSE OF THE PHENOMENON?

| *Activity* | *Learning Target* | *Connection to Phenomenon* | *NGSS* |
|---|---|---|---|
| | Eliciting Ideas Lesson: | *Introduce Phenomenon & Elicit Initial Ideas using model scaffold* | |
| **Activity 1:** Human Voice | Vibrations can travel through the air from the source of sound to another object and affect that object. Vibrations diminish over a distance. | The singer vibrates air by singing and that vibration travels to the glass making it vibrate, too. The farther away the sound source is from an object, the less it will vibrate. This is like how the sand jumped more when the sound was closer to the cup and less when it was farther away. | 1-PS4-1. Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate. 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound |
| **Activity 2:** Decibels at a Distance ***MATH CONNECTION*** | Vibrations diminish over a distance. Loudness diminishes over a distance. We measure sound in decibels. | Vibrations diminish over a distance so the singer must be close to the class so the vibrations hit the glass hardest at the highest decibels. | 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. |
| **Activity 3:** "Seeing" Sound Waves | Vibrations "cause" sound that we can hear. The harder the force to begin the vibration, the louder the sound and the more energy it has (wave amplitude represents volume) | The singer uses force from his diaphragm and vocal cords to make vibrations that make a loud sound. The harder he forces his muscles, the louder the sound. The louder the sound, the stronger the sound waves (like we see in the water, just in the air). | 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. |
| **Activity 4:** Sound Travels through matter | Matter is made of particles. Particles in gases are farther apart than particles in solids. Sound energy transfers through matter by bumping particles. | The singer vibrates the air particles using his vocal cords. Those air particles bump into other air particles and so on, out of his mouth and away from the singer. The shape of his mouth seems to direct the sound energy (particles bumping) towards the glass but some does go out in all directions (so we can hear it). The glass particles vibrate after the air particles bump into them. | 5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound |
| **Activity 5**: Absorbing or Reflecting Sound Energy | As it moves through matter, sound energy can be reflected (echo) or absorbed (muffled). The material/matter causes one of the other to happen. | In the video, the singer puts the glass in a transparent box to "prove it's not a trick." How would this material affect the singer's sound? Encourage students to draw a model at the particle/molecule level of what's happening | MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. |
| **Activity 6**: Resonance | Vibrating things make sounds and also sounds can make things vibrate if they are 'twins.' (Also, sound energy does not blow air but moves through it by bumping) | The singer flicks the glass at the start to hear the glass' natural resonant pitch. He sings at that pitch which makes the glass hum. He wouldn't need to sing at the 'right' pitch if he could be super duper loud (like an explosion) that would break the glass without being on the right pitch. Being at the right pitch helps him break the glass along with the force he is able to put into it. | 1-PS4-1. Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate. 4-PS4-1. Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move. 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound |
| *Revise Initial Models, Partner Compare, Check for Evidence Cited, Compare to Initial Ideas, Apply to Related Sound Energy Phenomena or to Solve a Sound Problem* | | | |

*Note: Activities and subsequent discussions will take longer than one class period. Typically data collection and sharing observations happens during a 45 minute period, then the next 45 minute period is devoted to making sense of these observations in the context of the phenomenon and bigger science ideas. Additional lessons may be added or lessons modified based on students' developing understanding of science concepts.*

# ELICITING IDEAS: INTRODUCE PHENOMENON & INITIAL MODELS

**OBJECTIVES**

This lesson introduces students to the sound energy phenomenon that will anchor this unit. This lesson asks students to develop their own models using their current levels of understanding to explain why the singer could shatter the glass. Students make observations and develop initial models to explain how the singer was able to shatter the glass. Students record and share their ideas and questions about what allows the singer to make sound, properties of sound such as volume and pitch, proximity to sound source, how sound travels from one place to another, and how sound energy can cause changes.

**BACKGROUND & EXPLANATION**

To gear up content knowledge, read the teacher explanation pages in this guide. This lesson will elicit students initial hypotheses about what caused the glass to break and how and why that happened. It helps to have a working understanding of the full causal explanation and science content knowledge going into this lesson in order to help focus students around ideas that will prove useful to them later in the unit. To prepare for interacting with students around this content, use information in appendix A to better understand how students are thinking about sound energy by how they choose to represent it in their models and appendix B to learn more about the ideas students may include in their initial models.

**MATERIALS**

**For the class:**

- Computer, projectors and speakers
- Chart paper and markers
- YouTube Video clips (Tip: Download them to the computer using keepvid.com instead of live streaming the videos to avoid inappropriate commercials or video suggestions.)
    - "Jaime Vendera How to Shatter a Glass you're your Voice" (46 seconds) https://www.youtube.com/watch?v=10lWpHyN0Ok
    - "Breaking Glass with Sound – Trevor Cox" (1 minute, 04 seconds; no sound in video but the glass is placed next to an amplifier speaker and the video captures the slow motion) https://www.youtube.com/watch?v=dU0OqVDl7kc
    - OPTIONAL: Clio SP AudioBreak Glass (only play part with speakers vibrating car windshield) https://www.youtube.com/watch?v=9VK4IAAFrPo

**Per student:**

- Model scaffold sheets for glass-shattering phenomenon
- Pencils (colored pencils optional)

**LESSON STEPS**

**Step 1. Eliciting Observations**

1. Introduce phenomenon by playing the "Jaime Vendera How to Shatter a Glass you're your Voice" video clip. Replay as needed. Use "Questions to Ask Students."

2. Allow students time to talk to a partner about their observations as the video replays.

3. Create a public list of observations using student input about what happens in the video (sample shown at right).

Step 1. Eliciting Observations

**Questions to Ask Students**

*What do you see? What do you hear?*

*What happens at the beginning, middle, and end? Or before, during, and after?*

| Observations | Initial Ideas and Hypotheses |
|---|---|
| • Singer flicks glass and glass makes a sound.<br>• Singer sings the same note the whole time.<br>• Singer is really loud.<br>• Glass breaks outward or explodes.<br>• Singer takes a deep breath before singing. | |

**Step 2. Eliciting Hypotheses without Explanation**

1. Have students choose an observation and take a minute of private think time to think about what caused this to happen.

2. Turn to a partner and share. *(Option: Write in NB then share) Sentence starters: I chose the observation about… I think this happened because… I think the singer has to ___ because…*

3. Create a public list of initial ideas or causes of this phenomenon. It may not be a complete list of all the ideas in the room (sample shown right).

4. Introduce the model scaffold sheet. Explain to students they can work with a partner or their group to talk about their ideas but that each individual student will fill out their own model sheet to show how they are thinking about this phenomenon. Also, tell students that as they are working they may think of questions or wonderings. Write these on the back of the model sheet.

Step 2. Eliciting Hypotheses

**Questions to Ask Students**

*What do you predict if the singer was farther away? Or didn't sing as loud?*

*What happened here? (level of inference)*

| Observations | Initial Ideas and Hypotheses |
|---|---|
| • Singer flicks glass and glass makes a sound.<br>• Singer sings the same note the whole time.<br>• Singer is really loud.<br>• Glass breaks outward or explodes.<br>• Singer takes a deep breath before singing. | • The sound made the glass break.<br>• The sound has to be loud and close to the glass.<br>• The vibrations make the glass shatter.<br>• The singer has to have enough air to make it happen. |

## Step 3. Pressing for Explanation

1. As students work on their models, listen in on conversations. Record notes on the Rapid Survey of Student thinking (RSST).
2. Ask students about particular parts of their drawing or writing using the "Questions to Ask Students." If students seem stuck, back up and ask observation-level question first then unobservable causes. Also, direct students attention to the public record of observations and hypotheses to help get them started adding to the model.

NOTE: The purpose is not to evaluate correctness of student ideas but rather to identify what resources and reasoning students are using to initially make sense of the phenomenon and how they use their prior experiences and knowledge. To prepare for this questioning prior to the lesson, use the student work samples in appendix B and pretend that is the work students have created. What questions would you ask that student to tell more about? What parts of the model are worth questioning about?

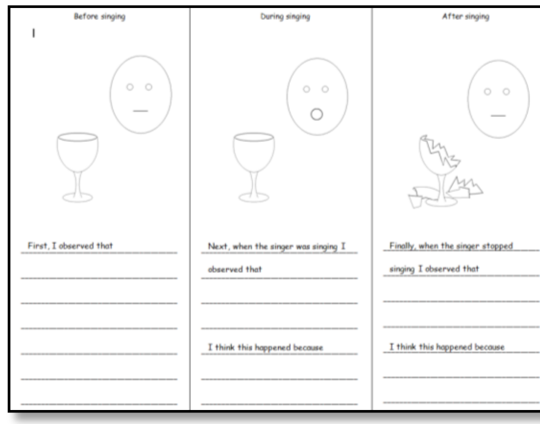
Step 3. Pressing for Explanation

**Questions to Ask Students**

*What do you think causes _____?*

*What's going on here that you can't see but you think might be happening?*

*Why do you think it happens that way?*




## Step 4. Summarizing

1. Have students help create a list of ideas they think are important for explaining this phenomenon. Add to or revise items on the "initial ideas and hypotheses" side of the public T-chart record.
2. Then ask students at least write questions on the back of their model scaffold about things they are wondering about. (They may have already done this as they were adding to their model.)

Step 4. Summarizing

**Questions to Ask Students**

*What are some things we aren't sure about?*

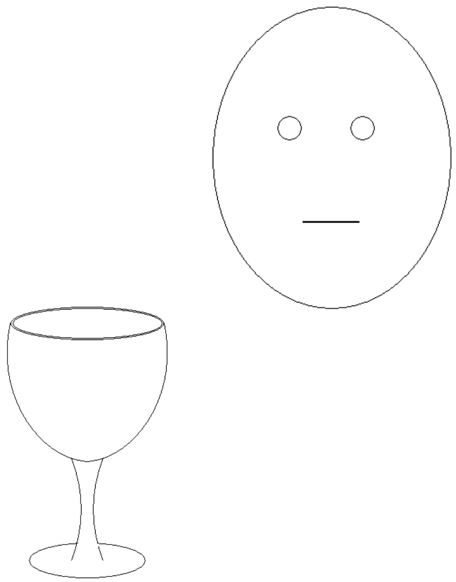
*What kinds of experiences do we need to learn more?*

*What are some ways we could test our hypotheses?*

**PREPARING FOR FUTURE LESSONS**

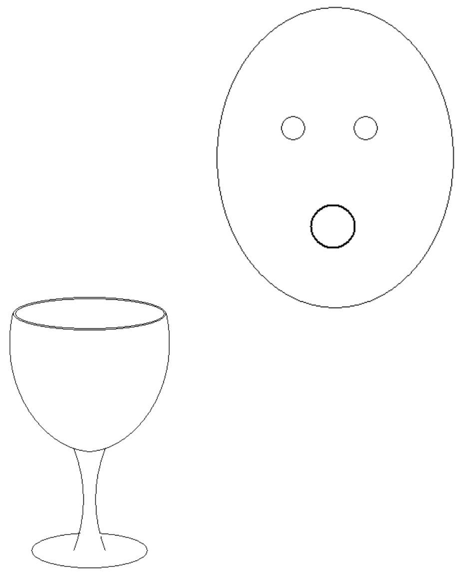
Use the RSST in appendix D to take notes during the lesson and after the lesson looking at student models. Make changes in upcoming lessons based on student thinking and what percentage of the class is thinking about them.

Before singing



First, I observed that

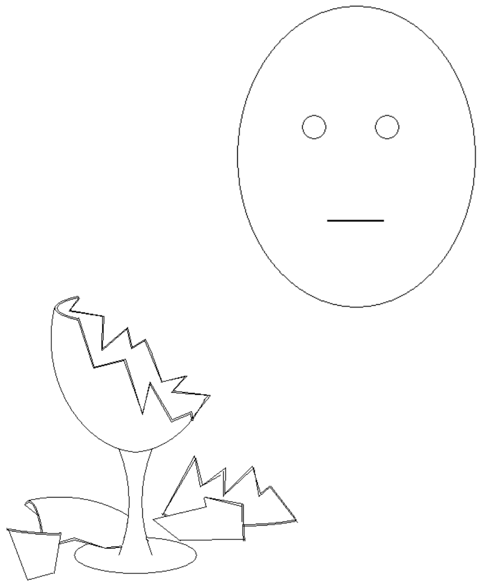
During singing



Next, when the singer was singing I observed that

I think this happened because

After singing



Finally, when the singer stopped singing I observed that

I think this happened because

# Rapid Survey of Student Thinking (RSST)

Directions: Complete the RSST either during class or right after a class.

| Categories | Trends in student understandings, language, experiences<br>[sample sentence starters included below] | Instructional decisions based on the trends of student understanding |
| --- | --- | --- |
| ***Partial understandings***<br>What facets/ fragments of understanding do students already have? | List partial understandings:<br><br>What approximate % of your students have these partial understandings? | ★Star the ideas on the list that need action. Instructional options:<br>• Do further eliciting of initial hypotheses to clarify your understanding of students' partial understandings<br>• Do 10-minute whole class whole class conversation of 2-3 key points elicited<br>• Write multiple hypotheses on board and/or develop an initial consensus model |
| ***Alternative understandings***<br>What ideas do students have that are inconsistent with the scientific explanation? | List alternative understandings:<br><br>What, if any, experiences or knowledge bases are they using to justify these explanations? | ★Star the ideas on the list that you *really* need to pay attention to based on the following criteria… 1. Which alt. conceptions seem deeply rooted (kids seem sure about)? 2. What % of kids think this? 3. Which are directly related to final explanation (not just a "side-story") Instructional options:<br>• Do further eliciting about what experiences/frames of reference students are drawing on<br>• Pose "what if" scenario to create conceptual conflict about validity of alt. ideas<br>• Challenge students to think further/give them a piece of evidence to reason with<br>• Target a lesson using "Teaching Practice 3" to address this alt. conception |
| ***Everyday language***<br>What terms did you hear students use that you can connect to academic language in upcoming lessons? | Cite examples:<br><br>What approximate % of your students use these terms and phrases? | ★Star the ideas on the list that you can leverage in non-trivial ways. Instructional options:<br>• Use this language to reframe your essential question in students' terms<br>• Use as label in initial models that you make public. Work in academic versions of these words into public models and discussions later. |
| ***Experiences students have had that you can leverage***<br>What familiar experiences did students describe during the elicitation activity? | What was the most common everyday or familiar experience that kids related to the essential question or task?<br><br>What were the less common experiences students cited? | ★Star the ideas on the list that you can leverage in non-trivial ways. Instructional options:<br>• Re-write the essential question to be about this experience<br>• Make their prior experiences a central part of the next set of classroom activities<br>• If kids cannot connect science idea to familiar experiences they've had, then provide a shared experience all kids can relate to (through lab, video, etc.) |

Sample RSST using Oliver, Greg, Mariana, Eva and video dialog

# Rapid Survey of Student Thinking (RSST)

Directions: Complete the RSST either during class or right after a class. This is an example. You may see things I missed!

| Categories | Trends in student understandings, language, experiences [sample sentence starters included below] | Instructional decisions based on the trends of student understanding |
|---|---|---|
| ***Partial understandings*** What facets/ fragments of understanding do students already have? | List partial understandings:<br>- solids have breaking point 50%<br>- sound has pressure 25%<br>- solids made of particles 50%<br>- volume and pitch "the right ones" are important 75%<br>- "sound" travels through the glass 80%<br>- thick solids (glass base) stronger than thin solids (glass top) 75%<br>What approximate % of your students have these partial understandings? | ★Star the ideas on the list that need action.<br><br>Instructional options:<br>• Do further eliciting of initial hypotheses to clarify your understanding of students' partial understandings<br>• Do 10-minute whole class whole class conversation of 2-3 key points elicited ✓<br>• Write multiple hypotheses on board and/or develop an initial consensus model ✓<br>• |
| ***Alternative understandings*** What ideas do students have that are inconsistent with the scientific explanation? | List alternative understandings:<br>- Sound is a thing that can move (rather than it being energy moving through particles)<br>- pressure makes vibration faster<br>What, if any, experiences or knowledge bases are they using to justify these explanations? | ★Star the ideas on the list that you *really* need to pay attention to based on the following criteria… 1. Which alt. conceptions seem deeply rooted (kids seem sure about)? 2. What % of kids think this? 3. Which are directly related to final explanation (not just a "side-story")<br><br>Instructional options:<br>• Do further eliciting about what experiences/frames of reference students are drawing on<br>• Pose "what if" scenario to create conceptual conflict about validity of alt. ideas ✓<br>• Challenge students to think further/give them a piece of evidence to reason with<br>• Target a round of "Discourse 2" to address this alt. conception ✓ |
| ***Everyday language*** What terms did you hear students use that you can connect to academic language in upcoming lessons? | Cite examples:<br>- "wiggling", brittle, → describe glass<br>↳ wiggle + shaking → synonyms for vibrations<br>- particles → for molecules<br>- "expand" "pressure"<br>~~[illegible]~~<br>What approximate % of your students use these terms and phrases? | ★Star the ideas on the list that you can leverage in non-trivial ways.<br><br>Instructional options:<br>• Use this language to reframe your essential question in students' terms<br>• Use as label in initial models that you make public. Work in academic versions of these words into public models and discussions later ✓<br>• wiggle, shaking = vibration |
| ***Experiences students have had that you can leverage*** What familiar experiences did students describe during the elicitation activity? | What was the most common everyday or familiar experience that kids related to the essential question or task?<br>- gum case ripping → material fatigue/flexing<br>- pipe breaking in winter freeze → not particularly helpful<br>What were the less common experiences students cited?<br>Ask students to notice sound around them for homework. What do they notice about how loud the sound is? How can they make a sound louder or quieter? Can they hear sound through other things? | ★Star the ideas on the list that you can leverage in non-trivial ways.<br><br>Instructional options:<br>• Re-write the essential question to be about this experience<br>• Make their prior experiences a central part of the next set of classroom activities<br>• If kids cannot connect science idea to familiar experiences they've had, then provide a shared experience all kids can relate to (through lab, video, etc.) |

# Sound Energy Unit Activity Planner

## How will these activities help students make sense of the phenomenon?

| Activity | Learning Target | Connection to Phenomenon | NGSS |
|---|---|---|---|
| | Eliciting Ideas Lesson: | *Introduce Phenomenon & Elicit Initial Ideas using model scaffold* | |
| **Activity 1:** Human Voice | Vibrations can travel through the air from the source of sound to another object and affect that object. Vibrations diminish over a distance. | The singer vibrates air by singing and that vibration travels to the glass making it vibrate, too. The farther away the sound source is from an object, the less it will vibrate. This is like how the sand jumped more when the sound was closer to the cup and less when it was farther away. | 1-PS4-1. Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate. 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound |
| **Activity 2:** Decibels at a Distance ***MATH CONNECTION*** | Vibrations diminish over a distance. Loudness diminishes over a distance. We measure sound in decibels. | Vibrations diminish over a distance so the singer must be close to the class so the vibrations hit the glass hardest at the highest decibels. | 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. |
| **Activity 3:** "Seeing" Sound Waves | Vibrations "cause" sound that we can hear. The harder the force to begin the vibration, the louder the sound and the more energy it has (wave amplitude represents volume) | The singer uses force from his diaphragm and vocal cords to make vibrations that make a loud sound. The harder he forces his muscles, the louder the sound. The louder the sound, the stronger the sound waves (like we see in the water, just in the air). | 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. |
| **Activity 4:** Sound Travels through matter | Matter is made of particles. Particles in gases are farther apart than particles in solids. Sound energy transfers through matter by bumping particles. | The singer vibrates the air particles using his vocal cords. Those air particles bump into other air particles and so on, out of his mouth and away from the singer. The shape of his mouth seems to direct the sound energy (particles bumping) towards the glass but some does go out in all directions (so we can hear it). The glass particles vibrate after the air particles bump into them. | 5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound |
| **Activity 5**: Absorbing or Reflecting Sound Energy | As it moves through matter, sound energy can be reflected (echo) or absorbed (muffled). The material/matter causes one of the other to happen. | In the video, the singer puts the glass in a transparent box to "prove it's not a trick." How would this material affect the singer's sound? Encourage students to draw a model at the particle/molecule level of what's happening | MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. |
| **Activity 6**: Resonance | Vibrating things make sounds and also sounds can make things vibrate if they are 'twins.' (Also, sound energy does not blow air but moves through it by bumping) | The singer flicks the glass at the start to hear the glass' natural resonant pitch. He sings at that pitch which makes the glass hum. He wouldn't need to sing at the 'right' pitch if he could be super duper loud (like an explosion) that would break the glass without being on the right pitch. Being at the right pitch helps him break the glass along with the force he is able to put into it. | 1-PS4-1. Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate. 4-PS4-1. Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move. 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound |
| *Revise Initial Models, Partner Compare, Check for Evidence Cited, Compare to Initial Ideas, Apply to Related Sound Energy Phenomena or to Solve a Sound Problem* | | | |

*Note: Activities and subsequent discussions will take longer than one class period. Typically data collection and sharing observations happens during a 45 minute period, then the next 45 minute period is devoted to making sense of these observations in the context of the phenomenon and bigger science ideas. Additional lessons may be added or lessons modified based on students' developing understanding of science concepts.*

# HUMAN VOICES

Exploring Vibrations in the Human Voice

**OBJECTIVES**

This lesson focuses students on how humans make sounds using our vocal cords and also how force, volume, and vibrations are related. Students will make observations about the strength of vibration in their own vocal cords and the kind of sound (whispering, humming, talking, or yelling) that results. Students will:

- Describe and discuss patterns in the vibrations they observed.
- Draw conclusions about the relationship between vibrations and volume.

**BACKGROUND & EXPLANATION**

Taken from https://www.entnet.org/content/how-voice-works

The Power Source: The power for your voice comes from air that you exhale. When we inhale, the diaphragm lowers and the rib cage expands, drawing air into the lungs. As we exhale, the process reverses and air exits the lungs, creating an airstream in the trachea. This airstream provides the energy for the vocal folds in the voice box to produce sound. The stronger the airstream, the stronger the voice. Give your voice good breath support to create a steady strong airstream that helps you make clear sounds.

The Vibrator: The larynx (or voice box) sits on top of the windpipe. It contains two vocal folds (also known as vocal cords) that open during breathing and close during swallowing and voice production. When we produce voice, the airstream passes between the two vocal folds that have come together. These folds are soft and are set into vibration by the passing airstream. They vibrate very fast – from 100 to 1000 times per second, depending on the pitch of the sound we make. Pitch is determined by the length and tension of the vocal folds, which are controlled by muscles in the larynx.

The Resonator: By themselves, the vocal folds produce a noise that sounds like simple buzzing, much like the mouthpiece on a trumpet. All of the structure above the folds, including the throat, nose, and mouth, are part of the resonator system. We can compare these structures to those of a horn or trumpet. The buzzing sound created by vocal fold vibration is changed by the shape of the resonator tract to produce our unique human sound.

When our voices are healthy, the three main parts work in harmony to provide effortless voice during speech and singing.

**MATERIALS**

**For the class:**

- Chart paper
- markers

**Table group baskets (1 per student):**

- “Human Voices” data sheet
- Copy of “Human Voices: A Reading”
- Penci

**LESSON PLAN**

**Step 1. Orient Students to the Concepts**

1. Draw on students’ models to describe one hypothesis that many students addressed relating to vibrations or how the singer makes or hears sound. Show some student work under the doc camera to feature drawings or writings about this “vibration hypothesis.”
2. Explain that today students will be exploring how we use vibrations to make sounds when we whisper, hum, talk, yell, and sing. Read today’s focus question: ***How do we make different sounds with our voices?***
3. Give activity directions and expectations. Tell students to begin by following the directions on their “Human Voices” data sheet. When they complete the data sheet, they will read their “Human Voices: A Reading” looking for information to help make sense of what we feel and observe in the activity. Use the questions in the box above to focus students first on the observations they will be making. If students are not familiar with the summary table idea, spend a few moments explaining the purpose of the summary table (see “Lesson 1: Summary Table Example”).

Step 1. Orienting Students

**Questions to Ask Students**

*What will we be observing today?*

*How will we measure or record our observations?*

**Step 2. Observations & Patterns – Making Sounds**

1. Students are feeling their vocal cords as they whisper, hum, and talk. What do they notice as their volume increases from whispering to talking? What kinds of sounds make the most vibrations? Students record observations on the data sheet.
2. As students follow directions on their data sheet, monitor student progress and ask back-pocket questions listed at right.
3. Fill in the “Observations & Patterns” section of the summary table. Pause the small group activity when all groups have completed their observations. Record observations and patterns in that part of the summary chart as a class.

Step 2. Observations & Patterns

**BACK POCKET QUESTIONS**

*What do you feel when you…?*

*How is what you feel different between when you whisper and when you talk?*

*What do you observe about vibrations when you increase or decrease your volume when you talk?*

**Step 3. What did we learn? – Using a Reading**

1. Students read "Human Voices: A Reading" on their own or with a partner and answer key questions using information from the reading.

2. As students are working to answer the questions, use the 'back pocket question' listed at right to help student connect the reading with their observations.

Step 3. What did we learn?

**BACK POCKET QUESTIONS**

*What's happening in our bodies that we can't see that helps us make these different sounds?*

*How did you use your diaphragm earlier? Why do you think you think the diaphragm is important?*

**Step 4. Connection to the Singer**

On the back of the data sheet, students are asked how this lesson helps us explain part of our overarching phenomenon. They can draw and write a response; however, they may need some partner talk time to answer this question. Use the back-pocket questions listed to help students work towards making the connection back to the singer. This can be done as students continue to work in their groups.

Step 4. Connection to Phenomenon

**BACK POCKET QUESTIONS**

*What can you tell us about vibrations and sound that you learned today? How is that like what happens with the singer as he shatters the glass?*

*How does today's lesson help us understand what's going on inside the singer's body that we can't see that helps him be able to shatter the glass?*

**Step 5. Whole Class Coordination of Students' Ideas & Questions**

1. Return to whole class conversation. This is where you can help students see broad trends or patterns of data for different groups in the classroom. You may have already filled in the "Observation & Pattern" section of the summary table, if not, do so now.
2. Use the reading to help students agree on a few short bullet points about what we learned about our focus question for this lesson: " How do we make different sounds with our voices?"
3. Finally, help students "map" these ideas onto a real world situation including the unit phenomenon. Use the "Lesson 1: Summary Table Example" to see what should potentially appear on the summary table as a result of this lesson.

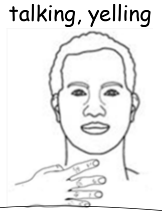
**PREPARING FOR FUTURE LESSONS**

Use the RSST in appendix D to take notes during the lesson and after the lesson looking at student models. Make changes in upcoming lessons based on student thinking and what percentage of the class is thinking about them.

## Activity 1: Summary Table Example

Keeping a public record of science activities is crucial for helping students link evidence with claims as they build their scientific explanations. The public record does not have to look like a summary table, it could take another form, but it does need to be publically accessible and contain the same parts: naming the activity (for easy reference), recording observations and patterns from the data, space for generalizable learning about the main ideas, and how this activity helps to explain a part of the whole science explanation of the phenomenon.

Fill in the summary table during an activity, as you complete each step of the lesson plan, or at the end of the lesson to reflect back. Use pre-planned back pocket questions to ask students in small groups about their observations, patterns in data, what they're learning about, and how this might connect to help us explain the phenomenon as student are working in small groups during the activity. Back-pocket questions help students think about these categories before having this discussion as a whole class.

| Activity | Observations & Patterns | What did we learn? | Connection to Singer? |
|---|---|---|---|
| **Humans Voices**:<br>Vibrations & Sounds when whispering, humming, talking, yelling<br> | • We felt vibrations in our throat as we made different sounds.<br>• The vibrations were stronger if we were louder. (Yelling vibrations were stronger than whispering) | • There are parts inside our body that help us talk.<br>• Vocal cords vibrate the air as we breathe out to make sounds.<br>• To make a sound louder we use more force with the diaphragm muscle which is below the lungs and push on the lungs to move air out. | • The singer uses his diaphragm, lungs, and vocal cords to sing.<br>• To make a louder sound, he uses more force and pushes harder with his diaphragm.<br>• His vocal cords vibrate the air so we hear him sing. |

**Step 2. Patterns**
*Identify Observations & Patterns in the Data*

**Step 3. Learning**
*What did we learn from the activity and/or reading?*

**Step 4. Connection**
*Connecting back to Explain the Phenomenon*

# Humans Voices Data Sheet

NAME: ____________________

*Observing vibrations when*
*whispering, humming, talking, and yelling*

*Directions: Make observations about sounds using your sense of touch by placing your fingers on your throat.*

| | Whisper | Hum | Talk | Yell |
|---|---|---|---|---|
| Circle the word that best describes the strength of the vibrations you feel. *(Add additional description on the lines.)* | None Weak Medium Strong<br>____________________<br>____________________ | None Weak Medium Strong<br>____________________<br>____________________ | None Weak Medium Strong<br>____________________<br>____________________ | None Weak Medium Strong<br>____________________<br>____________________ |
| How does the vibration change if you change your volume? | With **loud** whispers, the vibrations feel ____________ ____________________.<br>With **quiet** whispers, the vibrations feel ____________ ____________________. | With **loud** humming, the vibrations feel ____________ ____________________.<br>With **quiet** humming, the vibrations feel ____________ ____________________. | With **loud** talking, the vibrations feel ____________ ____________________.<br>With **quiet** talking, the vibrations feel ____________ ____________________. | With **loud** yelling, the vibrations feel ____________ ____________________.<br>With **quiet** yelling, the vibrations feel ____________ ____________________. |

What is the relationship between the **kind of sound** we make and the **strength of the vibration**?

______________________________________________

______________________________________________

______________________________________________

What is the relationship between the **volume** of the sound we make and how the **vibrations** feel?

______________________________________________

______________________________________________

______________________________________________

**Directions:**

- Read "Human Voices: A Reading."
- Use information from the reading and your own observations to answer the following questions.

1.) What's happening inside our bodies that we can't see (but we can feel) that makes us able to talk?

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

2.) How does today's lesson help us explain our big question: Why can the singer shatter a glass with his voice?

______________________________________________

______________________________________________

______________________________________________

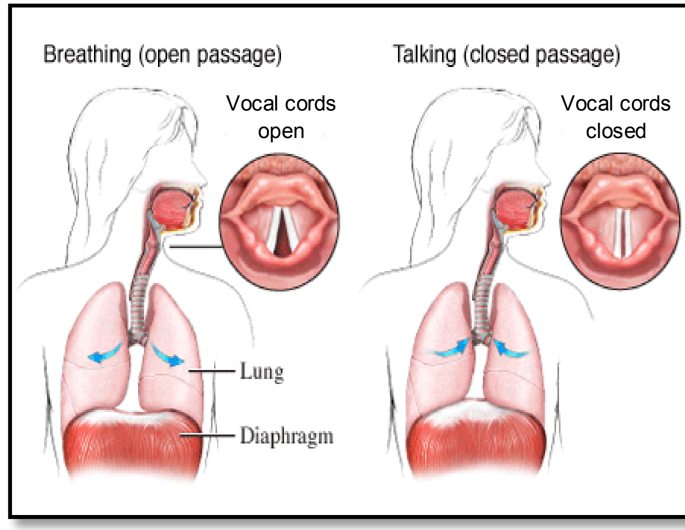
______________________________________________

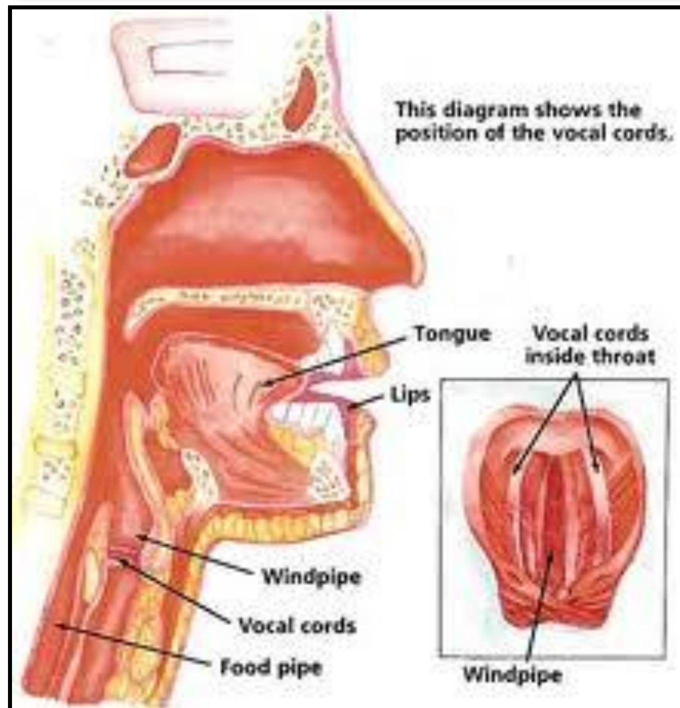
______________________________________________

______________________________________________

# Human Voices: A Reading

There are parts inside your body which are responsible for helping you make sounds like talking, yelling, and singing. The **diaphragm** is a muscle below your lungs. You can control your diaphragm muscle. To make loud sounds, you can feel your diaphragm pushing hard. The diaphragm muscle pushes on your **lungs**. Your lungs are kind of like balloons. Your diaphragm muscle moves air in and out of your lungs. The **windpipe** connects to your mouth and nose to your lungs. When you breathe, air goes through the windpipe and fills up your lungs. Your **vocal cords** are inside your windpipe. When you talk, muscles in your neck control your vocal chords. When you talk, your vocal cords close narrower than when you are breathing. You breathe in just before you talk or sing. While you are talking or singing, you are slowly breathing out. As air leaves your lungs, it moves up. The air passes through the vocal cords. As the moving air passes over your vocal cords and gets vibrated. The sound travels in the air from your vocal cords and out of your mouth through the air making different kinds of sounds that we can hear.



# DECIBELS AT A DISTANCE

The Volume Decreases as Distance Increases

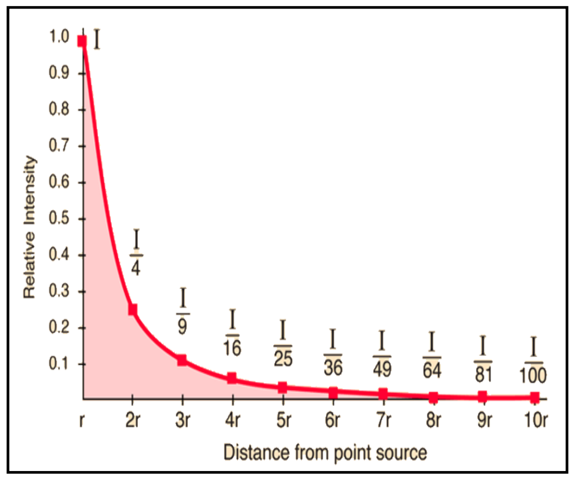
**OBJECTIVES**

This lesson focuses students on two key ideas: sound travels in all directions from the source, and that the volume of a sound decreases over a distance. Students will record and graph data to show the relationship between the intensity of a sound (measured in decibels) and distance (measured in meters). Students will:

- Observe that sound travels in all direction from a source.
- Represent the relationship between volume and distance to show that as distance from the source increases, volume decreases.

**BACKGROUND & EXPLANATION**

Decibels measure the intensity of a sound by capturing properties of both volume and pressure, though the term 'decibel' is colloquially used to describe volume. The decibel scale is a logarithmic scale By moving away from a sound source, the decibel level of a sound will decrease by a set amount every time you double the distance from the sound (following an "Inverse Square Law"). Students do not need to do the math calculations, however, the graphs they will create do show how the energy dissipates over distance. The graph at right shows that as distance increases the intensity of the sound decreases in a curve.




The closer objects are to the source of a sound the greater the pressure exerted on them by a sound wave. For our phenomenon, this lesson gives evidence to students about why the singer has to be so close to the glass. If he were to double his distance from the glass, the intensity (and volume) of his sound would decrease below the force he needs to break the glass. To shatter a glass between 100-140 decibels are required depending on the thickness and shape of the glass. The singer uses thin glassware. It is challenging for humans to produce sound over 100 decibels for an extended time but certainly doable.

*Notes on Room Sound Measurements:* Though the relationship between intensity (decibels) and distance (meters) should be logarithmic, actual measurements vary because of the influences of echo and reverberations as well as the initial source (speaker) being larger than a point source. For the purposes of this lab activity, finding the relationship that as distance increases, sound intensity decreases is the main purpose. Quantifying or representing that relationship mathematically is not appropriate. (Just a warning that you may not get perfectly lovely curves for the data you gather in the classroom and if the field you use when gathering data outside is surrounded by fences or concrete walls.)

**MATERIALS**

**For the class:**

- Meter sticks, string, or trundle wheel (to measure distances in a field)
- Plastic cones (to mark distances)
- Chart paper
- Markers
- Blender or vacuum
- Air horn or some sound generator

**Table group baskets:**

- Decibel meter (1 per group/pair) – a physical tool or using an iPad application.
- Data Sheet (1 per student)
- Pencil, with eraser (per student)
- SAFETY: earplugs per student if using sound generator over 85 decibels
- Colored pencils

**LESSON PLAN**

**<u>Prior to the lesson:</u>**

1. In the classroom, mark off distances away from the blender, vacuum, or other appliance you can use to collect the first set of data. This could be done on butcher paper by tracing an outline of the appliance then measuring out in 10cm increments
2. Outside in a large field, use the meter stick or trundle wheel to measure out distances from the center of the school yard. Use cones to mark the center and then distances at 1, 2, 4, 8, 16, and 32 meters from the center. It is preferable if you can be away from walls or buildings (to limit effects of reverberation).

**<u>Step 1. Orient Students to the Concepts</u>**

1. Draw on students' models to describe one hypothesis that many students addressed relating to volume or how the singer must be close to the glass. Show some student work under the doc camera to feature drawings or writings about this "Distance hypothesis."

2. Explain that today students will be investigating a relationship between volume and distance. Read today's focus question: ***What happens to the volume of a sound as we increase our distance from it?***

3. Ask students to think privately about this question: Why do you think the singer had to be close to the glass? What if he were standing across the room from it? Turn and share with your partner.

4. Lead students into gathering the first round of data using a household appliance and one decibel meter.

Step 1. Orienting Students

| **Questions to Ask Students** |
|---|
| *What will we be observing today?* |
| *How will we measure or record our observations?* |

**Step 2. Observations & Patterns – Measuring Decibels**

Step 2. Observations & Patterns

**BACK POCKET QUESTIONS**

*What happened as the decibel meter got farther from the source of sound?*

*What do you observe about the volume when we increase the distance from the source of sound?*

1. Explain that a decibel meter measures the intensity of sound so how loud it is and also how much pressure it has.

2. Collect the first set of data as a class. Each student needs their recording sheet and a pencil to be ready to record the class data at each measurement increment.

3. Have students come over to the class demonstration area and take turns reading the decibel meter, calling out the approximate measurement for everyone to record.

4. Once students have collected their first set of data (page 1 of the data sheet) then they can graph it.

   MATH ALERT: The scale on the data table is in centimeters but the x-axis distance scale is in meters! Students will have to convert centimeters to meters to correctly plot the points. (MATH CC 5.MDA1)

5. Share out a few observations and patterns using the graph and data table.

6. Then, explain that in order to make claims about sound generally, we should observe the same patterns with different sounds and in different places so now we will go outside to see if the same pattern happens with a new sound source.

7. Prepare to go outside to collect data using another sound source. Each group needs a decibel meter and each student needs ear plugs, a recording sheet and a pencil. Students can take turns holding the decibel meter and calling out the approximate reading to the group. Each group member is responsible for recording his or her own data. Explain that each group will start at a different cone and each time we test the sound, groups will rotate to a new cone to get the next measurement.

8. GO OUTSIDE & COLLECT DATA - Have one group stand at each cone (1m, 2m, 4m, 8m, 16m, and 32m). Some cones may have 2 groups. Blast the horn. Give some time to record. Shout for groups to rotate out one cone. Repeat until data is collected. (When a group reaches the 32 meter mark, they run down to the 1 meter mark). Return to the classroom.

9. Have students graph their group's data on their grid next to the data table.

10. Calculate and graph class average of data.

MATH ALERT: Use the "Class Data Recording Sheet" and have one member of each group come up and quickly fill in their group's data column. Find the range of readings for each distance. Calculate the average decibel measurement for each distance. Then students graph the class data average on their graph in another color.

11. Share out a few observations and patterns using the graph and data table. Did the same trend happen in both situations (inside vs outside)? Did all the groups observe a similar trend?

**<u>Step 3. What did we learn?</u>**

1. Have students think-pair-share about the back-pocket questions posted at right, in particular answering the lesson's focus question.

2. Students will observe the pattern of increasing distance, decreases volume; however, it may be useful to ask where the volume goes. "If the volume is decreasing, where is the volume going?" *(Possible answers that could lead into productive talk either today or later in the week: Spreading out in the air; Going in all directions; Being absorbed by the ground.)*

Step 3. What did we learn?

**BACK POCKET QUESTIONS**

*How can we use our data to answer today's question?*

*What claims can we make about the relationship between distance and volume?*

**<u>Step 4. Connection to the Singer</u>**

Have students think-pair-share about the question posted at right to connect it back to the lesson opening about the "distance hypothesis."

Step 4. Connection to Phenomenon

**BACK POCKET QUESTIONS**

*How does today's lesson help us understand about the "distance hypothesis" and why the singer must be close to the glass?*

**<u>Step 5. Whole Class Coordination of Students' Ideas & Questions</u>**

Recap today's lesson as students help fill in the summary table. This step could also be spread over steps 3 and 4 as students are answering the questions during pair-share adding a "write" component. Record questions students have relating to volume and distance to revisit in subsequent lessons.

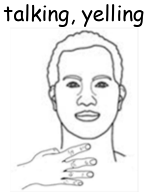
**PREPARING FOR FUTURE LESSONS**

Use the RSST in appendix D to take notes during the lesson and after the lesson looking at student models. Make changes in upcoming lessons based on student thinking and what percentage of the class is thinking about them.

## Summary Table Example

Keeping a public record of science activities is crucial for helping students link evidence with claims as they build their scientific explanations. The public record does not have to look like a summary table, it could take another form, but it does need to be publically accessible and contain the same parts: naming the activity (for easy reference), recording observations and patterns from the data, space for generalizable learning about the main ideas, and how this activity helps to explain a part of the whole science explanation of the phenomenon.

Fill in the summary table during an activity, as you complete each step of the lesson plan, or at the end of the lesson to reflect back. Use pre-planned back pocket questions to ask students in small groups about their observations, patterns in data, what they're learning about, and how this might connect to help us explain the phenomenon as student are working in small groups during the activity. Back-pocket questions help students think about these categories before having this discussion as a whole class.

| Activity | Observations & Patterns | What did we learn? | Connection to Singer? |
|---|---|---|---|
| **Humans Voices**:<br>Vibrations & Sounds when whispering, humming, talking, yelling<br> | • We felt vibrations in our throat as we made different sounds.<br>• The vibrations were stronger if we were louder. (Yelling vibrations were stronger than whispering) | • There are parts inside our body that help us talk.<br>• Vocal cords vibrate the air as we breathe out to make sounds.<br>• To make a sound louder we use more force with the diaphragm muscle which is below the lungs and push on the lungs to move air out. | • The singer uses his diaphragm, lungs, and vocal cords to sing.<br>• To make a louder sound, he uses more force and pushes harder with his diaphragm.<br>• His vocal cords vibrate the air so we hear him sing. |
| **Decibels at a Distance**:<br>What happens to the volume of a sound as we increase our distance from it? | • In the classroom, the farther away from the vacuum, the less volume was measured.<br>• Outside in the field, the farther away from the air horn, the less volume was measured. | • As distance increases, the decibels (volume) decreases.<br>• The closer to the source of the sound the more decibels the sound has. | • Singer sings close to the glass so all of the sound intensity can hit the glass. If he took a step back or sang from across the room, it wouldn't work because too much intensity spread out over the distance. |

**Step 2. Patterns**
*Identify Observations & Patterns in the Data*

**Step 3. Learning**
*What did we learn from the activity and/or reading?*

**Step 4. Connection**
*Connecting back to Explain the Phenomenon*

# Decibels at a Distance Data Sheet

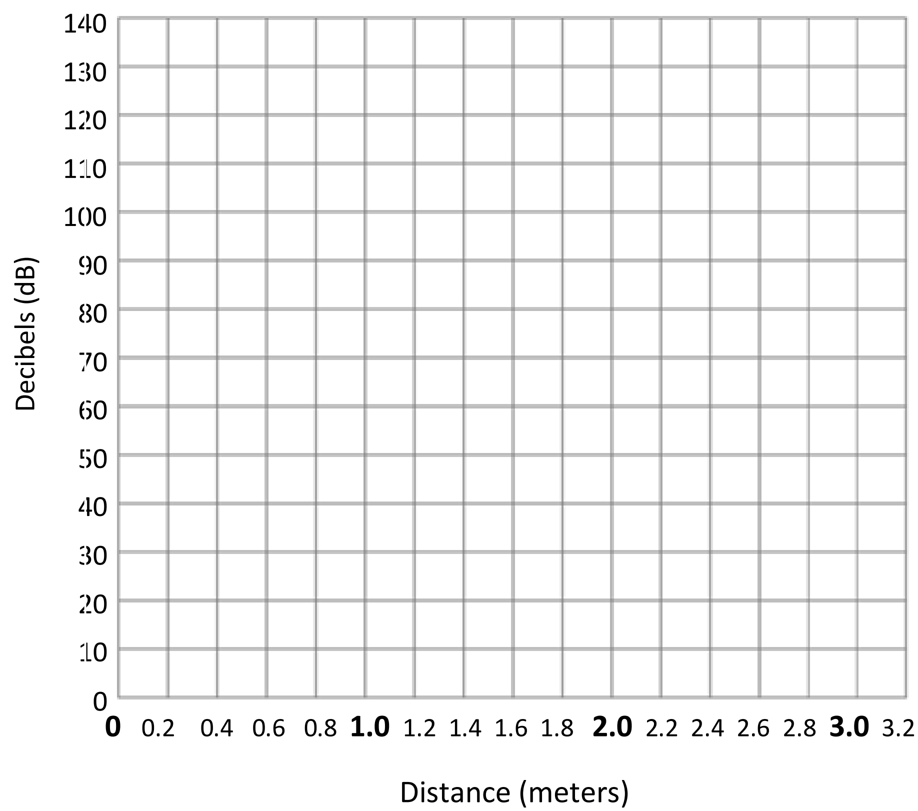
*Observing the relationship between sound intensity and distance from the source*

Source of sound: ______________________

Decibels of ambient sound: _________ dB

| Distance from Source (cm) | Our Decibel Reading (dB) |
|---|---|
| cm | |
| cm | |
| cm | |
| cm | |
| cm | |
| cm | |

Graph Title: ____________________________________________



Source of sound: ______________________

Decibels of ambient sound: _________ dB

| Distance from Source (m) | Our Decibel Reading (dB) | Class average (dB) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

What happens to the sound intensity the farther we moved away from the sound source?

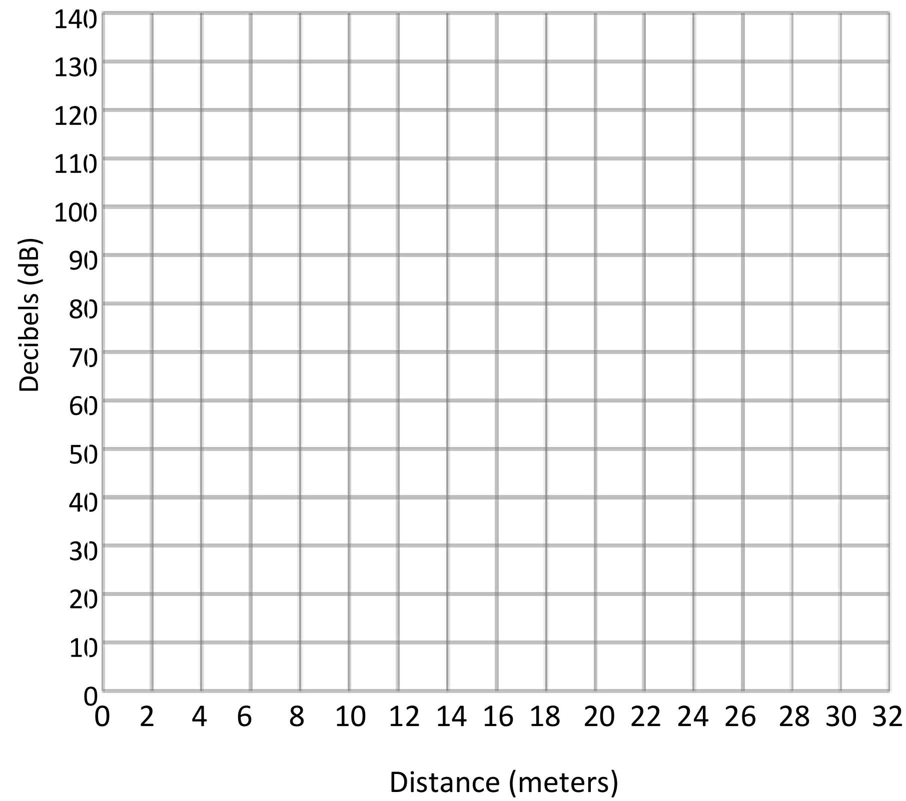
_________________________________________

What do you think causes this to happen?

_________________________________________

_________________________________________

Graph Title: ______________________________




How does this graph help us understand how the singer could shatter the glass if he were close to the glass?

_________________________________________

_________________________________________

_________________________________________

**Decibels at a Distance**

*Class Data Recording Sheet*

| Distance | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 6 | Range at each distance | Class Average |
|---|---|---|---|---|---|---|---|---|
| 1 m | | | | | | | | dB |
| 2 m | | | | | | | | dB |
| 4 m | | | | | | | | dB |
| 8 m | | | | | | | | dB |
| 16 m | | | | | | | | dB |
| 32 m | | | | | | | | dB |

# "SEEING" SOUND WAVES

Amplitude and Volume as Wave Properties

## OBJECTIVES

This lesson focuses students on two key ideas: more force goes into creating sounds with louder volumes, and the amplitude of a sound wave is one way to represent that force. Students will:

- Understand that vibrations transform mechanical energy into sound energy.
- Observe that as volume increases so does the amplitude of water waves.
- Represent the relationship between volume and force to show that as force used to create vibrations increases, the amplitude (or height) of those vibrations increases and the volume also increases.

## BACKGROUND & EXPLANATION

Vibrations are required to have sound energy. When tuning forks vibrate, we can hear sound (or see water waves when touched to water.) The volume of a sound is described by the amplitude of the sound wave – visible when translated to water waves. The spacing between waves remains the same whether the tuning fork is hit hard or softly; however, the height of the waves (volume) is higher when hit with more force and lower when the tuning fork is struck with less force. Volume and amplitude are related. When representing sound energy as a wave, the amplitude represents how much energy the sound has – the higher the amplitude, the more energy. This activity shows students qualitatively the relationship between force and amplitude as they observe that when they hit a tuning fork hard, it makes larger waves than if the tuning fork is initially stuck with less force. If additional energy is not added to the system, the sound energy will eventually dissipate as the tuning fork stops vibrating. Over time, the amplitude of the wave diminishes as does the volume of the sound.

Something must vibrate in the singer to make sound. Hitting the tuning fork harder makes a louder sound. Force is related to volume. Students need to understand that the singer pushes air through his vocal cords using his diaphragm muscle. The force he pushes the air with affects volume. The way he holds his vocal cords and his mouth shape affect the pitch of the sound but the volume comes from the pushing force of his diaphragm. The singer stays on the same pitch and at a loud volume in order to break the glass.

## MATERIALS

**For the class:**

- Chart paper
- Markers
- Summary table

**Per Group:**

- 1 shallow tray filled with water
- 2 or 3 tuning forks
- Paper towels
- Data recording sheets
- pencils

**LESSON PLAN**

**Prior to Lesson:** Read through the lesson guide. Work with other teachers to talk through how this lesson helps students explain the "singer shattering the glass" phenomenon and also how they learn more about how volume and measuring volume, as a property of sound energy. On page 4 of this guide is space to pre-plan the row for the summary table.

**Step 1. Orient Students to the Concepts**

1. Intro to lesson: We've been thinking about the singer and about how he was able to shatter the glass with his voice. Today we will be thinking about this idea of volume. Previously we've observed how volume decreases as we get farther away from the source. But in this lesson we will see what goes into creating that volume in the first place.

2. I am going to make a sustained sound, but I am going to change volumes. Observe what I do when I change volume (Hum a sustained note varying volume.) How would you describe volume? Did my body move differently when I was loud volume? Soft volume? Let's write our own definition of volume. ***Today we will address this question: How does the force of vibrations affect the volume of the sound?***

Step 1. Orienting Students

**Questions to Ask Students**

*What will we be observing today?*

*How will we make and record our observations?*

**Step 2. Observations & Patterns**

1. Show students their recording sheet and demonstrate how to make the observations. You will use the same tuning fork for both conditions.

2. As students engage in making observations about the tuning fork as they manipulate the *force* (variable), ask student pairs/groups the questions featured at right in "Step 2."

Step 2. Observations & Patterns

**BACK POCKET QUESTIONS**

*How can you make a louder volume? Softer volume?*

*What does the vibrating tuning fork do to the water?*

*Why do you think hitting the tuning fork harder makes it sound louder?*

*Why do you think more force make the water waves splash more?*

*After you hit the tuning fork, where does that energy go?*

**Step 3. What did we learn?**

1. Pause small group activity and have some whole group sharing of observations. Fill in the 'observations and patterns' part of the summary table at this time.
2. Ask students the questions at right in "step 3" using structure (i.e. pair-share or a think-write-share, etc.).
3. Share out hypotheses explaining our observations and patterns.
4. Introduce the idea that sound can be represented in waves and read the paragraph about waves on the back of their data sheet. Have a brief conversation about how the diagram is similar to the waves students observed in the pan of water with the tuning fork.
5. Model reading strategy to students using the "Measuring Sound" reading using the "What? So What?" reading strategy and the "Split Screen" notes on an index card.

Step 3. What did we learn?

**BACK POCKET QUESTIONS**

*How can we use our data to answer today's question?*

*What claims can we make about the relationship between force and volume?*

*How does the wave pictured in the diagram on the back of the data sheet similar to our observations of the waves we observed in the water?*

**Step 4. Connection to the Singer**

1. Give students a few minutes to consider the questions under the amplitude reading. Ask students to share their answers to the questions below the reading with a partner or group. Follow up with small groups using the questions at right.
2. The singer must be close to the glass, which we have evidence for from the prior lesson looking at volume over distance but the singer must also be loud. How does the singer make loud sounds? (Refer back to "Human Voices" lesson about the diaphragm as a muscle that pushes. The harder the push, the louder the volume – this is similar to the idea of "the harder the hit, the louder the tuning fork.")

Step 4. Connection to Phenomenon

**BACK POCKET QUESTIONS**

*How does today's lesson help us understand why the singer sing loudly at the glass?*

*If we were going to draw the singer's sound using this wave idea, what would the wave look like?*

**Step 5. Whole Class Coordination of Students' Ideas & Questions**

Recap today's lesson as students help fill in the summary table. This step could also be spread over steps 3 and 4. Record questions students have relating to volume, amplitude, and force to revisit in subsequent lessons.

**PREPARING FOR FUTURE LESSONS**

Use the RSST to take notes during the lesson and after the lesson looking at student models. Make changes in upcoming lessons based on student thinking and what percentage of the class is thinking about them.

## Summary Table Example

Fill in the summary table during an activity, as you complete each step of the lesson plan, or at the end of the lesson to reflect back. Use pre-planned back pocket questions to ask students in small groups about their observations, patterns in data, what they're learning about, and how this might connect to help us explain the phenomenon as student are working in small groups during the activity. Back-pocket questions help students think about these categories before having this discussion as a whole class. Here is an example of the summary table with information from 2 investigations:

| Activity | Observations & Patterns | What did we learn? | Connection to Singer? |
|---|---|---|---|
| **Humans Voices**: Vibrations & Sounds when whispering, humming, talking, yelling  | • We felt vibrations in our throat as we made different sounds.<br>• The vibrations were stronger if we were louder. (Yelling vibrations were stronger than whispering) | • There are parts inside our body that help us talk.<br>• Vocal cords vibrate the air as we breathe out to make sounds.<br>• To make a sound louder we use more force with the diaphragm muscle which is below the lungs and push on the lungs to move air out. | • The singer uses his diaphragm, lungs, and vocal cords to sing.<br>• To make a louder sound, he uses more force and pushes harder with his diaphragm.<br>• His vocal cords vibrate the air so we hear him sing. |
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**Step 2. Patterns**
*Identify Observations & Patterns in the Data*

**Step 3. Learning**
*What did we learn from the activity and/or reading?*

**Step 4. Connection**
*Connecting back to Explain the Phenomenon*

## PLAN YOUR SUMMARY TABLE ROW FOR "SEEING" SOUND WAVES ACTIVITY

| ACTIVITY | OBSERVATIONS & PATTERNS | WHAT DID WE LEARN? | CONNECTION TO SINGER? |
|---|---|---|---|
| **"Seeing" Sound Waves**<br>Vibrations & Volume  | • When we hit a tuning fork, it vibrates.<br>• When we put the vibrating tuning fork in water, it makes waves.<br>• If we hit the tuning fork, we hear a louder sound than if we tap it.<br>• If we hit the tuning fork and place it in water it makes BIG waves but a small tap only makes small waves. | | |

Student Sheet

# “Seeing” Sound Waves

*Observing the Effects of Force on*
*Amplitude and Volume*

Directions: Hit the tuning fork on the soft part of your leg or on your science notebook. Hold it to your ear and listen. Hit it again and touch the surface of the water. Record your observations below. Use the same tuning fork for both conditions.

Use the SAME tuning fork for both conditions.

**CONDITIONS**

| | | **HARD HIT**<br>*USE MORE FORCE* | **SOFT HIT**<br>*USE LESS FORCE* |
|---|---|---|---|
| **OBSERVATIONS** | **Hear** | | |
| | **See & Feel** | | |
| | **Draw a sketch** of the tuning fork, dish, and water waves. | | |

1.) Which condition resulted in higher waves or bigger amplitude (back-and-forth)? Hard or Soft

2.) Which condition resulted in hearing a louder volume when you listened to the tuning fork? Hard or Soft

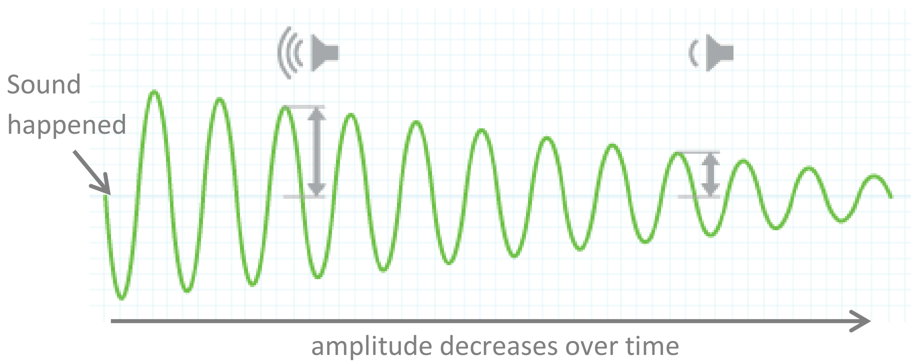
3.) What happens to the vibrations over time? ____________________________________________________

4.) How do you think the starting force and volume are related? ________________________________________

______________________________________________________________________________________

# What is amplitude?

**Amplitude** is a description of the sound wave's strength. As the amplitude of a sound wave decreases, the volume of the sound decreases. Amplitude, or wave height, decreases over time if no more energy or force is put back into the system. Strum a guitar string or hit a piano key one time and the volume of the sound gets less and less over time. One way computers represent sound waves is shown below. Over time, the amplitude, or wave height, decreases if no more energy is put into the system. This results in less and less volume over time.




5.) How does knowing about **amplitude** help us describe our observations of tuning forks?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

6.) What might **amplitude** have to do with our singer shattering the glass?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

# KNOCK, KNOCK?

Sound Transfers Through Matter

**OBJECTIVES**

This lesson focuses students on how sound energy transfers through different states of matter (namely, gas and solid). Sound energy is transferred through mediums differently based on the arrangement of the particles.

- Describe and discuss patterns in the knocking sounds they observed.
- Understand that matter is made up of particles that are too small to see.
- Draw conclusions about the relationship between sound energy traveling in gas versus solids.

**BACKGROUND & EXPLANATION**

*Taken From: http://www.physicsclassroom.com/class/waves/Lesson-1/What-is-a-Wave*

A medium is a substance or material that carries the wave. You have perhaps heard of the phrase *news media*. The news media refers to the various institutions (newspaper offices, television stations, radio stations, etc.) within our society that carry the news from one location to another. The news *moves through* the media. The media doesn't make the news and the media isn't the same as the news. The news media is merely the *thing* that carries the news from its source to various locations. In a similar manner, a wave medium is the substance that carries a wave (or disturbance) from one location to another. The wave medium is not the wave and it doesn't make the wave; it merely carries or transports the wave from its source to other locations. In the case of our slinky wave, the medium through that the wave travels is the slinky coils. In the case of a water wave in the ocean, the medium through which the wave travels is the ocean water. In the case of a sound wave moving from the church choir to the pews, the medium through which the sound wave travels is the air in the room. And in the case of the stadium wave, the medium through which the stadium wave travels is the fans that are in the stadium.

To fully understand the nature of a wave, it is important to consider the medium as a collection of interacting *particles*. In other words, the medium is composed of parts that are capable of interacting with each other. The interactions of one particle of the medium with the next adjacent particle allow the disturbance to travel through the medium. In the case of a sound wave in air, the *particles* or interacting parts of the medium are the individual molecules of air. And in the case of a stadium wave, the *particles* or interacting parts of the medium are the fans in the stadium. In a stadium wave, the fans do not get out of their seats and walk around the stadium. We all recognize that it would be silly (and embarrassing) for any fan to even contemplate such a thought. In a stadium wave, each fan rises up and returns to the original seat. The disturbance moves through the stadium, yet the fans are not transported. So as a sound wave is transferred through air, an individual molecule (matter) does not move very far at all. Waves involve the transport of energy without the transport of matter.

**MATERIALS**

**For the class:**

- Chart paper
- markers

**Table group baskets (1 per student):**

- “Knock Knock” data sheet
- Copy of “The Stuff in Our World” Reading
- Pencil

**LESSON PLAN**

**Step 1. Orient Students to the Concepts**

1. Intro to lesson: We've been thinking about the singer and about how he was able to shatter the glass with his voice. Today we will be thinking about how sound travels, or moves from one place to another. For example, as I'm talking to you, you can hear me. **How do you think the sound from my mouth gets to your ears so you can hear me?** (Wait time, and then invite to Pair-Share, Share-out a few.)

Step 1. Orienting Students

> **Questions to Ask Students**
>
> *What will we be observing today?*
>
> *How will we measure or record our observations?*

2. Today we will be making observations about how sounds travel through different materials like air or your table. You have a short task to do with a partner. Then we will come back whole group to talk about how this can help us understand where sound can travel.

3. Give activity directions and expectations. Students will make observations about knocking sounds under two conditions: (1) Knocking on the desk with their ear on the desk and (2) Knocking on the desk with their head lifted and ears in the air. In both cases they can hear the knocking sound. But they will hear that one condition sounds louder even if they knock with the same force. Try two force conditions (hard force and soft force) to see a pattern that in both force cases having the ear on the desk makes the knock sound much louder. Students may also notice they can feel the vibration in the table with their hands as well. Tell students to begin by following the directions on their "Knock Knock" data sheet. When they complete the data sheet, they will read their "The Stuff in Our World" reading looking for information to help make sense of what we feel and observe in the activity. Use the questions in the box above to focus students first on the observations they will be making.

**Step 2. Observations & Patterns – Making Sounds**

Step 2. Observations & Patterns

> **BACK POCKET QUESTIONS**
>
> *What do you hear when you…?*
>
> *How is what you hear different between listening in the table or in the air?*
>
> *What do you observe about the volume when you increase or decrease your knocking force?*

1. As students follow directions on their data sheet, monitor student progress and ask back-pocket questions listed at right. Additional questions are below:

   **Observation Questions:**
   - When you put your ear to the desk and knock, what do you hear?
   - Lift your head off the desk and knock, what do you hear?
   - Which condition makes the knocking sound louder? Is it the same even if we knock softly?
   - Comparing the hard knock and soft knock observations, what pattern do we see about how knocking sounds in the table compared to through the air?

   **Reasoning Questions (Unobservable):**
   - Why do you think we need to knock with the same amount of force to compare conditions?
   - If we knock with the same force, what do you think makes the knocks sound different?

**Some students may be reasoning about unobservable molecules or particles:**

- When your ear is on the desk, how do you think the knock gets to your ear so you hear the sound?
- When your head is off the desk, how do you think the knock gets to your ear so you can hear it?
- Why do you think it sounds louder when your ear is on the table and you knock on the table?
- Do you think sound can travel through other solids? Like a door? How do you know? (Prompt: Sometimes visitors knock on the door to let us know they are here. How can we hear that from the other side of the door?

2. Fill in the "Observations & Patterns" section of the summary table. Pause the small group activity when all groups have completed their observations. Record observations and patterns in that part of the summary chart as a class.

**Step 3. What did we learn? – Using a Reading**

1. Students read "The Stuff in Our World" on their own or with a partner and answer key questions using information from the reading.
2. Act-it-Out: Have a group of students stand up and act like table particles and then air particles and have a student "knock" on the table to see what the human-scale model does. (Requires teacher directives on how student-particles should behave but relates to content in reading.)
3. As students are working to answer the questions, use the 'back pocket question' listed at right to help student connect the reading with their observations.

Step 3. What did we learn?

**BACK POCKET QUESTIONS**

*How do you think sound energy travels through matter?*

*Which matter, solid or gas, does sound travel through best? Why do you think so?*

**Step 4. Connection to the Singer**

On the back of the data sheet, students are asked how this lesson helps us explain part of our overarching phenomenon. They can draw and write a response; however, they may need some partner talk time to answer this question. Use the back-pocket questions listed to help students work towards making the connection back to the singer. This can be done as students continue to work in their groups.

Step 4. Connection to Phenomenon

**BACK POCKET QUESTIONS**

*What can you tell us about vibrations and sound that you learned today? How is that like what happens with the singer as he shatters the glass?*

*How does today's lesson help us understand what's going on that we can't see in our glass-shattering phenomenon?*

**Step 5. Whole Class Coordination of Students' Ideas**

Return to whole class conversation. This is where you can help students see broad trends or patterns of data for different groups in the classroom. You may have already filled in the "Observation & Pattern" section of the summary table, if not, do so now. Use the reading to help students agree on a few short bullet points about what we learned about our focus question for this lesson: "**How do you think the sound from my mouth gets to your ears so you can hear me?**" Finally, help students "map" these ideas onto a real world situation including the unit phenomenon.

**PREPARING FOR FUTURE LESSONS**

Use the RSST to take notes during the lesson and after the lesson looking at student models. Make changes in upcoming lessons based on student thinking and what percentage of the class is thinking about them.

## Plan Your summary table row

| Activity | Observations & Patterns | What did we learn? | Connection to Singer? |
|---|---|---|---|
| | | | |

**LESSON NOTES**

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## Knock, Knock! Who's There? Data Recording Sheet

Directions: Put your ear on the table. Knock. Draw a sketch and record observations about the sound you hear. Then lift your head with your ears in the air. Knock with the same force. Do you hear something different?

| **<u>Hard</u>** Knock using more force | CONDITIONS | |
|---|---|---|
| | **1. Ear on the table** | **2. Ear in the air** |
| **OBSERVATIONS** Draw a sketch: | | |
| Describe the sound you hear: | ______________<br>______________<br>______________ | ______________<br>______________<br>______________ |

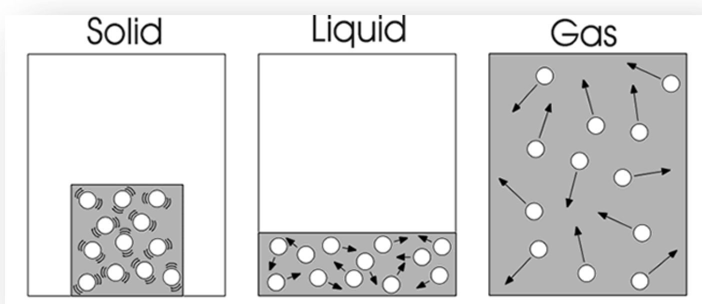
| **<u>Soft</u>** Knock using less force | CONDITIONS | |
|---|---|---|
| | **1. Ear on the table** | **2. Ear in the air** |
| **OBSERVATIONS** Draw a sketch: | | |
| Describe the sound you hear: | ______________<br>______________<br>______________ | ______________<br>______________<br>______________ |

## *The "Stuff" in our World*

Things in our world take up space and have some weight. There are three common types of stuff, or **matter**: solid, liquid, and gas. A jacket, chair, and cup are all examples of solids. You can't put your hand through a solid. If you had microscope eyes, you would see tiny particles in solids are packed together tightly.

Water, juice, and oil are all examples of liquids. We can move our hands through liquids, like swimming in a pool. Tiny particles in liquids are not packed as tightly as solids so we can move in between them.

Two examples of gases are the air that we breathe and helium in birthday balloons. We can also move through gases. Particles in gases are not close together. The spacing of the particles makes sound to travel much faster through a solid than a gas.




# Using Microscope Eyes:  Knock, Knock!

Directions:  From the reading, use what you learned about particles in solids (desk) and gases (air) to draw them.  Think about how knocking might move these particles to help you explain how sound travels.

| 1. **Ear on the table** |
|---|
| |

| 2. **Ear in the air** |
|---|
| |

# STOP THAT SOUND!

Sound Energy Can be Absorbed

## OBJECTIVES

This lesson focuses students on how sound energy transfers differently through different solid materials. As it moves through matter, sound energy can be reflected (echo) or absorbed (muffled). The material/matter causes one or the other to happen to varying degrees. Students will…

- Describe patterns in the sounds they perceived and measure as they try to muffle the sound.
- Explain their results about decreasing decibels with more materials (muffling) using knowledge that matter is made of tiny particles that can be bumped and drawing out the unobservable process of absorption and reflection of sound.
- Draw conclusions about the relationship between decibels (amplitude/volume) and the type/amount of wrapping material.

## BACKGROUND

Taken from: http://www.physicsclassroom.com/class/sound/Lesson-3/Reflection,-Refraction,-and-Diffraction

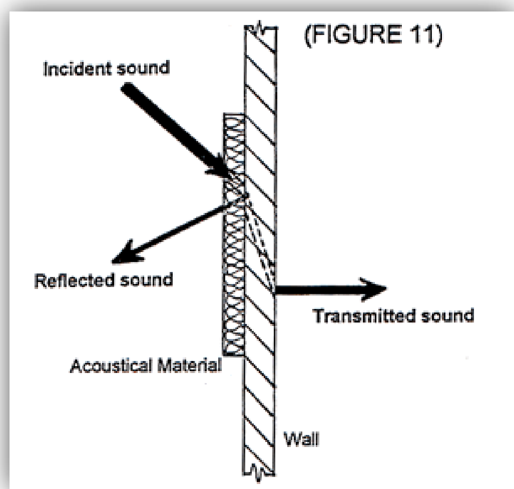
Like any wave, a sound wave doesn't just *stop* when it reaches the end of the medium or when it encounters an obstacle in its path. When a wave reaches the boundary between one medium another medium, a portion of the wave undergoes reflection and a portion of the wave undergoes transmission across the boundary. The amount of reflection is dependent upon the dissimilarity of the two media. For this reason, acoustically minded builders of auditoriums and concert halls avoid the use of hard, smooth materials in the construction of their inside halls. A hard material such as concrete is dissimilar to the air through which the sound moves; subsequently, most of the sound wave is reflected by the walls and little is absorbed. Walls and ceilings of concert halls are made softer materials such as fiberglass and acoustic tiles. These materials are more similar to air than concrete and thus have a greater ability to absorb sound. This gives the room more pleasing acoustic properties.

Reflection of sound waves off of surfaces can lead to one of two phenomena - an **echo** or a **reverberation**. [It is not important that students know the difference between a reverberation and an echo, however, they are explained below if you are interested.] Perhaps you have observed reverberations when talking in an empty room, when honking the horn while driving through a highway tunnel or underpass, or when singing in the shower. A reverberation is perceived when the reflected sound wave reaches your ear in less than 0.1 second after the original sound wave. Since the original sound wave is still held in memory, there is no time delay between the perception of the reflected sound wave and the original sound wave. The two sound waves tend to combine as one very prolonged sound wave. If you have ever sung in the shower (and we know that you have), then you have probably experienced a reverberation. The Pavarotti-like sound which you hear is the result of the reflection of the sounds you create combining with the original sounds. Because the shower walls are typically less than 17 meters away, these reflected sound waves combine with your original sound waves to create a prolonged sound - a reverberation. In auditoriums and concert halls, reverberations occasionally occur and lead to the displeasing garbling of a sound.

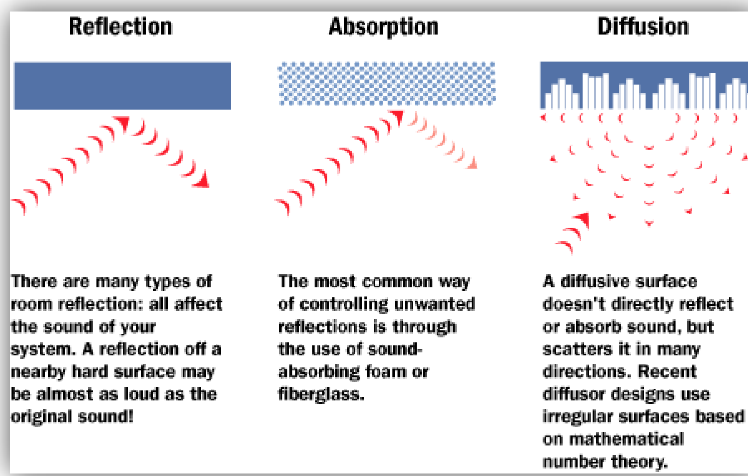
But reflection of sound waves in auditoriums and concert halls do not always lead to displeasing results, especially if the reflections are *designed right*. Smooth walls have a tendency to direct sound waves in a specific direction. Subsequently the use of smooth walls in an auditorium will cause spectators to receive a large amount of sound from one location along the wall; there would be only one possible path by which sound waves could travel from the speakers to the listener. The auditorium would not seem to be as lively and full of sound. Rough walls tend to diffuse sound, reflecting it in a variety of directions. This allows a spectator to perceive sounds from every part of the room, making it seem lively and full. For this reason, auditorium and concert hall designers prefer construction materials that are rough rather than smooth.

Reflection of sound waves also leads to **echoes**. Echoes are different than reverberations. Echoes occur when a reflected sound wave reaches the ear more than 0.1 seconds after the original sound wave was heard. If the elapsed time between the arrivals of the two sound waves is more than 0.1 seconds, then the sensation of the first sound will have *died out*. In this case, the arrival of the second sound wave will be perceived as a second sound rather than the prolonging of the first sound. There will be an echo instead of a reverberation.

Reflection of sound waves off of surfaces is also affected by the shape of the surface. Reflection of sound waves off of curved surfaces leads to an interesting phenomenon. Curved surfaces with a parabolic shape have the habit of focusing sound waves to a point. Sound waves reflecting off of parabolic surfaces concentrate all their energy to a single point in space; at that point, the sound is amplified. Perhaps you have seen a museum exhibit that utilizes a parabolic-shaped disk to collect a large amount of sound and focus it at a **focal point**. If you place your ear at the focal point, you can hear even the faintest whisper of a friend standing across the room. Parabolic-shaped satellite disks use this same principle of reflection to gather large amounts of electromagnetic waves and focus it at a point (where the receptor is located). Scientists have recently discovered some evidence that seems to reveal that a bull moose utilizes his antlers as a satellite disk to gather and focus sound. Finally, scientists have long believed that owls are equipped with spherical facial disks that can be maneuvered in order to gather and reflect sound towards their ears.




From: http://www.acousticalsurfaces.com/acoustic_IOI/101_7.htm




From: http://www.crutchfield.com/S-p5FgGLlgVMH/learn/learningcenter/home/speakers_roomacoustics.html

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Students may have been talking about how they can hear sounds through walls (for example, their neighbors are too noisy and wake the baby.) Here is some additional information about insulating for sound. Taken from http://www.houselogic.com/home-advice/home-improvement/soundproofing-walls/#

Down the hall, your 10-year-old practices saxophone. In the garage, your husband fires up his table saw. The racket has the artwork on the walls jiggling. Wouldn't it be great if you could muffle all that noise? By soundproofing your walls, you'll gain peace and quiet, and restore a little sanity to your household. To quiet household noise, you'll need to reduce vibrations, plug sound leaks, and absorb sounds.

- *Solution #1: Extra drywall*. Sounds are vibrations. Deadening those vibrations is best done with heavy, dense materials that stop noise in its tracks. When it comes to heavy, brick and stone are great but impractical for retrofitting your interior walls. The easiest strategy is to add a second layer of drywall to build up a thick, sound-deadening barrier.
- *Solution #2: The caulk sandwich*. As an extra defense, separate the two layers of drywall with 3/8-inch-thick beads of acoustical caulk. The caulk deadens vibrations that try to travel from one layer of drywall to the other.
- *Solution #3: Plugging sound leaks*. Plug gaps around ceiling fixtures, switch boxes, door casings and add weather stripping to door frames.
- *Solution* #4: Absorbing sound with acoustic panels. Acoustic panels absorb sounds before they can bounce off walls and ceilings.
- *Solution #5: Quieting ambient noise*. Adding soft items to rooms — rugs, carpets, drapes, potted plants — helps reduce vibrations and ambient noise.
- *Solution #6: Use solid-core doors*. A solid core interior door absorbs sound better than a hollow door.
- *olution #7: Knowing your STC ratings*. Soundproofing products often come with a Sound Transmission Class (STC) rating. STC is a measure of how many decibels of sound reduction a product provides. The higher the STC rating, the better. An improvement of 10 STC makes the noise seem like it's been cut in half. On the other hand, a rating difference of 3 STC or less is nearly imperceptible — worth knowing when comparing products.

**MATERIALS**

**For the class:**

- Chart paper
- markers

**1 per student:**

- "Stop that Sound!" data sheet
- Pencil

**Table group baskets**

- sound generator or iPad with app*
- decibel meter or iPad with app*
- box with lid (large enough to hold the sound generator)
- miscellaneous variety of materials to muffle sound (i.e. bubble wrap, small pillow, sweater, foam or quilting batting, etc.)

*\* If using iPads, each group needs 2 to use one as a sound generator and the other as a sound meter*
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**LESSON PLAN**

**Step 1. Orient Students to the Concepts**

1. Intro to lesson: Orient students to the concepts of echo and absorption of sound by using experiences they may have discussed earlier in the unit. For example, students may be able to hear students playing at recess outside when they are inside the building – but it doesn't sound as loud as if they were outside. **Why can we hear outside noises when we are inside the classroom?** Have students silently listen to see if they can hear sounds that are happening outside the classroom (i.e. cars, airplanes, children playing.) Keep a record of observations. Have student draw out how they think that sound energy can get into the classroom from outside. Direct students to use what they've learned about particles.

2. Today we will be making observations about sound travels through some materials better than others. You have a short task to do with a partner. Then we will come back whole group to talk about how this can help us understand how sound energy can travel.

3. Give activity directions and expectations. Students will measure the decibels of a sound generator (kept at constant volume) placed in a box. Measurements will be at (1) open box, no lid, (2) closed box, just the lid, (3) closed and wrapped up box. Students can do a 4th measurement using materials from their table box or classroom. They will record their observations and decibel measurements. How does each condition seem to affect the loudness of the sound energy that can get out of the box?

Step 1. Orienting Students

**Questions to Ask Students**

*What will we be observing today?*

*How will we measure or record our observations?*

**Step 2. Observations & Patterns – Making Sounds**

1. As students follow directions on their data sheet, monitor student progress and ask back-pocket questions listed at right.

2. Fill in the "Observations & Patterns" section of the summary table. Pause the small group activity when all groups have completed their observations. Record observations and patterns in that part of the summary chart as a class.

Step 2. Observations & Patterns

**BACK POCKET QUESTIONS**

*Which condition had the hightest decibel reading?*

*How is the sound different when the box is open versus closed?*

*What do you observe about the volume when you change the box covering?*

**Step 3. What did we learn?**

1. Have students fill in the question on the back of their data sheet that has them explaining how/why the change in volume happens with different conditions.
2. Prompt students to use what they learned about the particulate nature of matter to speculate about the particle arrangement in the different wrapping materials. How is the hard, flat surface of the box different than a softer surface like the foam or quilt batting?
3. If time permits, watch a short clip about echoes and absorption of sound. [Need to find a good clip that shows echo or absorption of sound.]Turn-and-talk about how this video helps make sense of what we've observed so far.

Step 3. What did we learn?

> **BACK POCKET QUESTIONS**
>
> *Why do you think the volume of the sound changes?*
>
> *Which material do you think is best at muffling or absorbing the sound? Draw how you think it does that.*

**Step 4. Connection to the Singer**

On the back of the data sheet, students are asked how this lesson helps us explain part of our overarching phenomenon. They can draw and write a response; however, they may need some partner talk time to answer this question. Use the back-pocket questions listed to help students work towards making the connection back to the singer. This can be done as students continue to work in their groups.

Step 4. Connection to Phenomenon

> **BACK POCKET QUESTIONS**
>
> *The singer puts the glass in a clear box to "prove it's not a trick." How do you think this flat, hard surface affects the sound he makes?*
>
> *What if the singer were in a super padded room with lots of furniture and rugs? How might his sound be different? Do you think it would make a difference at all?*
>
> *How does today's lesson help us understand what's going on that we can't see in our glass-shattering phenomenon?*

**Step 5. Whole Class Coordination of Students' Ideas**

Return to whole class conversation. This is where you can help students see broad trends or patterns of data for different groups in the classroom. You may have already filled in the "Observation & Pattern" section of the summary table, if not, do so now. Use the reading to help students agree on a few short bullet points about what we learned about our focus question for this lesson: "**Why can we hear outside noises when we are inside the classroom?**" Finally, help students "map" these ideas onto a real world situation including the unit phenomenon. Have students draw cross sections of the classroom and the particles of matter to show how sound energy affects these particles.

**PREPARING FOR FUTURE LESSONS**

Use the RSST to take notes during the lesson and after the lesson looking at student models. Make changes in upcoming lessons based on student thinking and what percentage of the class is thinking about them.

## PLAN YOUR SUMMARY TABLE ROW

| ACTIVITY | OBSERVATIONS & PATTERNS | WHAT DID WE LEARN? | CONNECTION TO SINGER? |
|---|---|---|---|
| | | | |

**LESSON NOTES**

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___________________________________________________________________________

Name:___________________________________

# Stop that Sound!
## Data Recording Sheet

You need to decide on what to cover your box with in order to "Stop that sound!" from coming out. What material do you think would do the best job at stopping the sound energy?

Directions:
1. Place sound generator inside box and get your decibel meter ready.
2. Turn sound generator on.
3. Use decibel meter to measure sound just above the box. Numbers may not be stable. Write an estimate.
4. Repeat the same condition 3 times to make sure the numbers are pretty accurate.
5. Repeat steps 1-5 for each condition: (1) Open box, (2) Box with lid, (3) Box with lid covered.

| | Trial #1 | Trial #2 | Trial #3 | Average |
|---|---|---|---|---|
| Open box | dB | dB | dB | dB |
| Box with lid | dB | dB | dB | dB |
| Box with lid covered with ____________ | dB | dB | dB | dB |

## Observations about your data:

1.) What did you choose to cover your box with? ______________________

Why? ________________________________________________________________________

2.) Which condition had the **highest** average decibel reading? ____________________________

3.) Which condition had the **lowest** average decibel reading? ____________________________

4.) What did you notice about the decibels as you covered the sound generator with more and more stuff? ___________________________________________________________________

5.) Did you see the same patterns as another group? Go check. YES NO

*If you had a different pattern, why do you think you results might be different?*

## Explaining your data:

Draw what think is happening with the sound energy in the following condition.
Include what you observed using your decibel meter and sound generator but also what you can't directly see. Use your knowledge about particles or molecules that make up matter.

How does the sound energy get through the box?

Box with Lid

## So What?

What did you learn about sound today?

______________________________________________________________________

______________________________________________________________________

How does this connect to your life? Think about the sounds you hear.

______________________________________________________________________

______________________________________________________________________

In the singer video, he put the glass in a clear box with flat, hard sides to "prove it isn't a trick." Do you think the clear box affected the sound energy he used to break the glass?

______________________________________________________________________

______________________________________________________________________

# RESONANCE: FINDING THE RIGHT PITCH

Using the “right pitch” to make another object vibrate

**OBJECTIVES**

This lesson focuses students on how vibrating things make sounds and also sounds can make things vibrate if they are ‘twins.’ (Also, sound energy does not blow air but moves through it by bumping particles around) Students will…

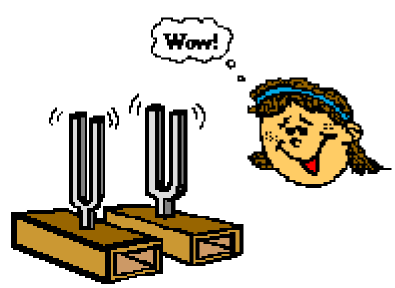
- Use observations from video/demonstrations about what happens to vibrations of other objects when a sound is made at the ‘right pitch’ for that object (resonant frequency).
- Explain that sound energy is transferred through air by bumping particles and not by actually moving or blowing the air particles around.

**BACKGROUND**

Taken from: http://www.physicsclassroom.com/Class/sound/u11l4b.cfm

Musical instruments and other objects are set into vibration at their natural frequency when a person hits, strikes, strums, plucks or somehow disturbs the object. For instance, a guitar string is strummed or plucked; a piano string is hit with a hammer when a pedal is played; and the tines of a tuning fork are hit with a rubber mallet. Whatever the case, a person or thing puts energy into the instrument by direct contact with it. This input of energy disturbs the particles and forces the object into vibrational motion - at its natural frequency.

If the tuning fork is held in your hand and hit with a rubber mallet, a sound is produced as the tines of the tuning fork set surrounding air particles into vibrational motion. The sound produced by the tuning fork is barely audible to students in the back rows of the room. However, if the tuning fork is set upon the whiteboard panel or the glass panel of the overhead projector, the panel begins vibrating at the same natural frequency of the tuning fork. The tuning fork forces surrounding glass (or vinyl) particles into vibrational motion. The vibrating whiteboard or overhead projector panel in turn forces surrounding air particles into vibrational motion and the result is an increase in the amplitude and thus loudness of the sound. This principle of forced vibration explains why demonstration tuning forks are mounted on a sound box, why a commercial music box mechanism is mounted on a sounding board, why a guitar utilizes a sound box, and why a piano string is attached to a sounding board. A louder sound is always produced when an accompanying object of greater surface area is forced into vibration at the same natural frequency.



Resonating Tuning Forks

Suppose that a tuning fork is mounted on a sound box and set upon the table; and suppose a second tuning fork/soundbox system having the same natural frequency (say 256 Hz) is placed on the table near the first system. Neither of the tuning forks is vibrating. Suppose the first tuning fork is struck with a rubber mallet and the tines begin vibrating at its natural frequency - 256 Hz. These vibrations set its sound box and the air inside the sound box vibrating at the same natural frequency of 256 Hz. Surrounding air particles are set into vibrational motion at the same natural frequency of 256 Hz and every student in the classroom hears the sound. Then the tines of the tuning fork are grabbed to prevent their vibration and remarkably the sound of 256 Hz is still being heard. Only now the sound is being produced by the second tuning fork - the one which wasn't hit with the mallet. Amazing!! The demonstration is often repeated to assure that the same surprising results are observed. They are! What is happening?

The two forks are *connected* by the surrounding air particles. As the air particles surrounding the first fork (and its connected sound box) begin vibrating, the pressure waves that it creates begin to impinge at a periodic and regular rate of 256 Hz upon the second tuning fork (and its connected sound box). The energy carried by this sound wave through the air is *tuned* to the frequency of the second tuning fork. Since the incoming sound waves share the same natural frequency as the second tuning fork, the tuning fork easily begins vibrating at its natural frequency. This is an example of **resonance** - when one object vibrating at the same natural frequency of a second object forces that second object into vibrational motion.

## MATERIALS

**For the class:**

- Pair of Resonance Boxes with tuning forks and mallet
- Grandpa John Video about Resonance
  https://www.youtube.com/watch?v=hiHOqMOJTH4
- Different sized glass bowls
- Saran wrap
- Salt
- Goggles (if observing up close because we don't want salt in our eyes!)
- Chart paper
- Markers
- Singer shattering glass video
  https://www.youtube.com/watch?v=10lWpHyN0Ok

**1 per student:**

- Recording sheet
- Pencil

## LESSON PLAN

**Prior to the lesson:** Cover glass bowls in saran wrap

**Step 1. Orient Students to the Concepts**

1. Intro to lesson: Students have been studying vibrations, volume, distance, and absorption as it relates to sound waves. Today we will revisit the idea of vibrations and how sound energy can work at a distance.
2. Explain that today we will be observing different ways that we can make objects vibrate without touching them and keeping a written record using the recording sheet.

Step 1. Orienting Students

**Questions to Ask Students**

*What will we be observing today?*
*How will we measure or record our observations?*

**Step 2. Observations & Patterns**

*Note: It is helpful if one adult can be the 'hummer' and one can facilitate discourse. Students could do the humming but they run out of breath faster and also may get light headed. Also, keeping the same 'hummer' eliminates a variable about the amount of force and quality of the pitch. But student volunteers can be used if desired.*

Step 2. Observations & Patterns

> **BACK POCKET QUESTIONS**
>
> *Which bowl needed the lowest pitch/note to make it vibrate?*
>
> *Which bowl needed the highest pitch/note to make it vibrate?*
>
> *Did high or low volume work better?*

1. Demonstrate for students humming at the saran wrap covered bowls. Sprinkle salt so they can see the vibrations. Have some students come up and feel the bowl as you hum at it. Share out that they feel the bowl vibrate even through you're not actually touching it.

2. Record observations about the size of the bowl and the pitch/note of the sound needed to make the salt "dance" (bowl vibrate). What happens just before and after the sound? A sample chart is shown below of what kinds of things students may mention.

3. **How can one object make another object vibrate without touching it?** Have students turn-and-talk about why only certain sounds and volumes vibrate the bowl. As students follow directions on their data sheet, monitor student progress and ask back-pocket questions.

4. Tell students they will now see a similar event, where one sound makes another object start vibrating. Demonstrate the tuning fork boxes. Let students draw on their data sheet what they observe and how they think it works.

**How can we vibrate objects without touching them?**

**Humming Bowl**

| | Observations |
|---|---|
| Big bowl | *Lower note*<br>*Loud volume*<br>*Looks like lots of force* |
| Medium bowl | *Middle note*<br>*Loud volume*<br>*Looks like lots of force* |
| Small bowl | *Higher note*<br>*Loud volume*<br>*Looks like lots of force* |

Ideas

- Had to have high volume to jiggle the air particles enough to bump the glass particles
- Different pitch is because bowls are different sizes

***Tuning Forks***

| Observations |
|---|
| ○ *Hit one, the other one starts vibrating*<br>○ *The tuning forks are the same size and shape*<br>○ *Tuning forks are not touching* |

- Starting sound has to match the sound the other one "likes"
- It's like they're twins and can pick up the other sound
- Has something to do with the material (metal tuning forks)

**Step 3. What did we learn?**

1. Watch Grandpa John's video about resonance. He demonstrates the tuning fork resonance box phenomenon again and explains it briefly (at the level students should understand it).

2. Have students fill the boxes on their data sheet about the tuning fork demonstration. Writing to the side what they learned from the video.

Step 3. What did we learn?

> ? **BACK POCKET QUESTIONS** ?
>
> *How do you think the tuning fork makes the other tuning fork start vibrating?*
>
> *What's happening that we can't see that might be going on? (using knowledge of particles)*

**Step 4. Connection to the Singer**

1. Let's revisit what's happening at the beginning of our singer story before he starts singing. Rewatch only beginning of singer video. Have students make observations. Ask students what they observe as you play each of these parts (1) when the glass keeps humming when he runs out of breath and (2) when he flicks the glass and then sings on the same note.

2. Turn-and –talk about how this connects to what we just learned about the 'right pitch'.

Step 4. Connection to Phenomenon

> ? **BACK POCKET QUESTIONS** ?
>
> Why do you think he flicks the glass before he starts singing?
>
> *How does today's lesson help us understand what's going on that we can't see in our glass-shattering phenomenon?*

**Step 5. Whole Class Coordination of Students' Ideas**

Return to whole class conversation. This is where you can help students see broad trends or patterns of data for different groups in the classroom. You may have already filled in the "Observation & Pattern" section of the summary table, if not, do so now. Use the reading to help students agree on a few short bullet points about what we learned about our focus question for this lesson: "**How can one object make another object vibrate without touching it?**" Finally, help students "map" these ideas onto a real world situation including the unit phenomenon. Have students draw cross sections of the classroom and the particles of matter to show how sound energy affects these particles.

**PREPARING FOR FUTURE LESSONS**

Use the RSST to take notes during the lesson and after the lesson looking at student models. Make changes in upcoming lessons based on student thinking and what percentage of the class is thinking about them.

## PLAN YOUR SUMMARY TABLE ROW

| ACTIVITY | OBSERVATIONS & PATTERNS | WHAT DID WE LEARN? | CONNECTION TO SINGER? |
|---|---|---|---|
| | | | |

**LESSON NOTES**

___________________________________________________________________________

___________________________________________________________________________

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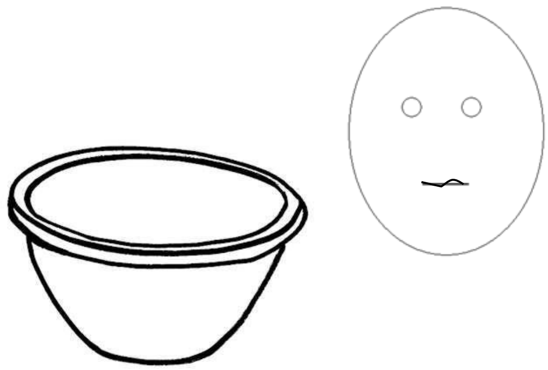
# RESONANCE: FINDING THE RIGHT PITCH

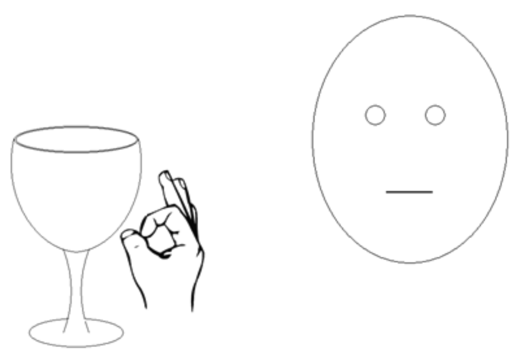
Recording Sheet

Observations about Bowl Humming Demonstration:  What happened to the salt? Why?



Observations about the tuning fork boxes:  What happened?  How did that happen?

So what?  How does this explain why the singer flicks the glass?

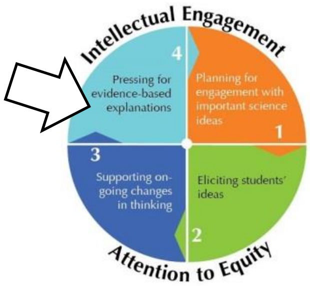


# Sound Energy Unit Activity Planner

## How will these activities help students make sense of the phenomenon?

| *Activity* | *Learning Target* | *Connection to Phenomenon* | *NGSS* |
|---|---|---|---|
| | Eliciting Ideas Lesson: | *Introduce Phenomenon & Elicit Initial Ideas using model scaffold* | |
| **Activity 1:** Human Voice | Vibrations can travel through the air from the source of sound to another object and affect that object. Vibrations diminish over a distance. | The singer vibrates air by singing and that vibration travels to the glass making it vibrate, too. The farther away the sound source is from an object, the less it will vibrate. This is like how the sand jumped more when the sound was closer to the cup and less when it was farther away. | 1-PS4-1. Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate. 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound |
| **Activity 2:** Decibels at a Distance ***MATH CONNECTION*** | Vibrations diminish over a distance. Loudness diminishes over a distance. We measure sound in decibels. | Vibrations diminish over a distance so the singer must be close to the class so the vibrations hit the glass hardest at the highest decibels. | 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. |
| **Activity 3:** "Seeing" Sound Waves | Vibrations "cause" sound that we can hear. The harder the force to begin the vibration, the louder the sound and the more energy it has (wave amplitude represents volume) | The singer uses force from his diaphragm and vocal cords to make vibrations that make a loud sound. The harder he forces his muscles, the louder the sound. The louder the sound, the stronger the sound waves (like we see in the water, just in the air). | 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. |
| **Activity 4:** Sound Travels through matter | Matter is made of particles. Particles in gases are farther apart than particles in solids. Sound energy transfers through matter by bumping particles. | The singer vibrates the air particles using his vocal cords. Those air particles bump into other air particles and so on, out of his mouth and away from the singer. The shape of his mouth seems to direct the sound energy (particles bumping) towards the glass but some does go out in all directions (so we can hear it). The glass particles vibrate after the air particles bump into them. | 5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound |
| **Activity 5**: Absorbing or Reflecting Sound Energy | As it moves through matter, sound energy can be reflected (echo) or absorbed (muffled). The material/matter causes one of the other to happen. | In the video, the singer puts the glass in a transparent box to "prove it's not a trick." How would this material affect the singer's sound? Encourage students to draw a model at the particle/molecule level of what's happening | MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. |
| **Activity 6**: Resonance | Vibrating things make sounds and also sounds can make things vibrate if they are 'twins.' (Also, sound energy does not blow air but moves through it by bumping) | The singer flicks the glass at the start to hear the glass' natural resonant pitch. He sings at that pitch which makes the glass hum. He wouldn't need to sing at the 'right' pitch if he could be super duper loud (like an explosion) that would break the glass without being on the right pitch. Being at the right pitch helps him break the glass along with the force he is able to put into it. | 1-PS4-1. Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate. 4-PS4-1. Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move. 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound |
| *Revise Initial Models, Partner Compare, Check for Evidence Cited, Compare to Initial Ideas, Apply to Related Sound Energy Phenomena or to Solve a Sound Problem* | | | |

*Note: Activities and subsequent discussions will take longer than one class period. Typically data collection and sharing observations happens during a 45 minute period, then the next 45 minute period is devoted to making sense of these observations in the context of the phenomenon and bigger science ideas. Additional lessons may be added or lessons modified based on students' developing understanding of science concepts.*




# EVIDENCE-BASED EXPLANATION: WHAT-HOW-WHY LEVELS OF EXPLANATION

By the end of this unit, students will be able to use evidence from activities to explain why the singer was able to shatter the glass using his voice. This rubric below shows what the science explanation looks like for each part of the story board. See the 'Summary Table Planner' pages for more details about the purpose of each activity. Students should aim for a 'why' level explanation though it is the most challenging to achieve because it requires wrestling with unobservable mechanisms. Students may have a blend of what-how-why depending on which parts they best understand. This is why working in pairs or groups to explain the whole phenomenon is helpful.

| ***Level*** | ***Sound Unit Example of what ideas students may address each level of explanation:*** |
|---|---|
| **WHAT**<br>*Student describes what is observable or measureable in a phenomenon.* | ☑ Singer flicks glass and listens.<br>☑ Singer sings at the same pitch the glass makes when he flicked it.<br>☑ Singer sings loudly near the glass.<br>☑ The glass wobbles, flexes back-and-forth.<br>☑ The singer takes a deep breath to sing because it takes time to make the glass flex to the point of breaking and he needs to exhale while singing for a long time.<br>☑ The glass eventually shatters. The singer stops singing.<br><br>All of these items are observable from the phenomenon video. |
| **HOW**<br>*Student tells a one-step "cause and effect" story. Describes but does not explain relationships between variables, trends over time, or qualitative observations. Predicts how systems will behave without using the unobservable.* | ☑ The singer flicks the glass to make the glass vibrate so he could hear it. We know vibrating things make sound because when we flicked the ruler it vibrated and we could hear it.<br><br>☑ The vibrating glass makes a sound unique to that particular glass so then he finds the right note or pitch to sing at. This is just like Grandpa John's video with the twin (identical) tuning forks where one objects 'picks up' a sound from another object if it's at the right pitch or note.<br><br>☑ The sound energy from the singer is transformed into energy of motion as the glass vibrates.<br><br>☑ The singer needs to be close to the glass because sound dissipates or gets weaker over a distance so he wants it to be near the glass so the glass 'feels' the most sound. We observed that father away we were from the sound source, the lower the decibels or loudness of the sound even though the sound itself didn't change. |

## WHY

Student can trace a full causal story for why a phenomenon unfolded the way it did. Student uses powerful science ideas that have unobservable/theoretical components that link to observable events. Explanation is about a system of events and processes that are linked.

☑ The singer flicks the glass to make the glass vibrate. The whole glass can vibrate from a flick in one place because the molecules in the glass are in a solid phase so there isn't much room between them. The flick jiggles the glass particles which bump into the air particles inside and surrounding the glass. Like dominoes the air particles bump into each other in all directions out from the glass. The singer can hear because these air particle dominoes hit his ear drum. Sound energy can travel through different matter like the solid glass or air because of how particles are arranged. We observed sound travels best through a table when we knocked on a table we had our ear on instead of hearing the knock through the air. The reading about matter and acting like particles served as a model for how sound travels by making particles bump into each other.

☑ The singer then uses his diaphragm muscle to exhale air from his lungs through his larynx in his wind pipe. Muscles also make the vocal cords vibrate which vibrates or bumps the air molecules as the singer exhales. In the reading about the inside of the body, we saw that there were parts of our body that work together as a system (diaphragm, lungs, wind pipe, vocal cords) that help us make different sounds. We also made a model of vocal cords using a cup and rubber bands to model how this system works to jiggle air. We could hear the sounds it made by vibrating the rubber band.

☑ These air molecules again act as dominoes bumping into other air molecules going out in all directions from the singer. This explains not only why the glass starts vibrating with the sound wave but also how other people in the room can hear his sound, too, it isn't only going to the glass. The reading about matter and acting like particles served as a model for how sound travels by making particles bump into each other. Also, when we talk in a room or when we were outside, we could hear the sound when we all stood in a circle around it.

☑ The singer had to be at the right pitch to really get the glass to wobble to the point of breaking. Each object has its own pitch that it will really vibrate at – this is because of what he object is made out of and its shape. The glass is thin and made of one material, glass. This is just like Grandpa John's video with the twin (identical) tuning forks where one objects 'picks up' a sound from another object if it's at the right frequency.

☑ The singer has to be loud to create enough pressure in bumping the air particles to affect the glass hard enough to make a solid wobble and flex. The loudness comes from how much force he uses in his diaphragm. We know that force affects volume because when we talked versus yelled on the field we felt different amount of pushing in our diaphragm to make the sound go louder or quieter. A louder sound will have more pressure because the initial air particles are jostled with more force from the vocal cords and diaphragm.

☑ Once these air dominoes bump into the glass particles then the glass begins to flex back-and-forth at particular places but only in the thinner places at the top of the glass. In the thick stem, it is likely that there are enough glass particles to disperse the force from the air particles bumping into them that they won't wobble enough to break – at least not with the force from a human voice. The singer also has to be close to the glass because sound dissipates or gets weaker over a distance. This is because sound travels though bumping particles in all directions. The more bumping over a distance the less force each particle has left to bump the subsequent particle.

# Next Generation Science Standards (NGSS)

For more information about the Next Generation Science Standards, please visit this website http://www.nextgenscience.org/ There is also a free app available for smart phones and tablets.

# *Overview of NGSS for Summer STEM Academy - Sound Energy Unit*

*This sound energy unit includes NGSS from 1st, 4th, 5th grades and Middle School. The following pages has more details about each standard, the science and engineering practices, disciplinary core ideas, and cross cutting concepts. This overview shows the relevant pieces taken from each grade level on one page. For more details read through additional pages.*

| Performance Expectations | Disciplinary Core Ideas | Crosscutting | Sci & Eng Prac. |
|---|---|---|---|
| **1-PS4-1.** Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.<br><br>**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.<br><br>**4-PS3-1**. Use evidence to construct an explanation relating the speed of an object to the energy of that object.<br><br>**4-PS3-2.** Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.<br><br>**5-PS1-1.** Develop a model to describe that matter is made of particles too small to be seen<br><br>**MS-PS1-4**. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.<br><br>**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<br><br>**MS-PS4-2**. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. | **PS4.A: Wave Properties**<br>○ Sound can make matter vibrate, and vibrating matter can make sound. (1-PS4-1)<br>○ Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach. (Note: This grade band endpoint was moved from K–2.) (4-PS4- 1)<br>○ Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). (4-PS4-1)<br>○ A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1)<br>○ A sound wave needs a medium through which it is transmitted. (MS-PS4-2)<br><br>**PS3.A: Definitions of Energy**<br>○ The faster a given object is moving, the more energy it possesses. (4- PS3-1)<br>○ Energy can be moved from place to place by moving objects or through sound, (4-PS3-2).<br><br>**PS3.B: Conservation of Energy and Energy Transfer**<br>○ Energy is present whenever there is sound. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. (4-PS3-2)<br><br>**PS1.A: Structure and Properties of Matter**<br>○ Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects. (5-PS1-1)<br>○ Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4)<br>○ In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (MS-PS1-4)<br>○ Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS-PS1-1) | **Cause and Effect**<br>• Simple tests can be designed to gather evidence to support or refute student ideas about causes.<br><br>**Patterns**<br>• Similarities and differences in patterns can be used to sort and classify natural phenomena.<br>• Graphs and charts can be used to identify patterns in data.<br><br>**Cause and Effect**<br>• Cause and effect relationships are routinely identified.<br>• Cause and effect relationships are routinely identified, tested, and used to explain change.<br><br>**Energy and Matter**<br>• Energy can be transferred in various ways and between objects<br>• The transfer of energy can be tracked as energy flows through a designed or natural system. | **Developing and Using Models**<br>• Develop a model using an analogy, example, or abstract representation to describe a scientific principle.<br>• Develop a model to predict and/or describe phenomena.<br>• Develop a model to describe unobservable mechanisms.<br><br>**Planning and Carrying Out Investigations**<br>• Make observations to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. |

# 1-PS4 Waves and their Applications in Technologies for Information Transfer

**1-PS4 Waves and their Applications in Technologies for Information Transfer**

Students who demonstrate understanding can:

**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.]

**1-PS4-2. Make observations to construct an evidence-based account that objects can be seen only when illuminated.** [Clarification Statement: Examples of observations could include those made in a completely dark room, a pinhole box, and a video of a cave explorer with a flashlight. Illumination could be from an external light source or by an object giving off its own light.]

**1-PS4-3. Plan and conduct an investigation to determine the effect of placing objects made with different materials in the path of a beam of light.** [Clarification Statement: Examples of materials could include those that are transparent (such as clear plastic), translucent (such as wax paper), opaque (such as cardboard), and reflective (such as a mirror).] [Assessment Boundary: Assessment does not include the speed of light.]

**1-PS4-4. Use tools and materials to design and build a device that uses light or sound to solve the problem of communicating over a distance.*** [Clarification Statement: Examples of devices could include a light source to send signals, paper cup and string "telephones," and a pattern of drum beats.] [Assessment Boundary: Assessment does not include technological details for how communication devices work.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

## Science and Engineering Practices

**Planning and Carrying Out Investigations**

Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.

- Plan and conduct investigations collaboratively to produce data to serve as the basis for evidence to answer a question. (1-PS4-1),(1-PS4-3)

**Constructing Explanations and Designing Solutions**

Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions.

- Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena. (1-PS4-2)
- Use tools and materials provided to design a device that solves a specific problem. (1-PS4-4)

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***Connections to Nature of Science***

**Scientific Investigations Use a Variety of Methods**

- Science investigations begin with a question. (1-PS4-1)
- Scientists use different ways to study the world. (1-PS4-1)

## Disciplinary Core Ideas

**PS4.A: Wave Properties**

- Sound can make matter vibrate, and vibrating matter can make sound. (1-PS4-1)

**PS4.B: Electromagnetic Radiation**

- Objects can be seen if light is available to illuminate them or if they give off their own light. (1-PS4-2)
- Some materials allow light to pass through them, others allow only some light through and others block all the light and create a dark shadow on any surface beyond them, where the light cannot reach. Mirrors can be used to redirect a light beam. (Boundary: The idea that light travels from place to place is developed through experiences with light sources, mirrors, and shadows, but no attempt is made to discuss the speed of light.) (1-PS4-3)

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

- People also use a variety of devices to communicate (send and receive information) over long distances. (1-PS4-4)

## Crosscutting Concepts

**Cause and Effect**

- Simple tests can be designed to gather evidence to support or refute student ideas about causes. (1-PS4-1),(1-PS4-2),(1-PS4-3)

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***Connections to Engineering, Technology, and Applications of Science***

**Influence of Engineering, Technology, and Science, on Society and the Natural World**

- People depend on various technologies in their lives; human life would be very different without technology. (1-PS4-4)

*Connections to other DCIs in first grade:* N/A

*Articulation of DCIs across grade-levels:* **K.ETS1.A** (1-PS4-4); **2.PS1.A** (1-PS4-3); **2.ETS1.B** (1-PS4-4); **4.PS4.C** (1-PS4-4); **4.PS4.B** (1-PS4-2); **4.ETS1.A** (1-PS4-4)

*Common Core State Standards Connections:*

*ELA/Literacy –*

**W.1.2** Write informative/explanatory texts in which they name a topic, supply some facts about the topic, and provide some sense of closure. *(1-PS4-2)*

**W.1.7** Participate in shared research and writing projects (e.g., explore a number of "how-to" books on a given topic and use them to write a sequence of instructions). (1-PS4-1),(1-PS4-2),(1-PS4-3),(1-PS4-4)

**W.1.8** With guidance and support from adults, recall information from experiences or gather information from provided sources to answer a question. (1-PS4-1),(1-PS4-2),(1-PS4-3)

**SL.1.1** Participate in collaborative conversations with diverse partners about grade 1 topics and texts with peers and adults in small and larger groups. *(1-PS4-1),(1-PS4-2),(1-PS4-3)*

*Mathematics –*

**MP.5** Use appropriate tools strategically. *(1-PS4-4)*

**1.MD.A.1** Order three objects by length; compare the lengths of two objects indirectly by using a third object. *(1-PS4-4)*

**1.MD.A.2** Express the length of an object as a whole number of length units, by layering multiple copies of a shorter object (the length unit) end to end; understand that the length measurement of an object is the number of same-size length units that span it with no gaps or overlaps. *(1-PS4-4)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

# 4-PS4 Waves and their Applications in Technologies for Information Transfer

**4-PS4 Waves and their Applications in Technologies for Information Transfer**

Students who demonstrate understanding can:

**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.] [Assessment Boundary: Assessment does not include interference effects, electromagnetic waves, non-periodic waves, or quantitative models of amplitude and wavelength.]

**4-PS4-2. Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.** [Assessment Boundary: Assessment does not include knowledge of specific colors reflected and seen, the cellular mechanisms of vision, or how the retina works.]

**4-PS4-3. Generate and compare multiple solutions that use patterns to transfer information.*** [Clarification Statement: Examples of solutions could include drums sending coded information through sound waves, using a grid of 1's and 0's representing black and white to send information about a picture, and using Morse code to send text.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

## Science and Engineering Practices

**Developing and Using Models**

Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.

- Develop a model using an analogy, example, or abstract representation to describe a scientific principle. (4-PS4-1)
- Develop a model to describe phenomena. (4-PS4-2)

**Constructing Explanations and Designing Solutions**

Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.

- Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. (4-PS4-3)

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***Connections to Nature of Science***

**Scientific Knowledge is Based on Empirical Evidence**

- Science findings are based on recognizing patterns. (4-PS4-1)

## Disciplinary Core Ideas

**PS4.A: Wave Properties**

- Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach. *(Note: This grade band endpoint was moved from K–2.)* (4-PS4-1)
- Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). (4-PS4-1)

**PS4.B: Electromagnetic Radiation**

- An object can be seen when light reflected from its surface enters the eyes. (4-PS4-2)

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

- Digitized information can be transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa. (4-PS4-3)

**ETS1.C: Optimizing The Design Solution**

- Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. *(secondary to 4-PS4-3)*

## Crosscutting Concepts

**Patterns**

- Similarities and differences in patterns can be used to sort and classify natural phenomena. (4-PS4-1)
- Similarities and differences in patterns can be used to sort and classify designed products. (4-PS4-3)

**Cause and Effect**

- Cause and effect relationships are routinely identified. (4-PS4-2)

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***Connections to Engineering, Technology, and Applications of Science***

**Interdependence of Science, Engineering, and Technology**

- Knowledge of relevant scientific concepts and research findings is important in engineering. (4-PS4-3)

*Connections to other DCIs in fourth grade:* **4.PS3.A** (4-PS4-1); **4.PS3.B** (4-PS4-1); **4.ETS1.A** (4-PS4-3)

*Articulation of DCIs across grade-levels:* **K.ETS1.A** (4-PS4-3); **1.PS4.B** (4-PS4-2); **1.PS4.C** (4-PS4-3); **2.ETS1.B** (4-PS4-3); **2.ETS1.C** (4-PS4-3); **3.PS2.A** (4-PS4-3); **MS.PS4.A** (4-PS4-1); **MS.PS4.B** (4-PS4-2); **MS.PS4.C** (4-PS4-3); **MS.LS1.D** (4-PS4-2); **MS.ETS1.B** (4-PS4-3)

*Common Core State Standards Connections:*

*ELA/Literacy –*

**RI.4.1** Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text. *(4-PS4-3)*

**RI.4.9** Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably. (4-PS4-3)

**SL.4.5** Add audio recordings and visual displays to presentations when appropriate to enhance the development of main ideas or themes. *(4-PS4-1),(4-PS4-2)*

*Mathematics –*

**MP.4** Model with mathematics. *(4-PS4-1),(4-PS4-2)*

**4.G.A.1** Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures. *(4-PS4-1),(4-PS4-2)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

# 4-PS3 Energy

## 4-PS3 Energy

Students who demonstrate understanding can:

**4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.** [Assessment Boundary: Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.]

**4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.** [Assessment Boundary: Assessment does not include quantitative measurements of energy.]

**4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide.** [Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.] [Assessment Boundary: Assessment does not include quantitative measurements of energy.]

**4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.*** [Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and, a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.] [Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

### Science and Engineering Practices

**Asking Questions and Defining Problems**
Asking questions and defining problems in grades 3–5 builds on grades K–2 experiences and progresses to specifying qualitative relationships.
- Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. (4-PS3-3)

**Planning and Carrying Out Investigations**
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.
- Make observations to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (4-PS3-2)

**Constructing Explanations and Designing Solutions**
Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.
- Use evidence (e.g., measurements, observations, patterns) to construct an explanation. (4-PS3-1)
- Apply scientific ideas to solve design problems. (4-PS3-4)

### Disciplinary Core Ideas

**PS3.A: Definitions of Energy**
- The faster a given object is moving, the more energy it possesses. (4-PS3-1)
- Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (4-PS3-2),(4-PS3-3)

**PS3.B: Conservation of Energy and Energy Transfer**
- Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. (4-PS3-2),(4-PS3-3)
- Light also transfers energy from place to place. (4-PS3-2)
- Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. (4-PS3-2),(4-PS3-4)

**PS3.C: Relationship Between Energy and Forces**
- When objects collide, the contact forces transfer energy so as to change the objects' motions. (4-PS3-3)

**PS3.D: Energy in Chemical Processes and Everyday Life**
- The expression "produce energy" typically refers to the conversion of stored energy into a desired form for practical use. (4-PS3-4)

**ETS1.A: Defining Engineering Problems**
- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. *(secondary to 4-PS3-4)*

### Crosscutting Concepts

**Energy and Matter**
- Energy can be transferred in various ways and between objects. (4-PS3-1),(4-PS3-2),(4-PS3-3),(4-PS3-4)

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***Connections to Engineering, Technology, and Applications of Science***

**Influence of Science, Engineering and Technology on Society and the Natural World**
- Engineers improve existing technologies or develop new ones. (4-PS3-4)

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***Connections to Nature of Science***

**Science is a Human Endeavor**
- Most scientists and engineers work in teams. (4-PS3-4)
- Science affects everyday life. (4-PS3-4)

*Connections to other DCIs in fourth grade:* N/A

*Articulation of DCIs across grade-levels:* **K.PS2.B** (4-PS3-3); **K.ETS1.A** (4-PS3-4); **2.ETS1.B** (4-PS3-4); **3.PS2.A** (4-PS3-3); **5.PS3.D** (4-PS3-4); **5.LS1.C** (4-PS3-4); **MS.PS2.A** (4-PS3-3); **MS.PS2.B** (4-PS3-2); **MS.PS3.A** (4-PS3-1),(4-PS3-2),(4-PS3-3),(4-PS3-4); **MS.PS3.B** (4-PS3-2),(4-PS3-3),(4-PS3-4); **MS.PS3.C** (4-PS3-3); **MS.PS4.B** (4-PS3-2); **MS.ETS1.B** (4-PS3-4); **MS.ETS1.C** (4-PS3-4)

*Common Core State Standards Connections:*

*ELA/Literacy –*

| | |
|---|---|
| **RI.4.1** | Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text. (4-PS3-1) |
| **RI.4.3** | Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text. (4-PS3-1) |
| **RI.4.9** | Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably. *(4-PS3-1)* |
| **W.4.2** | Write informative/explanatory texts to examine a topic and convey ideas and information clearly. (4-PS3-1) |
| **W.4.7** | Conduct short research projects that build knowledge through investigation of different aspects of a topic. (4-PS3-2),(4-PS3-3),(4-PS3-4) |
| **W.4.8** | Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information, and provide a list of sources. (4-PS3-1),(4-PS3-2),(4-PS3-3),(4-PS3-4) |
| **W.4.9** | Draw evidence from literary or informational texts to support analysis, reflection, and research. (4-PS3-1) |

*Mathematics –*

| | |
|---|---|
| **4.OA.A.3** | Solve multistep word problems posed with whole numbers and having whole-number answers using the four operations, including problems in which remainders must be interpreted. Represent these problems using equations with a letter standing for the unknown quantity. Assess the reasonableness of answers using mental computation and estimation strategies including rounding. *(4-PS3-4)* |

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

# 5-PS1 Matter and Its Interactions

## 5-PS1 Matter and Its Interactions

Students who demonstrate understanding can:

**5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen.** [Clarification Statement: Examples of evidence could include adding air to expand a basketball, compressing air in a syringe, dissolving sugar in water, and evaporating salt water.] [Assessment Boundary: Assessment does not include the atomic-scale mechanism of evaporation and condensation or defining the unseen particles.]

**5-PS1-2. Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.** [Clarification Statement: Examples of reactions or changes could include phase changes, dissolving, and mixing that form new substances.] [Assessment Boundary: Assessment does not include distinguishing mass and weight.]

**5-PS1-3. Make observations and measurements to identify materials based on their properties.** [Clarification Statement: Examples of materials to be identified could include baking soda and other powders, metals, minerals, and liquids. Examples of properties could include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility; density is not intended as an identifiable property.] [Assessment Boundary: Assessment does not include density or distinguishing mass and weight.]

**5-PS1-4. Conduct an investigation to determine whether the mixing of two or more substances results in new substances.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

### Science and Engineering Practices

**Developing and Using Models**

Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.

- Develop a model to describe phenomena. (5-PS1-1)

**Planning and Carrying Out Investigations**

Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (5-PS1-4)
- Make observations and measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. (5-PS1-3)

**Using Mathematics and Computational Thinking**

Mathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions.

- Measure and graph quantities such as weight to address scientific and engineering questions and problems. (5-PS1-2)

### Disciplinary Core Ideas

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

- Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects. (5-PS1-1)
- The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. (5-PS1-2)
- Measurements of a variety of properties can be used to identify materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.) (5-PS1-3)

**PS1.B: Chemical Reactions**

- When two or more different substances are mixed, a new substance with different properties may be formed. (5-PS1-4)
- No matter what reaction or change in properties occurs, the total weight of the substances does not change. (Boundary: Mass and weight are not distinguished at this grade level.) (5-PS1-2)

### Crosscutting Concepts

**Cause and Effect**

- Cause and effect relationships are routinely identified, tested, and used to explain change. (5-PS1-4)

**Scale, Proportion, and Quantity**

- Natural objects exist from the very small to the immensely large. (5-PS1-1)
- Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume. (5-PS1-2),(5-PS1-3)

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***Connections to Nature of Science***

**Scientific Knowledge Assumes an Order and Consistency in Natural Systems**

- Science assumes consistent patterns in natural systems. (5-PS1-2)

*Connections to other DCIs in fifth grade:* N/A

*Articulation of DCIs across grade-levels:* **2.PS1.A** (5-PS1-1),(5-PS1-2),(5-PS1-3); **2.PS1.B** (5-PS1-2),(5-PS1-4); **MS.PS1.A** (5-PS1-1),(5-PS1-2),(5-PS1-3),(5-PS1-4); **MS.PS1.B** (5-PS1-2),(5-PS1-4)

*Common Core State Standards Connections:*

*ELA/Literacy –*

**RI.5.7** Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. *(5-PS1-1)*

**W.5.7** Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. *(5-PS1-2),(5-PS1-3),*(5-PS1-4)

**W.5.8** Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources. *(5-PS1-2),(5-PS1-3),*(5-PS1-4)

**W.5.9** Draw evidence from literary or informational texts to support analysis, reflection, and research. *(5-PS1-2),(5-PS1-3),(5-PS1-4)*

*Mathematics –*

**MP.2** Reason abstractly and quantitatively. *(5-PS1-1),*(5-PS1-2),(5-PS1-3)

**MP.4** Model with mathematics. *(5-PS1-1),*(5-PS1-2),(5-PS1-3)

**MP.5** Use appropriate tools strategically. (5-PS1-2),(5-PS1-3)

**5.NBT.A.1** Explain patterns in the number of zeros of the product when multiplying a number by powers of 10, and explain patterns in the placement of the decimal point when a decimal is multiplied or divided by a power of 10. Use whole-number exponents to denote powers of 10. (*5-PS1-1)*

**5.NF.B.7** Apply and extend previous understandings of division to divide unit fractions by whole numbers and whole numbers by unit fractions. (*5-PS1-1)*

**5.MD.A.1** Convert among different-sized standard measurement units within a given measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real-world problems. *(5-PS1-2)*

**5.MD.C.3** Recognize volume as an attribute of solid figures and understand concepts of volume measurement. *(5-PS1-1)*

**5.MD.C.4** Measure volumes by counting unit cubes, using cubic cm, cubic in, cubic ft, and improvised units. *(5-PS1-1)*

# MS-PS1 Matter and Its Interactions

## MS-PS1 Matter and Its Interactions

Students who demonstrate understanding can:

**MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.** [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.] [Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete depiction of all individual atoms in a complex molecule or extended structure.]

**MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.** [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.] [Assessment Boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.]

**MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.** [Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [Assessment Boundary: Assessment is limited to qualitative information.]

**MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.** [Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawings and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.]

**MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.** [Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms, that represent atoms.] [Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.]

**MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*** [Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride.] [Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

### Science and Engineering Practices

**Developing and Using Models**
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems.
- Develop a model to predict and/or describe phenomena. (MS-PS1-1),(MS-PS1-4)
- Develop a model to describe unobservable mechanisms. (MS-PS1-5)

**Analyzing and Interpreting Data**
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.
- Analyze and interpret data to determine similarities and differences in findings. (MS-PS1-2)

**Constructing Explanations and Designing Solutions**
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.
- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. (MS-PS1-6)

**Obtaining, Evaluating, and Communicating Information**
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods.
- 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-PS1-3)

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***Connections to Nature of Science***

**Scientific Knowledge is Based on Empirical Evidence**
- Science knowledge is based upon logical and conceptual connections between evidence and

### Disciplinary Core Ideas

**PS1.A: Structure and Properties of Matter**
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-2),(MS-PS1-3)
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4)
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (MS-PS1-4)
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS-PS1-1)
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4)

**PS1.B: Chemical Reactions**
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2),(MS-PS1-3),(MS-PS1-5)
- The total number of each type of atom is conserved, and thus the mass does not change. (MS-PS1-5)
- Some chemical reactions release energy, others store energy. (MS-PS1-6)

**PS3.A: Definitions of Energy**
- The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. *(secondary to MS-PS1-4)*
- The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends

### Crosscutting Concepts

**Patterns**
- Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-2)

**Cause and Effect**
- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

**Scale, Proportion, and Quantity**
- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

**Energy and Matter**
- Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-5)
- The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS1-6)

**Structure and Function**
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS1-3)

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***Connections to Engineering, Technology, and Applications of Science***

**Interdependence of Science, Engineering, and Technology**
- Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (MS-PS1-3)

**Influence of Science, Engineering and Technology on Society and the Natural World**
- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

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|---|---|---|
| explanations. (MS-PS1-2)<br>**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**<br>▪ Laws are regularities or mathematical descriptions of natural phenomena. (MS-PS1-5) | jointly on the temperature, the total number of atoms in the system, and the state of the material. *(secondary to MS-PS1-4)*<br>**ETS1.B: Developing Possible Solutions**<br>▪ A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. *(secondary to MS-PS1-6)*<br>**ETS1.C: Optimizing the Design Solution**<br>▪ Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design. *(secondary to MS-PS1-6)*<br>▪ The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. *(secondary to MS-PS1-6)* | resources, and economic conditions. Thus technology use varies from region to region and over time. (MS-PS1-3) |

*Connections to other DCIs in this grade-band*: **MS.PS3.D** (MS-PS1-2),(MS-PS1-6); **MS.LS1.C** (MS-PS1-2),(MS-PS1-5); **MS.LS2.A** (MS-PS1-3); **MS.LS2.B** (MS-PS1-5); **MS.LS4.D** (MS-PS1-3); **MS.ESS2.A** (MS-PS1-2),(MS-PS1-5); **MS.ESS2.C** (MS-PS1-1),(MS-PS1-4); **MS.ESS3.A** (MS-PS1-3); **MS.ESS3.C** (MS-PS1-3)

*Articulation across grade-bands:* **5.PS1.A** (MS-PS1-1); **5.PS1.B** (MS-PS1-2),(MS-PS1-5); **HS.PS1.A** (MS-PS1-1),(MS-PS1-3),(MS-PS1-4),(MS-PS1-6); **HS.PS1.B** (MS-PS1-2),(MS-PS1-4),(MS-PS1-5),(MS-PS1-6); **HS.PS3.A** (MS-PS1-4),(MS-PS1-6); **HS.PS3.B** (MS-PS1-6); **HS.PS3.D** (MS-PS1-6); **HS.LS2.A** (MS-PS1-3); **HS.LS4.D** (MS-PS1-3); **HS.ESS1.A** (MS-PS1-1); **HS.ESS3.A** (MS-PS1-3)

*Common Core State Standards Connections:*

*ELA/Literacy –*

| | |
|---|---|
| **RST.6-8.1** | Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions *(MS-PS1-2)*,(MS-PS1-3) |
| **RST.6-8.3** | Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. (MS-PS1-6) |
| **RST.6-8.7** | Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). *(MS-PS1-1)*,(MS-PS1-2),*(MS-PS1-4),(MS-PS1-5)* |
| **WHST.6-8.7** | Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-PS1-6) |
| **WHST.6-8.8** | Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. (MS-PS1-3) |

*Mathematics –*

| | |
|---|---|
| **MP.2** | Reason abstractly and quantitatively. (MS-PS1-1),(MS-PS1-2),(MS-PS1-5) |
| **MP.4** | Model with mathematics. *(MS-PS1-1)*,(MS-PS1-5) |
| **6.RP.A.3** | Use ratio and rate reasoning to solve real-world and mathematical problems. *(MS-PS1-1),(MS-PS1-2)*,(MS-PS1-5) |
| **6.NS.C.5** | Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, positive/negative electric charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (MS-PS1-4) |
| **8.EE.A.3** | Use numbers expressed in the form of a single digit times an integer power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other. *(MS-PS1-1)* |
| **6.SP.B.4** | Display numerical data in plots on a number line, including dot plots, histograms, and box plots. *(MS-PS1-2)* |
| **6.SP.B.5** | Summarize numerical data sets in relation to their context (MS-PS1-2) |

# MS-PS4 Waves and Their Applications in Technologies for Information Transfer

**MS-PS4 Waves and Their Applications in Technologies for Information Transfer**

Students who demonstrate understanding can:

**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.] [Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.]

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

**MS-PS4-3. Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.** [Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [Assessment Boundary: Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

## Science and Engineering Practices

**Developing and Using Models**
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.
- Develop and use a model to describe phenomena. (MS-PS4-2)

**Using Mathematics and Computational Thinking**
Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.
- Use mathematical representations to describe and/or support scientific conclusions and design solutions. (MS-PS4-1)

**Obtaining, Evaluating, and Communicating Information**
Obtaining, evaluating, and communicating information in 6-8 builds on K-5 and progresses to evaluating the merit and validity of ideas and methods.
- 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)

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***Connections to Nature of Science***

**Scientific Knowledge is Based on Empirical Evidence**
- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS4-1)

## Disciplinary Core Ideas

**PS4.A: Wave Properties**
- 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)

**PS4.B: Electromagnetic Radiation**
- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. (MS-PS4-2)
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. (MS-PS4-2)
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves. (MS-PS4-2)

**PS4.C: Information Technologies and Instrumentation**
- Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (MS-PS4-3)

## Crosscutting Concepts

**Patterns**
- Graphs and charts can be used to identify patterns in data. (MS-PS4-1)

**Structure and Function**
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS4-2)
- Structures can be designed to serve particular functions. (MS-PS4-3)

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***Connections to Engineering, Technology, and Applications of Science***

**Influence of Science, Engineering, and Technology on Society and the Natural World**
- Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. (MS-PS4-3)

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***Connections to Nature of Science***

**Science is a Human Endeavor**
- Advances in technology influence the progress of science and science has influenced advances in technology. (MS-PS4-3)

*Connections to other DCIs in this grade-band:* **MS.LS1.D** (MS-PS4-2)

*Articulation across grade-bands:* **4.PS3.A** (MS-PS4-1); **4.PS3.B** (MS-PS4-1); **4.PS4.A** (MS-PS4-1); **4.PS4.B** (MS-PS4-2); **4.PS4.C** (MS-PS4-3); **HS.PS4.A** (MS-PS4-1),(MS-PS4-2),(MS-PS4-3); **HS.PS4.B** (MS-PS4-1),(MS-PS4-2); **HS.PS4.C** (MS-PS4-3); **HS.ESS1.A** (MS-PS4-2); **HS.ESS2.A** (MS-PS4-2); **HS.ESS2.C** (MS-PS4-2); **HS.ESS2.D** (MS-PS4-2)

*Common Core State Standards Connections:*

*ELA/Literacy –*

| | |
|---|---|
| **RST.6-8.1** | Cite specific textual evidence to support analysis of science and technical texts. (MS-PS4-3) |
| **RST.6-8.2** | Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. *(MS-PS4-3)* |
| **RST.6-8.9** | Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-PS4-3) |
| **WHST.6-8.9** | Draw evidence from informational texts to support analysis, reflection, and research. (MS-PS4-3) |
| **SL.8.5** | Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. *(MS-PS4-1),(MS-PS4-2)* |

*Mathematics –*

| | |
|---|---|
| **MP.2** | Reason abstractly and quantitatively. (MS-PS4-1) |
| **MP.4** | Model with mathematics. (MS-PS4-1) |
| **6.RP.A.1** | Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-PS4-1) |
| **6.RP.A.3** | Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-PS4-1) |
| **7.RP.A.2** | Recognize and represent proportional relationships between quantities. (MS-PS4-1) |
| **8.F.A.3** | Interpret the equation $y = mx + b$ as defining a linear function, whose graph is a straight line; give examples of functions that are not linear. *(MS-PS4-1)* |

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.