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. (Use the following YouTube videos)

- "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

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

Key Science Ideas:

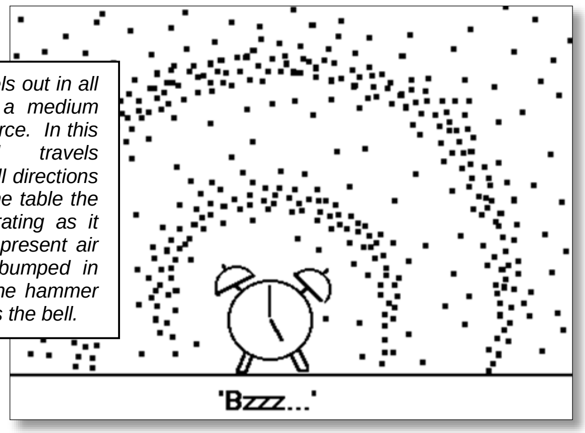
1. **Energy can be transferred through matter.**
2. **Energy can be transformed or changed from one form to another.**
3. **There is a relationship between energy and forces: Sound can make matter vibrate and vibrating objects "make"* sound.**

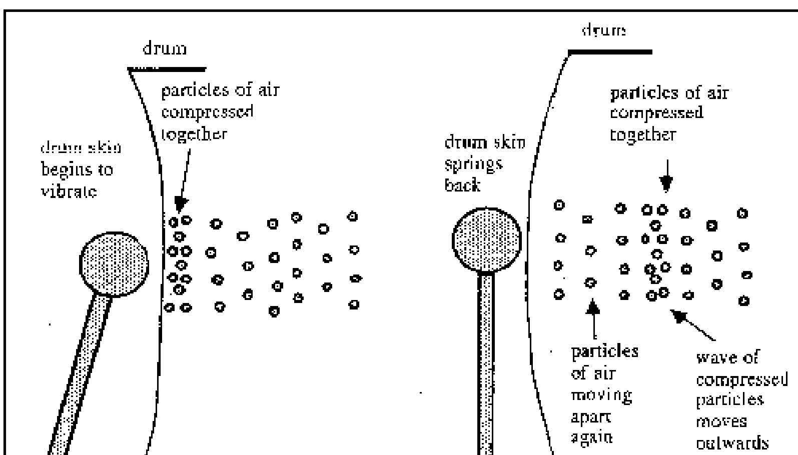
** Sound is a form of energy. Energy is never produced, created, made or conversely destroyed. Energy is only transferred and transformed. Students may use the terms "make" instead of "transform". Vibrating objects do "produce" sound that we can hear but really the vibrating object is transferring mechanical 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.

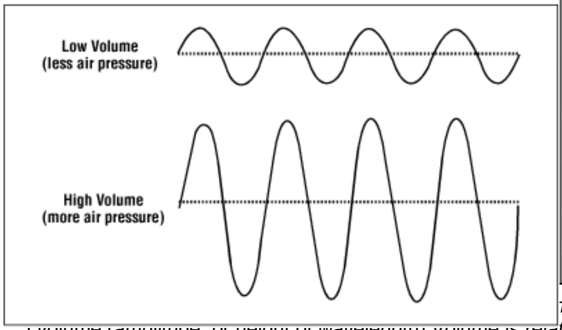
Sound energy travels out in all directions through a medium from the sound source. In this example, sound travels through the air in all directions and also through the table the alarm clock is vibrating as it rings. The dots represent air particles that get bumped in waves each time the hammer in the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

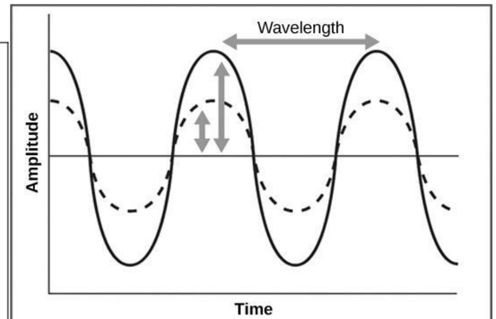




How drums transform mechanical energy (hitting with the mallet) into sound energy by jiggling surrounding air molecules. As the drum flexes back-and-forth as it vibrates, it pushes air molecules and then does not, resulting in a pattern of compressions.

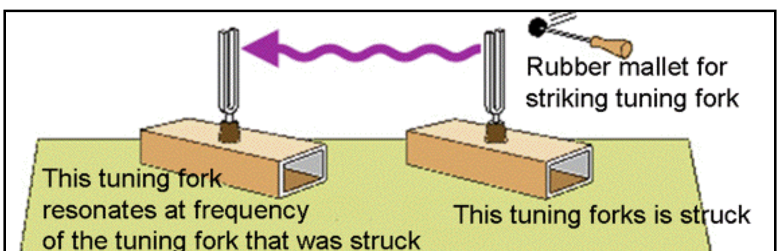
Sound has specific properties, like pitch and volume. Higher pitch sounds have higher frequency. This means that the vibration goes back-and-forth faster and therefore is pushing surrounding molecules in pulses at a high rate over time. If the sound also has high volume, then the vibration pushes the 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.





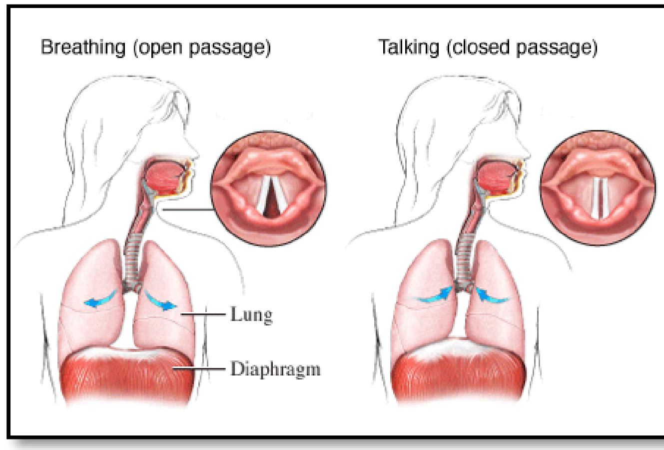
measured from crest to crest is equal) but different volume (amplitude, or height of wavelength). Volume is related to force. The top sound has less pressure when traveling through air than the sound on the bottom. RIGHT: Diagram labeling the amplitude (height of the wave) which is related to volume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

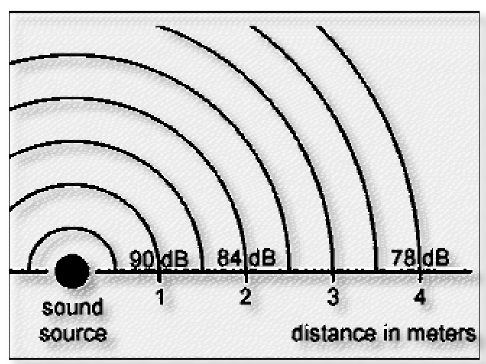


Two identical tuning forks can exemplify the idea of resonant frequencies affecting objects over a distance. Each tuning fork is identical. When one is struck, vibrations of the tuning fork transform mechanical energy to sound energy. This sound energy bumps the surrounding air molecules in all directions. 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.



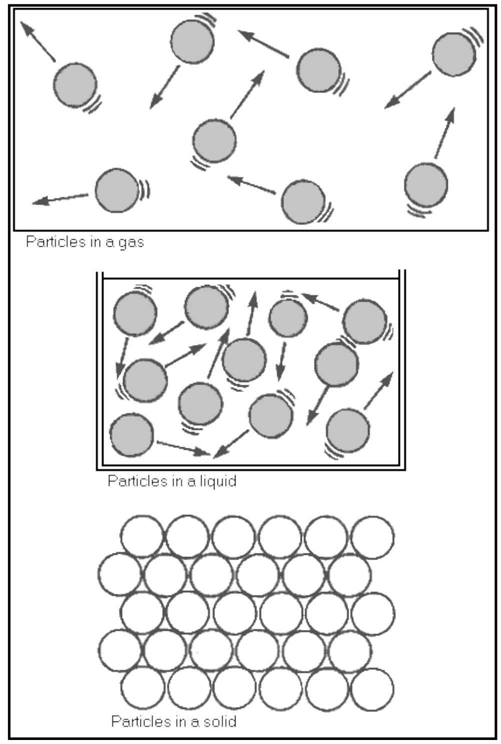
The singer must be loud and close to the glass. Sound energy dissipates over a distance. A loud volume will jiggle the air molecules with more force (or air pressure) than a soft volume. If that volume is close to the glass, then the glass "feels" the pressure directly as opposed to if the singer stood 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.



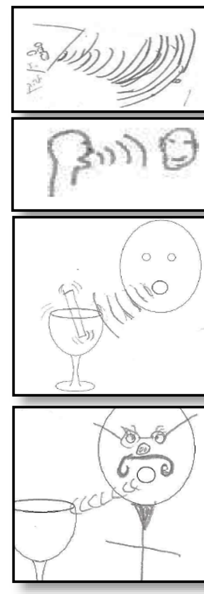
Sound is a form of energy. Sound energy is all about vibrating air, water, wood, whatever material the vibration/mechanical motion is near. Sound energy travels most efficiently through solids and least quickly through gases because of how the particles are arranged in each material. This connects to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

[This page intentionally left blank.]

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

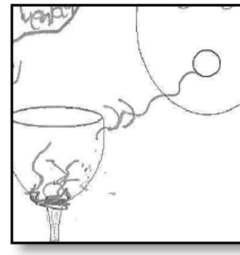
Sound threads are typically used to show how sound travels in a particular direction and the number of threads may represent the intensity or volume of the sound. The top drawings show student initial models about how the singer's voice traveled to the glass. The student's drawing (bottom) of "sound 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?

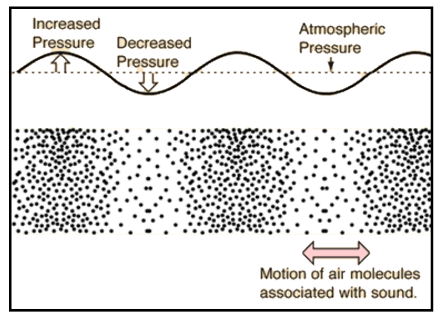
- Represent volume (and the related idea of force) by using multiple threads for louder sounds and fewer numbers of threads for quieter sounds (and less force)
- Representing pitch is possible (change thread thickness so that a high pitch could be thinner and a low pitch could be thicker); however, this 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.

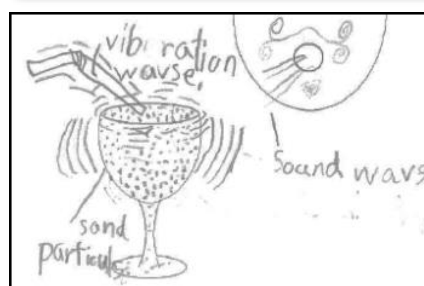


PRODUCTIVE DISCUSSION ABOUT MODEL CONVENTIONS



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.

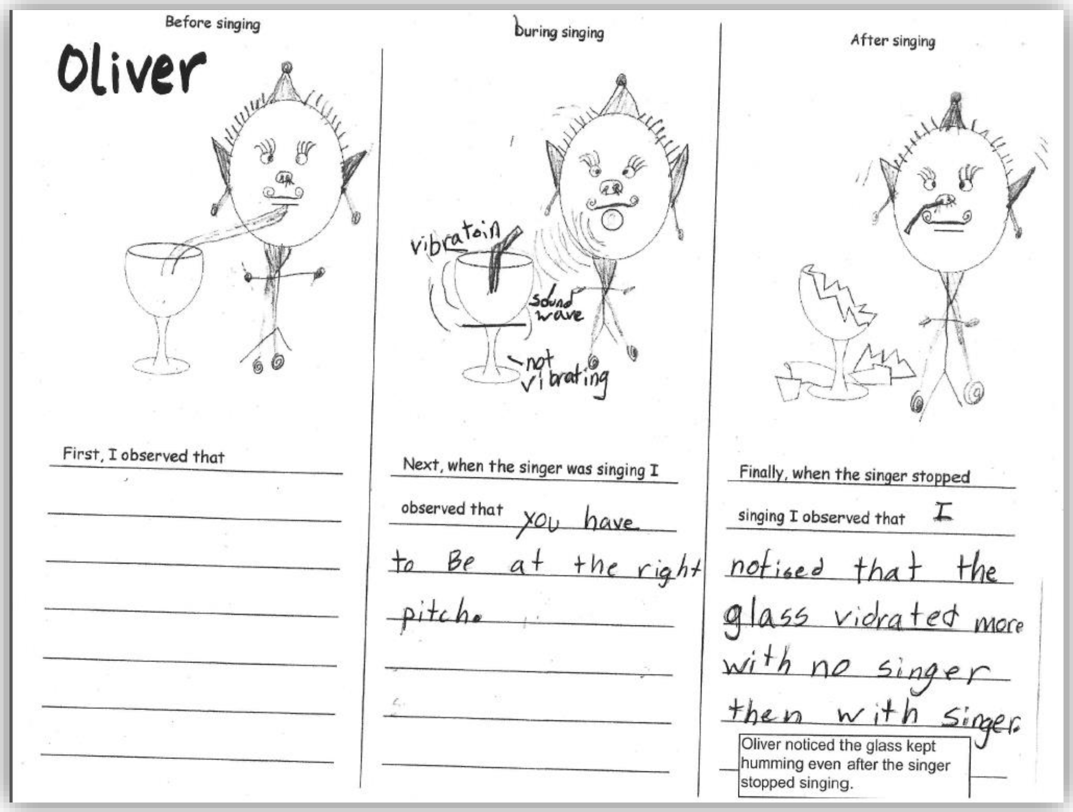
Between contexts students may switch between representations (without even knowing they do it) which can also be a place for productive discussion.
An additional modelling option may be introduced to help students think about how sound travels through different states of matter by attending to particle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

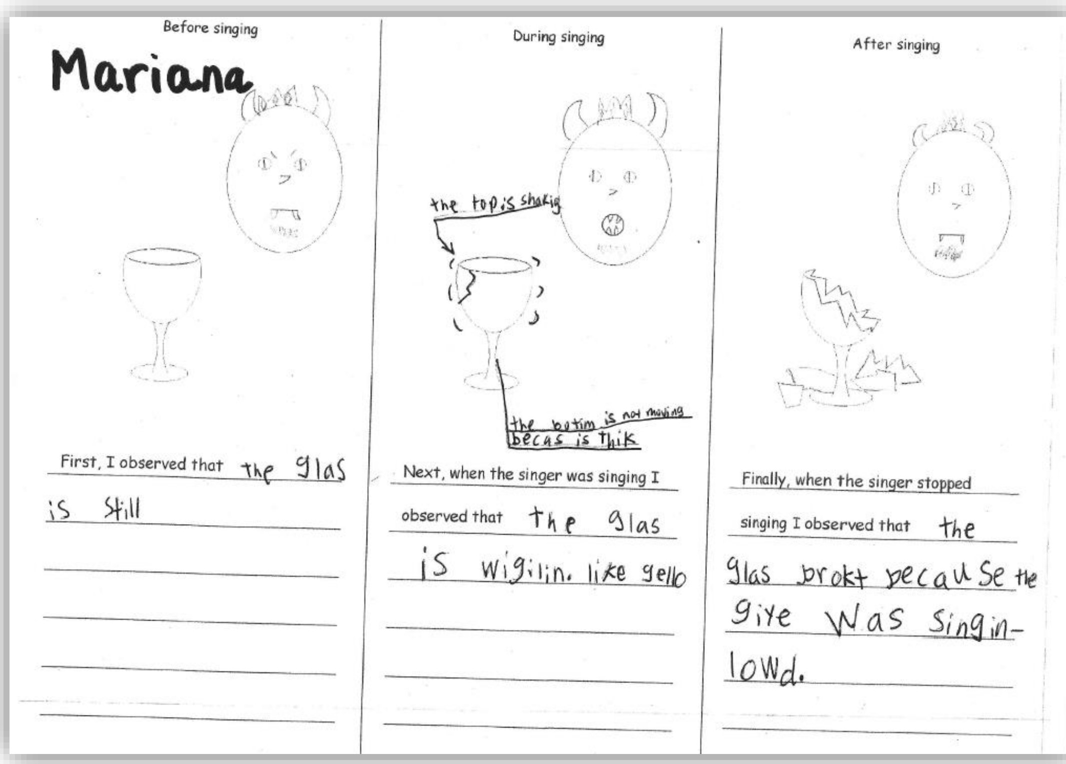


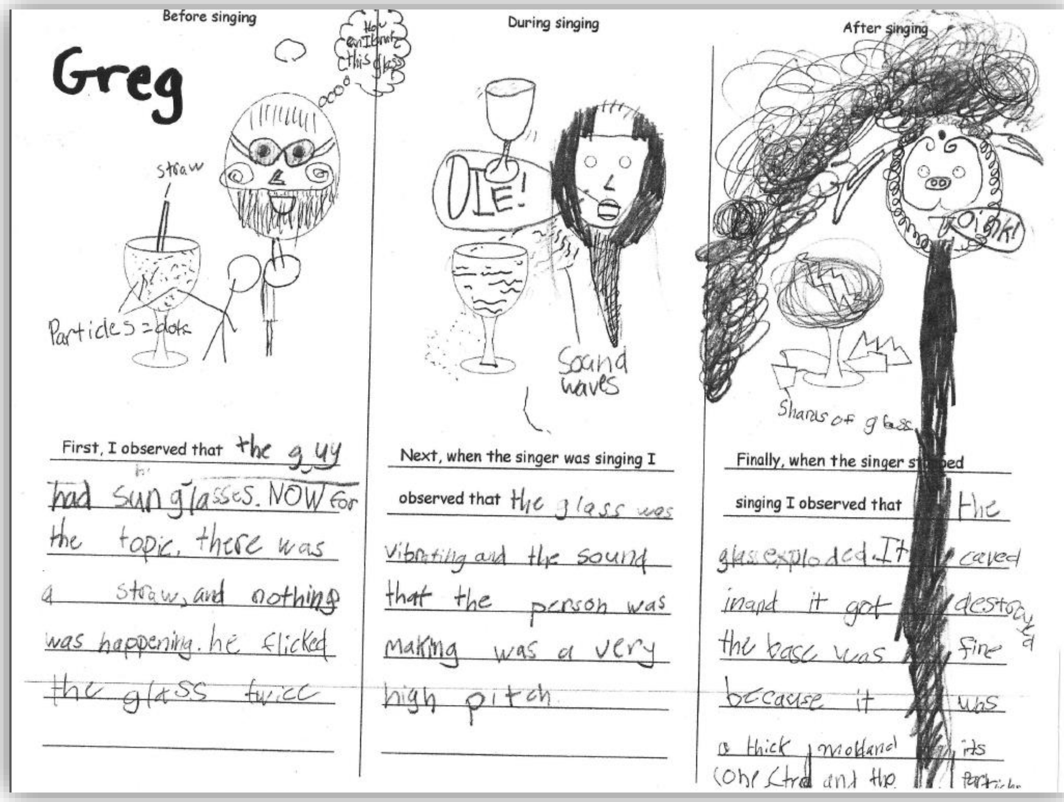
Students may attend to particles on their own prior to instruction using their prior knowledge that matter is made of particles and solids, liquids, and gases have different particle arrangements. But what will be new is helping students represent how sound energy can transfer through matter and into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



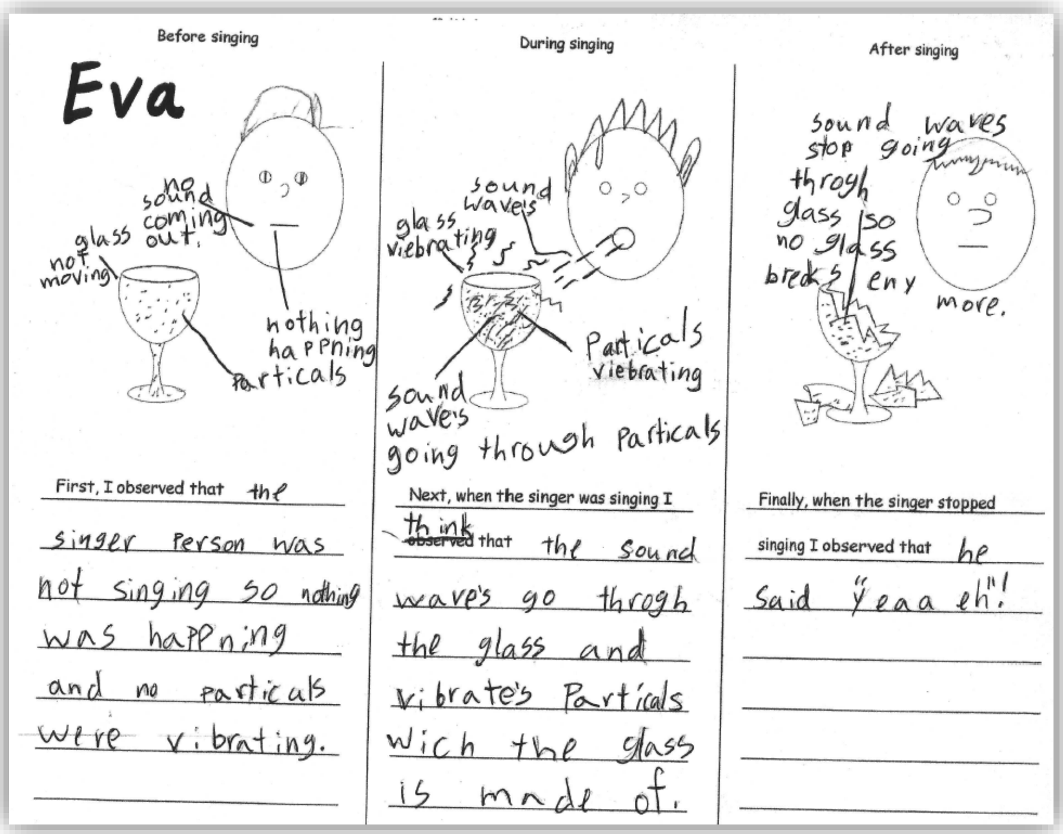




First, I observed that the guy had sunglasses. NOW for the topic, there was a straw, and nothing was happening. he flicked ~~the glass twice~~

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 a thick molded its constructed and the particles

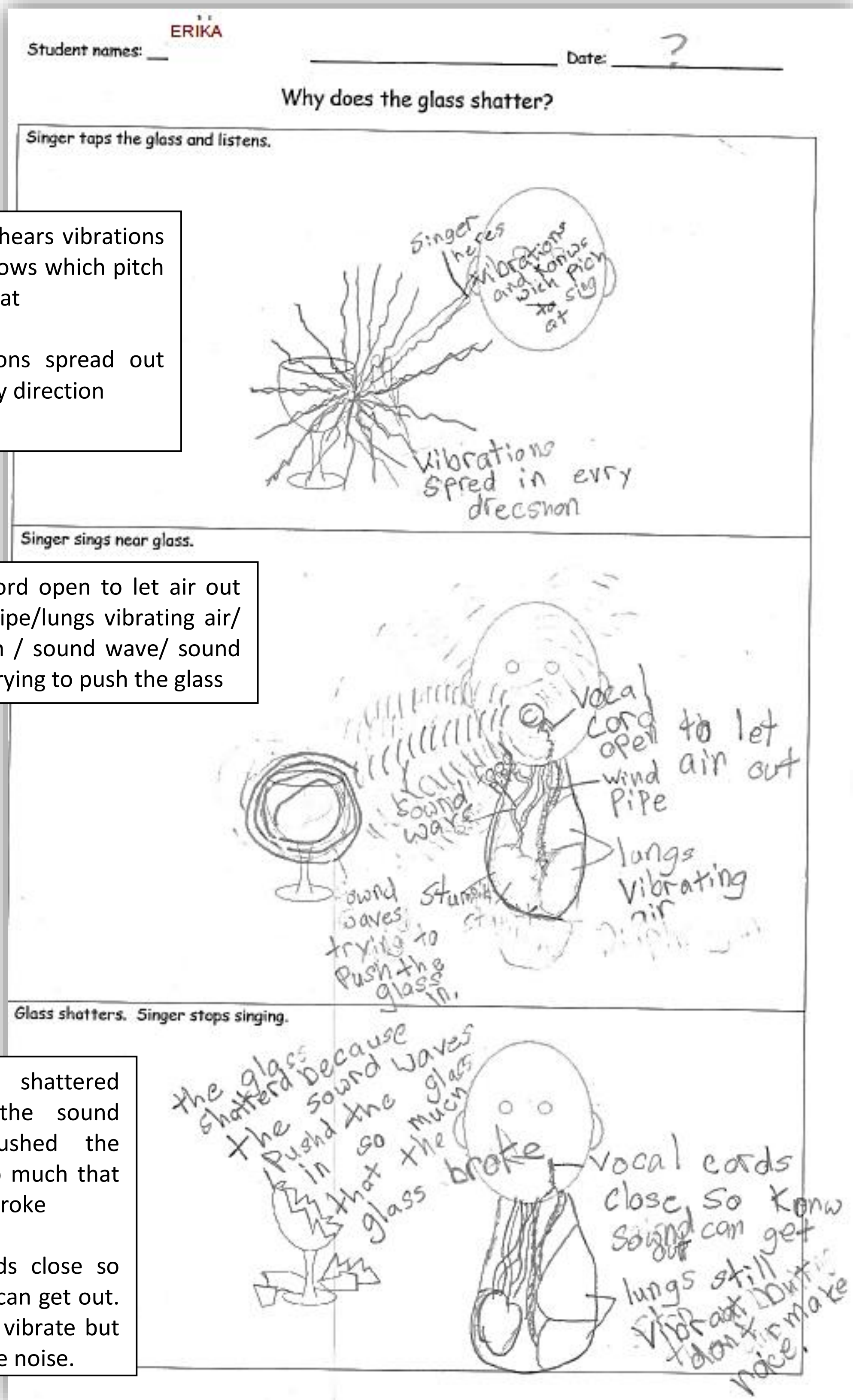


First, I observed that the singer person was not singing so nothing was happening and no particals were vibrating.

Next, when the singer was singing I ~~observed~~ think 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.

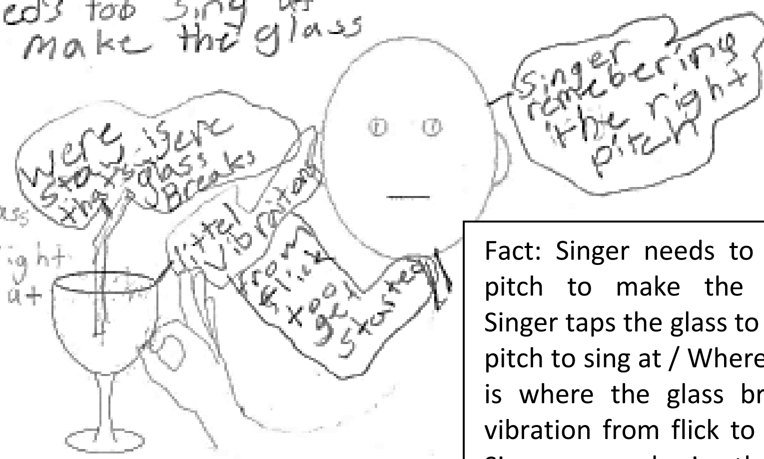
Student names: OLIVER Date: 5/29/12

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

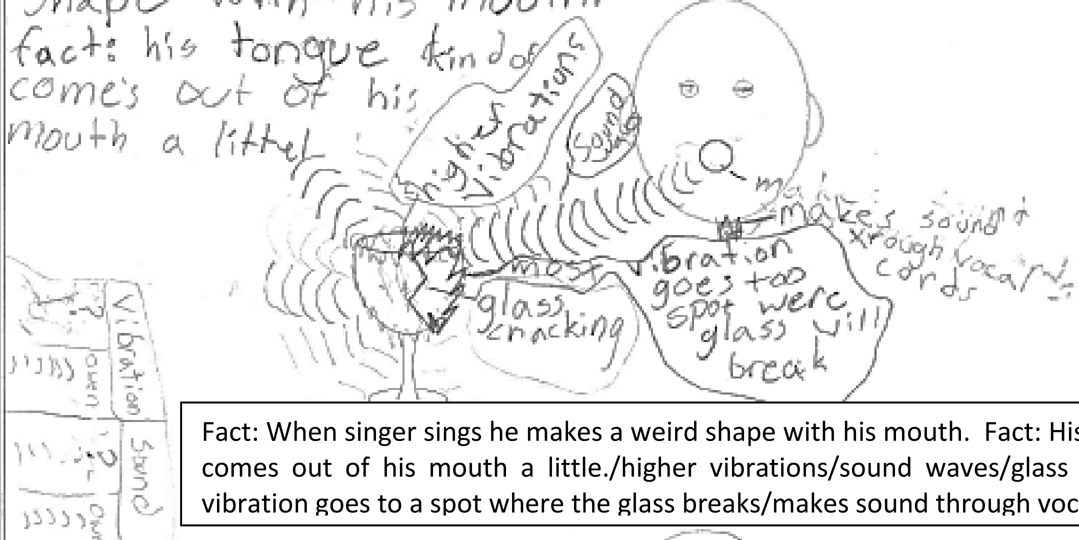


Fact: Singer needs to sing at right pitch to make the glass break. Singer taps the glass to find the right pitch to sing at / Where straw is that is where the glass breaks / Little vibration from flick to get started / Singer remembering the right pitch

~~Singer sings near glass.~~

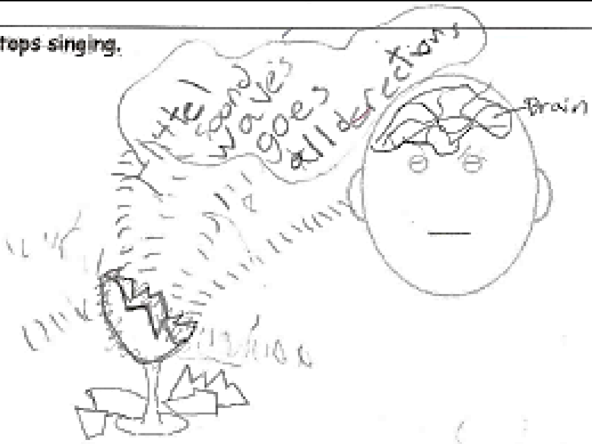
fact: when singer sing's he make's a wierd shape with his mouth.

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

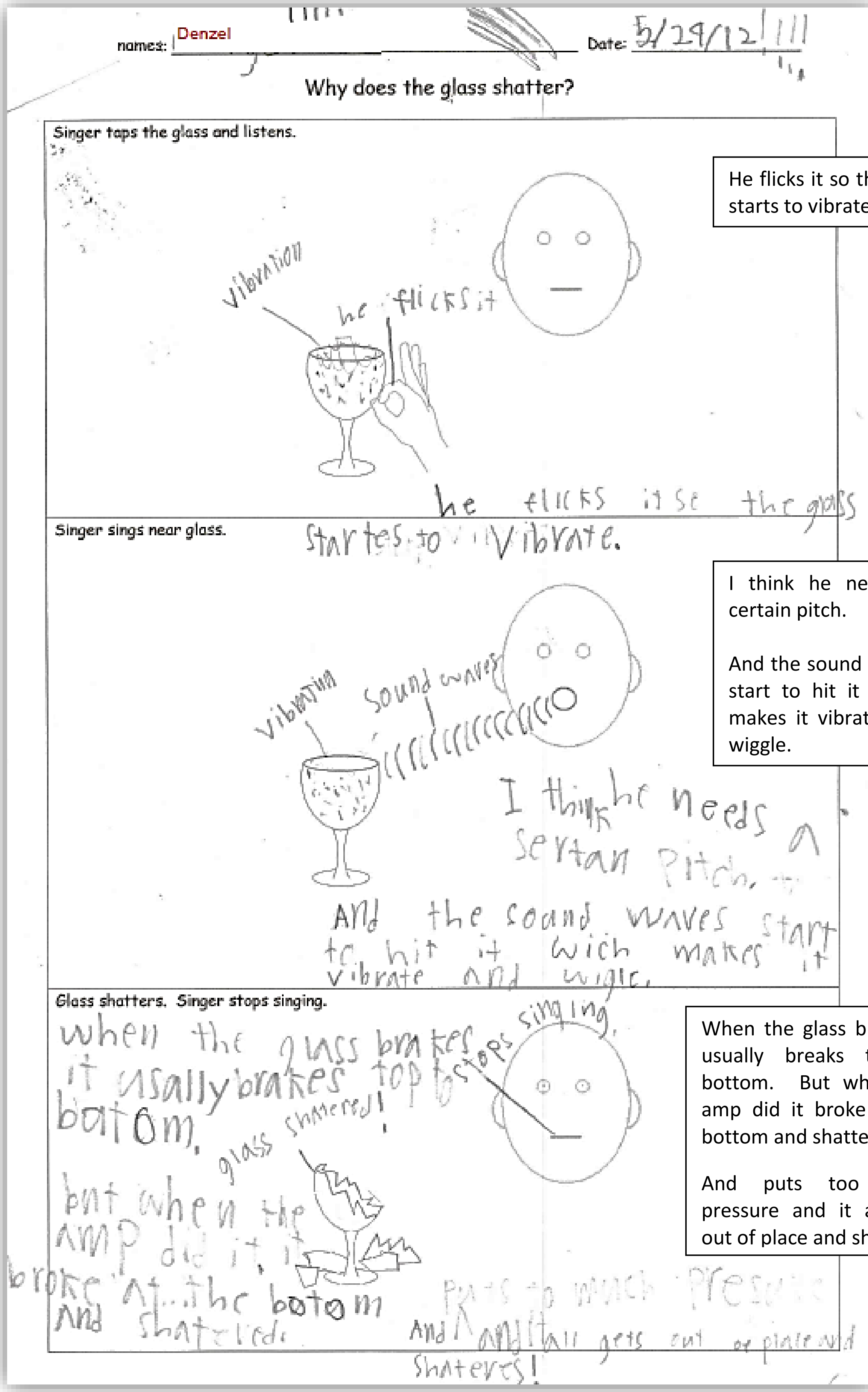


Fact: When singer sings he makes a weird shape with his mouth. Fact: His tongue kind of comes out of his mouth a little./higher vibrations/sound waves/glass cracking/ Most vibration goes to a spot where the glass breaks/makes sound through vocal cords

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.

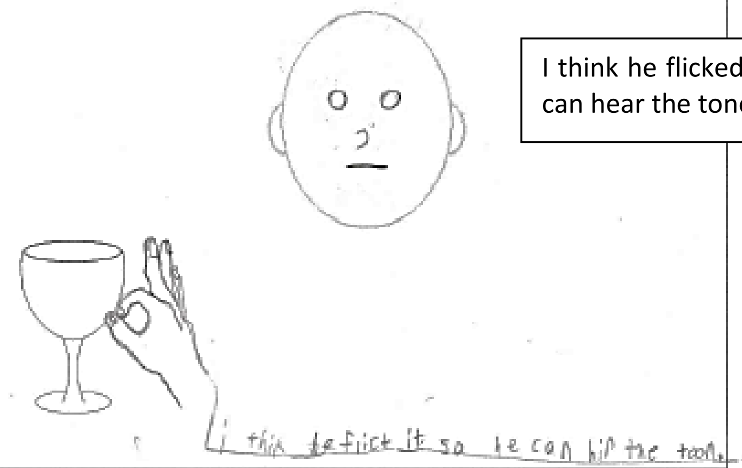
When the glass breaks it usually breaks top to bottom. But when the amp did it broke at the bottom and shattered.

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

Student names: MARIANA Date: 5/29/12

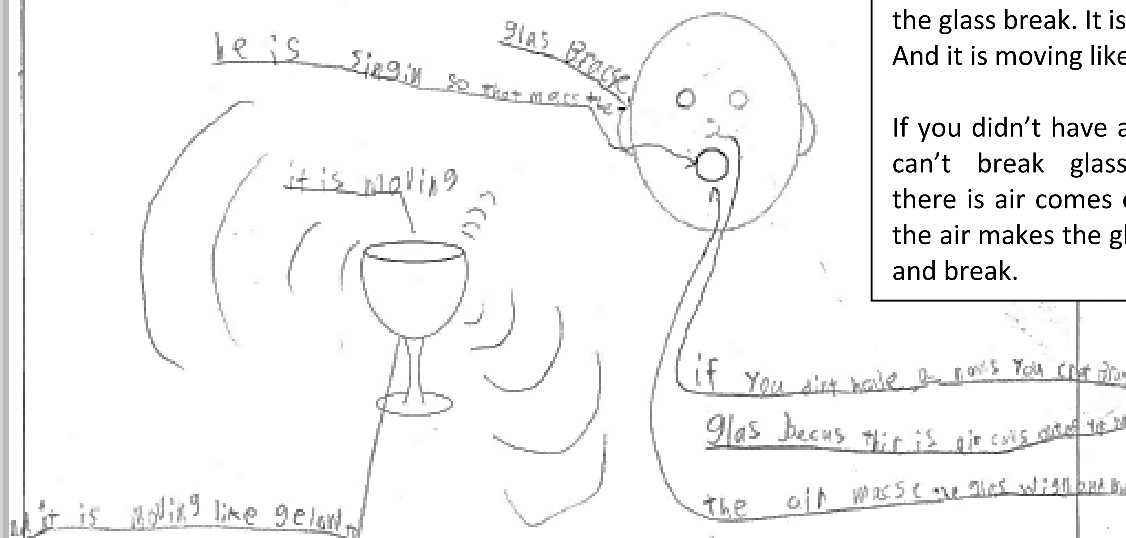
Why does the glass shatter?

Singer taps the glass and listens.



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

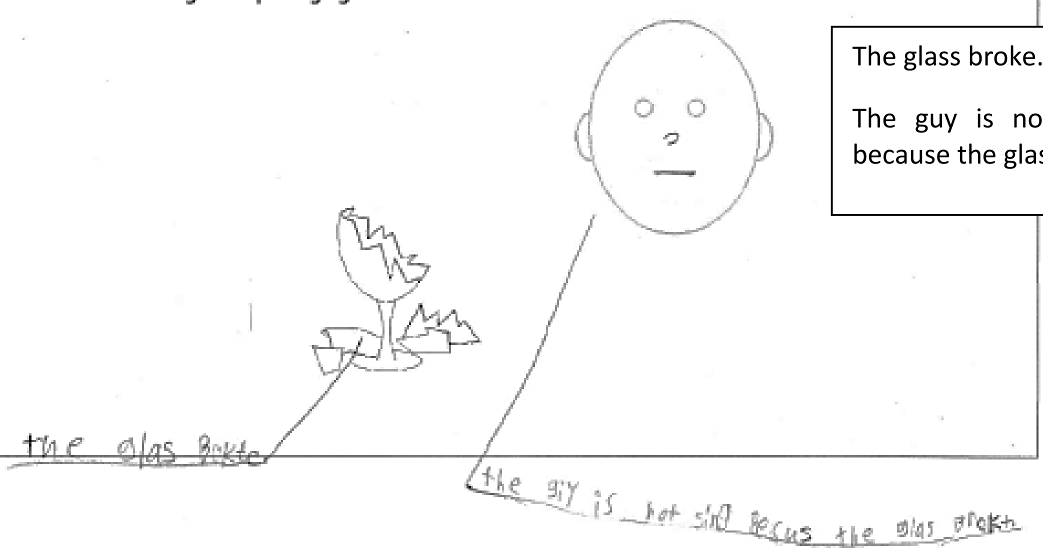
Singer sings near glass.



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

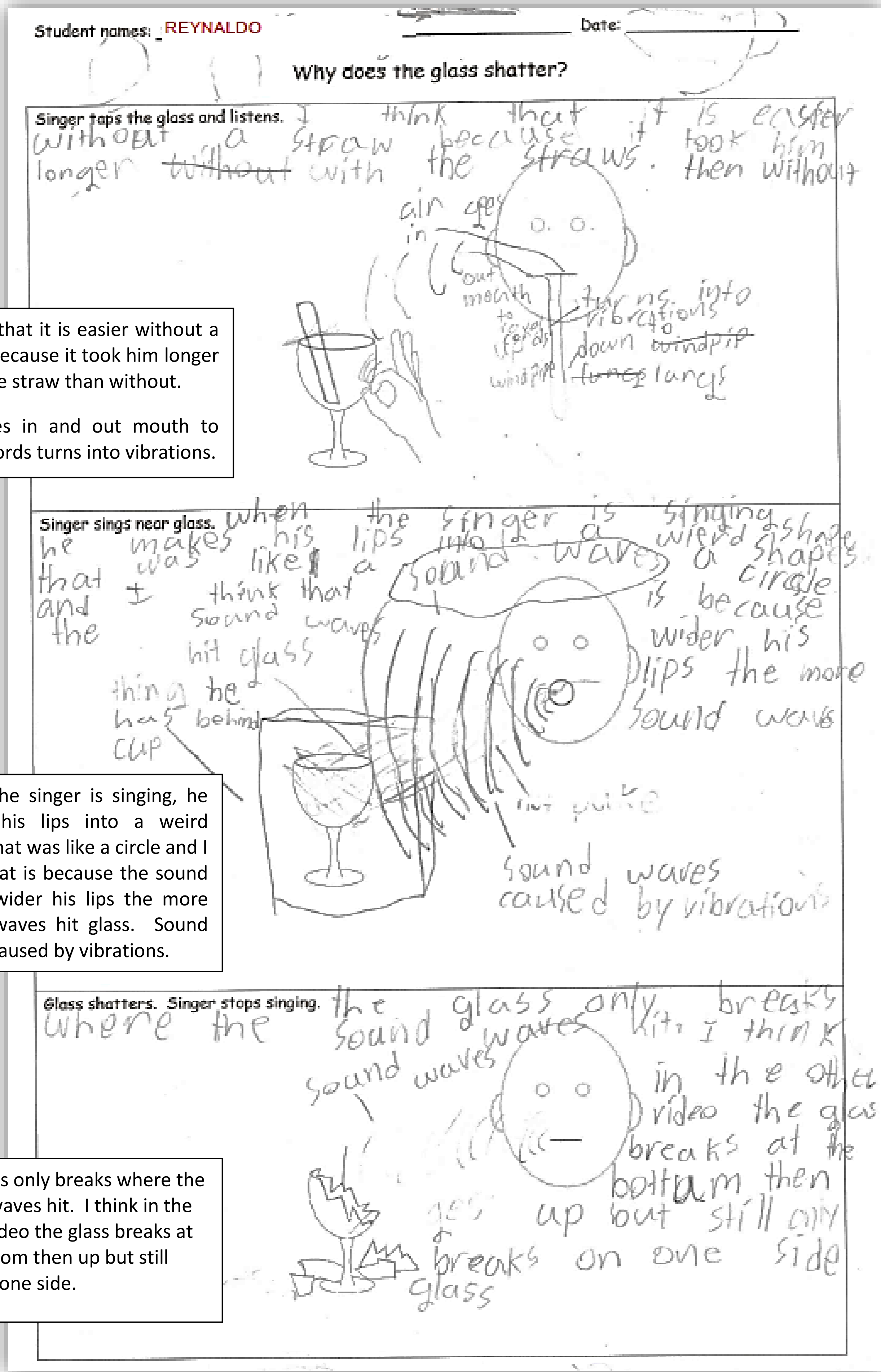
If you didn't have a nose you can't break glass because there is air comes out of you the air makes the glass wiggle and break.

Glass shatters. Singer stops singing.



The 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:

Sound Energy Unit Activity Planner

How will the 3 activities help students make sense of the phenomenon during the week-long academy?

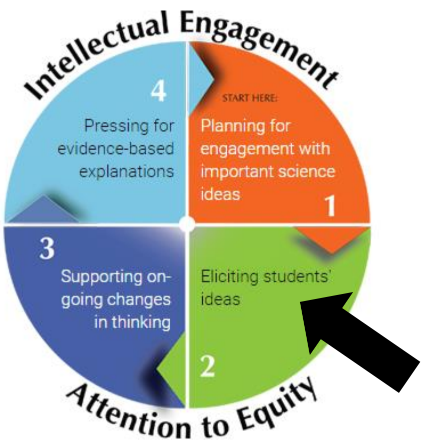
	Activity	*Learning Target*	*Connection to Phenomenon*	*Next Generation Science Standards*
Monday	**LESSON 1:** Eliciting Ideas	Elicit students' initial ideas about the singer-shatters-glass phenomenon. Generate multiple plausible hypotheses based on students prior everyday experiences		SEP: Developing and Using Models SEP: Asking questions CCC: Cause and Effect CCC: Energy and Matter
Tuesday	**LESSON 2:** Human Voices & Vibrations	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.	DCI PS3.C Relationship between energy and forces SEP: Asking questions CCC: Patterns
Wednesday	**LESSON 3:** Decibels at a Distance	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.	DCI PS3.C Relationship between energy and forces DCI PS2.B Types of Interactions SEP: Analyzing and Interpreting Data CCC: Cause and Effect
Thursday	**LESSON 4:** Sound Waves and air	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.	DCI PS1.A Structure and Properties of Matter DCI PS3.B Energy Transfer DCI PS4.A Wave Properties SEP: Developing and Using Models CCC: Energy and Matter
Friday	**LESSON 5**: Evidence-based explanations	Revising models and describing changes in thinking based on evidence from the prior activities to construct evidence-based explanations of the phenomenon (and other related sound phenomenon 'what if' scenarios).		DCI (see all of the above) SEP: Developing and Using Models SEP: Constructing Explanations CCC: Cause and Effect CCC: Energy and Matter

Note: This summer academy only represents the first third of the sound unit. The full unit could last 6-8 weeks. There would also be activities for students to explore and learn more about waves, properties of matter, resonance, and other related phenomena.

[This page intentionally left blank.]

LESSON 1: START THE UNIT BY ELICITING STUDENT IDEAS

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 provided prior to this lesson. 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 (per individual or per pair)
- Pencils (colored pencils optional)

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).

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. • Singer sings the same note the whole time. • Singer is really loud. • Glass breaks outward or explodes. • 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.

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. • Singer sings the same note the whole time. • Singer is really loud. • Glass breaks outward or explodes. • Singer takes a deep breath before singing.	• The sound made the glass break. • The sound has to be loud and close to the glass. • The vibrations make the glass shatter. • The singer has to have enough air to make it happen.

Step 3. Pressing for Explanation

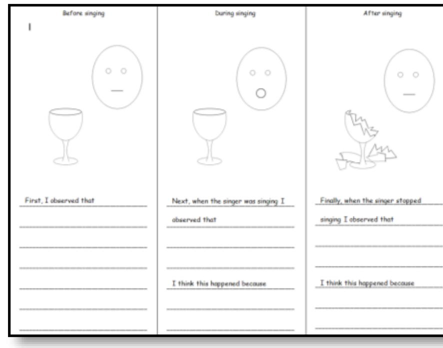
1. As students work on their models, listen in on conversations. Record notes on the Rapid Survey of Student thinking (RSST).

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?

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.)

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?*

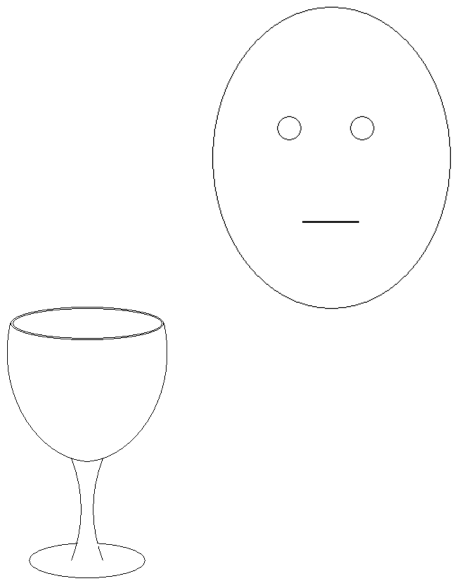
PREPARING FOR FUTURE LESSONS

Use the Rapid Survey of Student Thinking tool (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.

Rapid Survey of Student Thinking (RSST)

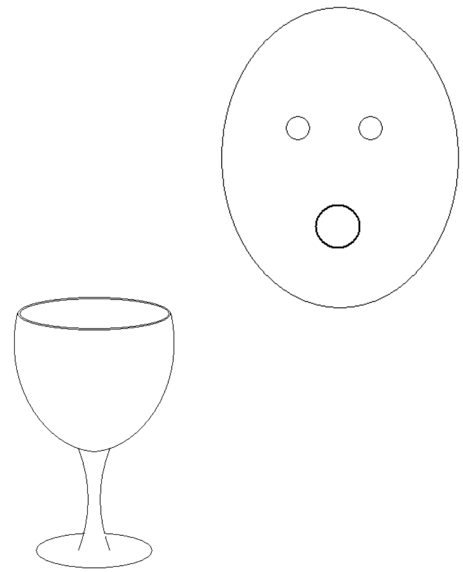
Categories	Trends in student understandings, language, experiences [sample sentence starters included below]	Instructional decisions based on the trends of student understanding
Partial understandings What facets/ fragments of understanding do students already have?	List partial understandings: What approximate % of your students have these partial understandings?	★Star the ideas on the list that need action. Instructional options: • Do further eliciting of initial hypotheses to clarify your understanding of students' partial understandings • Do 10-minute whole class whole class conversation of 2-3 key points elicited • Write multiple hypotheses on board and/or develop an initial consensus model
Alternative understandings What ideas do students have that are inconsistent with the scientific explanation?	List alternative understandings: 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: • Do further eliciting about what experiences/frames of reference students are drawing on • Pose "what if" scenario to create conceptual conflict about validity of alt. ideas • Challenge students to think further/give them a piece of evidence to reason with • Target a lesson using "Teaching Practice 3" 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: 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: • Use this language to reframe your essential question in students' terms • 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 What familiar experiences did students describe during the elicitation activity?	What was the most common or familiar experience that kids related to the essential question or task? What were the less common experiences students cited?	Star the ideas on the list that you can leverage in non-trivial ways. Instructional options: • Re-write the essential question to be about this experience • Make their prior experiences a central part of the next set of classroom activities • 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.)

Before singing



First, I observed that

During singing

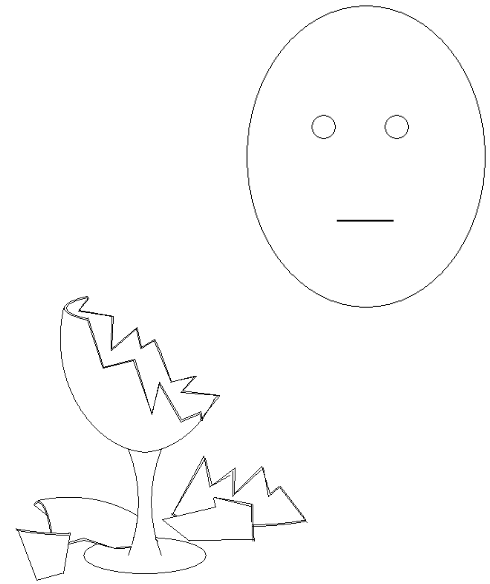


Next, when the singer was singing I

observed that

I think this happened because

After singing



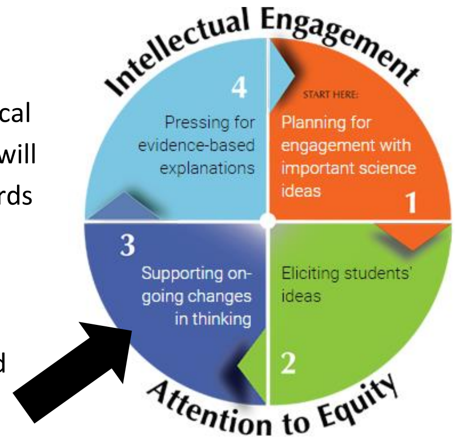
Finally, when the singer stopped

singing I observed that

I think this happened because

[This page intentionally left blank.]

LESSON 2: HUMAN VOICES & VIBRATIONS



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

Per student:

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

Step 1. Orienting Students to the Concepts

1. Use students' models from Lesson 1 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. **JUST-IN-TIME INSTRUCTION**: Introduce terms 'vibration' and 'vocal cords.' Using the reading "Human Voices". Read together as a whole class. Make a cross-section drawing with labels. This reading will help students make sense of what they feel and observe in the activity.

4. Write the name of today's activity "Human Voices & Vibrations" in the summary table row.

Questions to Ask Students

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

Science Vocabulary

vibration

vocal cords

Write the terms "vibration" and "vocal cords" on the board.

This reading is considered "just-in-time" instruction because it has new information students need to learn about how humans produce sounds.

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.

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 re-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.

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.

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 to take notes during the lesson and after the lesson listening to students and looking at student work or notebook entries. 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: Vibrations & Sounds when whispering, humming, talking, yelling 	• We felt vibrations in our throat as we made different sounds. • The vibrations were stronger if we were louder. (Yelling vibrations were stronger than whispering)	• There are parts inside our body that help us talk. • Vocal cords vibrate the air as we breathe out to make sounds. • 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. • To make a louder sound, he uses more force and pushes harder with his diaphragm. • 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**
Describe the strength of the vibrations you feel. *(Add additional description on the line if needed.)*				

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?

____

____

____

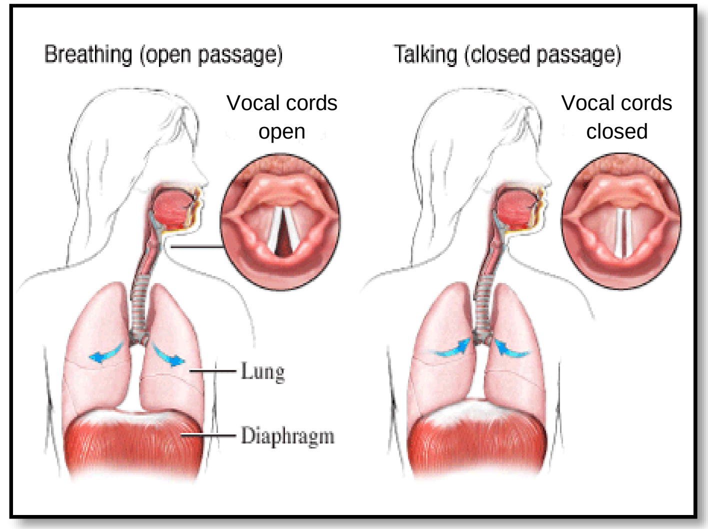
____

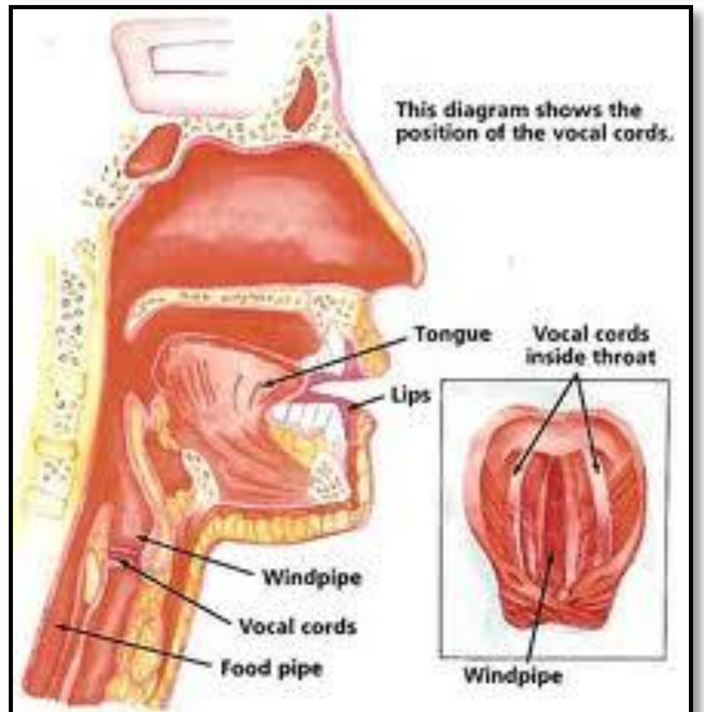
____

____

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.

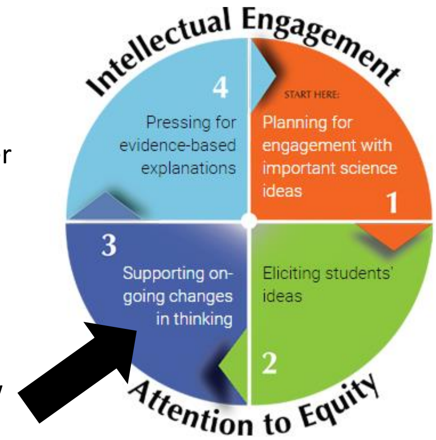




[This page intentionally left blank.]

LESSON 3: DECIBELS AT A DISTANCE

OBJECTIVES

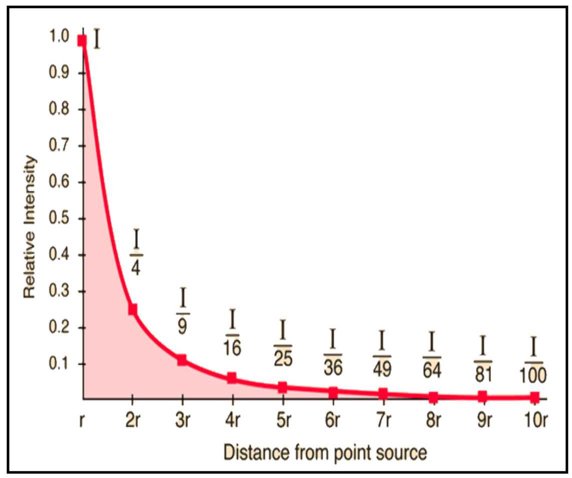


This lesson focuses students on two key ideas: sound travels in all directions from the source, and that the volume of a sound decreases over a distance. Students will record and graph data to show the relationship between the intensity of a sound (measured in decibels) and distance (measured in meters).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

Groups of 3-4 students:

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

LESSON PLAN

Prior to the lesson:

Outside in a large field, use a meter stick to measure off a long length of string (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 in 3 or 4 lines extending from a central place. It is preferable if you can be away from walls or buildings (to limit effects of reverberation).

On chart paper, draw an aerial view of the field and location of where you'll blow the air horn and where the cones are.

Step 1. Orient Students to the Concepts

1. Use students' models from lesson 1 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. Review a definition of 'volume' as how loud or quiet a sound is and write the word on the board. 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.

Questions to Ask Students

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

Science Vocabulary

volume
distance

Step 2. Observations & Patterns - Measuring Decibels

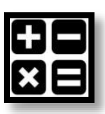
1. Explain that a decibel meter measures the intensity of sound so how loud it is and also how much pressure it has. Give members of groups some time to explore the functions of the decibel meter. Practice taking some measurements as a class (i.e. everyone is silent ready to measure, teacher yells, students read meter).

2. 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 is responsible for recording data along one line. 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.

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?*

3. 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.



4. Share data points, calculate averages and graph class average of data on the chart paper map. Use the “Class Data Recording Sheet” and have one member of each group come up and write decibel levels on the aerial map in pencil. Calculate the average decibel measurement for each distance. Map averages onto places at each point on the field map (on chart paper).

5. Share out a few observations and patterns using the graph and data table. What trends do you notice as measurements are farther away from the air horn? Did all the groups observe a similar trend?

Step 3. What did we learn?

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

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?

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.)*

<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."

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

<u>Summary Table Example</u>

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. • The vibrations were stronger if we were louder. (Yelling vibrations were stronger than whispering)	• There are parts inside our body that help us talk. • Vocal cords vibrate the air as we breathe out to make sounds. • 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. • To make a louder sound, he uses more force and pushes harder with his diaphragm. • His vocal cords vibrate the air so we hear him sing.
Decibels at a Distance: 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. • Outside in the field, the farther away from the air horn, the less volume was measured.	• As distance increases, the decibels (volume) decreases. • 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.

Source of sound: ____________________

Decibels of ambient sound: ________ dB

Distance from Source (m)	Our Decibel Reading (dB)	Class average (dB)
2m		
4m		
8m		
16m		
32m		
64m		

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

____

What do you think causes this to happen?

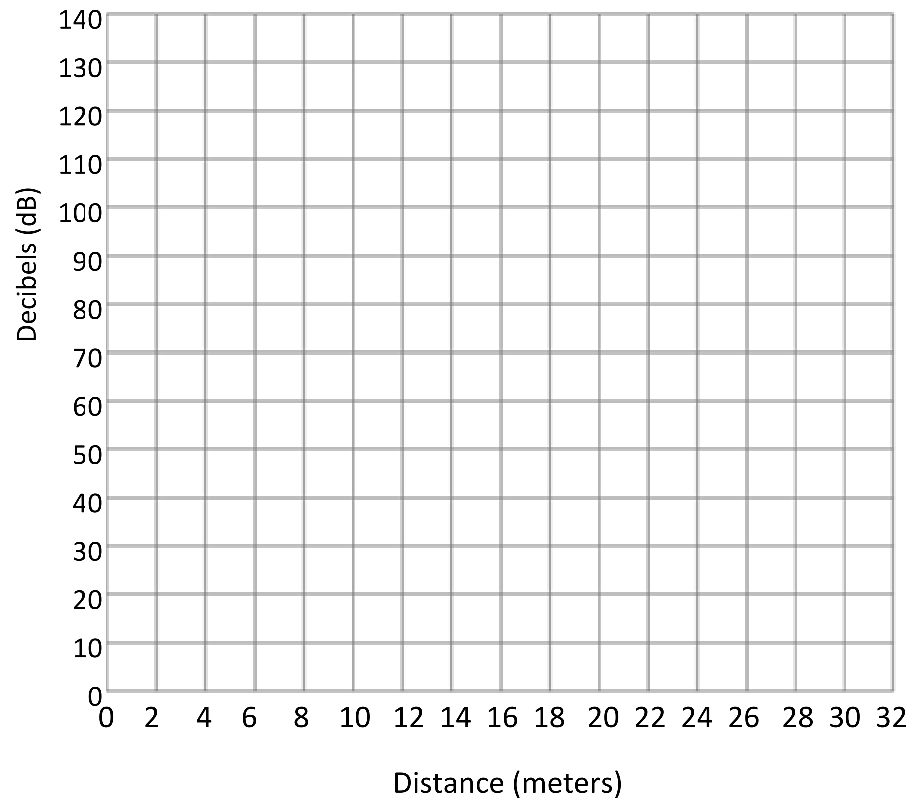
____

____

Decibels at a Distance Data Sheet

Observing the relationship between sound intensity and distance from the source

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

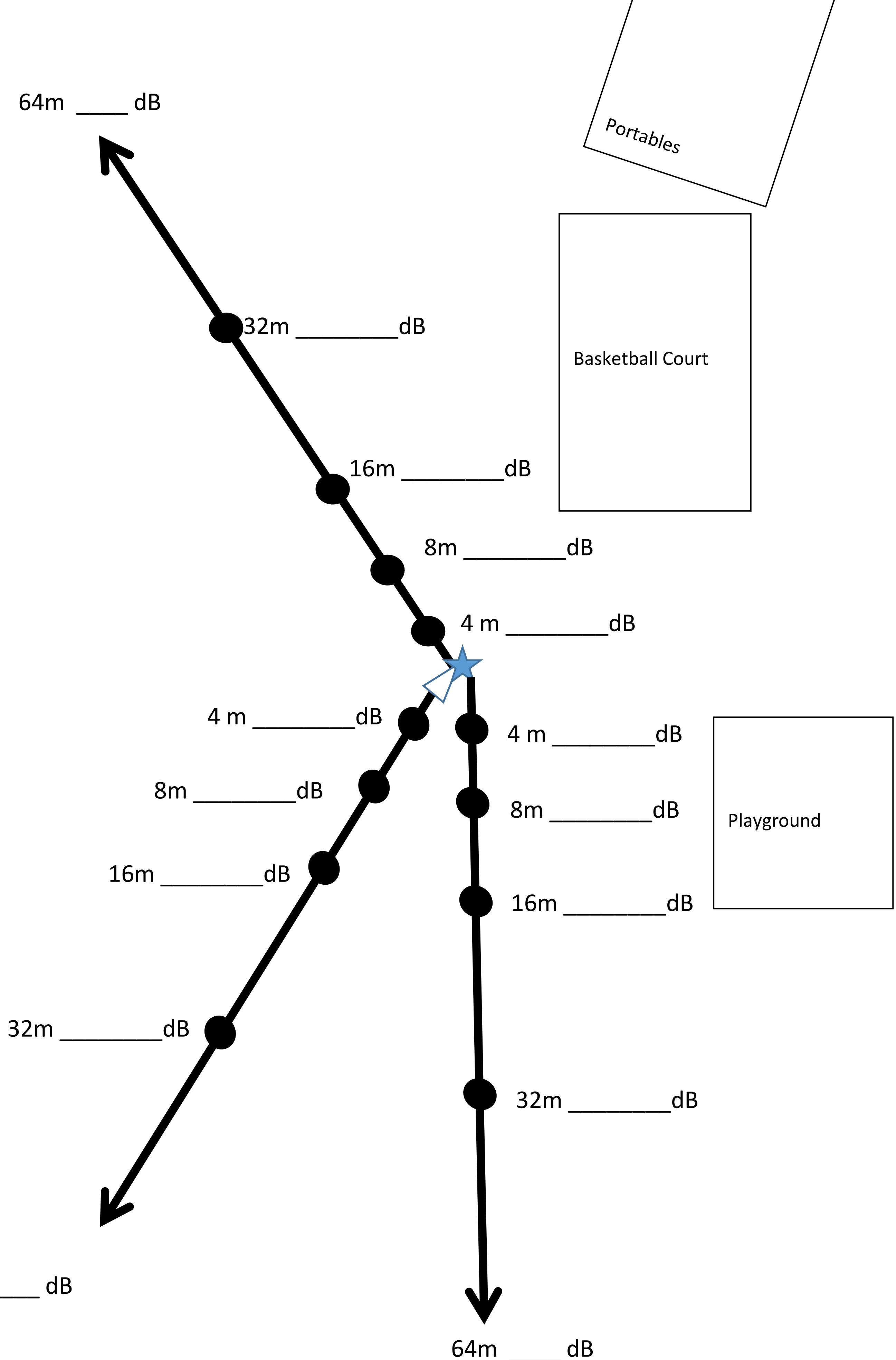
Class Data Recording Sheet

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

Pod Names ____________

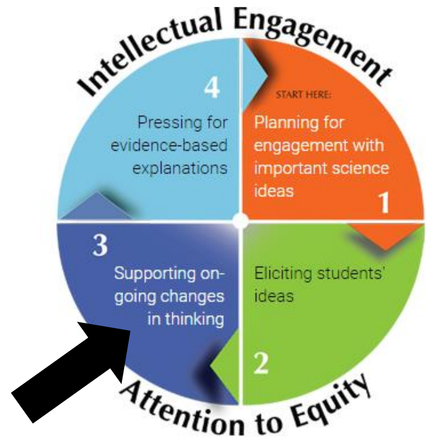
Period ____________

Date ____________



[This page intentionally left blank.]

LESSON 4: MODELLING SOUND WAVES IN AIR



OBJECTIVES

This lesson focuses students on how sound travels through air in waves using video clips and analogies. Students will:

- Describe how sound travels through air.
- Apply knowledge of how sound travels to the phenomenon.

BACKGROUND & EXPLANATION

Sound travels through the air or any other medium. Sound is transmitted from a source to the surrounding air particles, which vibrate or collide and pass the sound energy along to our ears. Without any particles to vibrate, we wouldn't hear the sound. Sound energy is transmitted through matter by jostling the particles such that they bump into each other – this transmits the energy wave but does not move the particle of matter as far (analogies: dominos bumping into each other; air hockey pucks)

MATERIALS

For the class:

- Computer with projector
- Video clips:
  - Bill Nye: https://www.youtube.com/watch?v=ACeUO4ufx2I (start at 0:38)
  - DSN animation: https://www.youtube.com/watch?v=27a26e2CnuM (25 seconds long)
- List of representations of sound
- whiteboard + markers

Per student:

- notebook paper + pencils

Step 1. Orienting Students to the Concepts

1. Use list of representations of sound that came out of students' models from Lesson 1 to show the different ways we have been representing sound.
2. Explain that today students will learn more about how sound travels in air. Read today's focus question: ***How does sound energy travel through air?***
3. Write the name of today's activity "Sound energy in air" in the summary table row.

Questions to Ask Students

- *What will we be learning today?*
- *How will we learn about sound waves?*

Step 2. Observations & Patterns

1. **JUST-IN-TIME INSTRUCTION**: Introduce terms 'sound wave' and 'air molecule'. Using the video clip from Bill Nye (start at 0:38), show students the hockey puck analogy. Also show the DSN animation (25 seconds) https://www.youtube.com/watch?v=27a26e2CnuM. Pair-share: Replay each video and give students time to make observations and share their reactions to these models.
2. If needed, act out how sound travels using students as 'air molecules' to show how bumping shows energy transfer.

This video is considered "just-in-time" instruction because it has new information students need.

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?*

Science Vocabulary

sound wave

air molecule

Write the terms "vibration" and "vocal cords" on the board.

Step 3. What did we learn?

1. Have students summarize what they learned from the video and add it to the summary table (under 'observations' and 'learning').
2. Have students draw a side-view or aerial view of the field and air horn scenario (from the Decibels at a Distance activity). Encourage students to try and incorporate what we just learned about how sound travels using air molecules.

Back Pocket Questions

- *What's happening in the air that we can't see that helps sound travel?*
- *How can we model what sound looks like as the energy moves if we can't see it?*
- *What do certain representations show best about the sound?*

Step 4. Connection to the Singer

1. Have students think-pair-share about how this knowledge about how sound travels through the air applies to the singer Fill in the connection on the summary table.
2. What representation best shows how sound travels from the singer to the glass? Why? Give time for

BACK POCKET QUESTIONS

- *What representation of sound best shows how the sound energy travels from the singer to the glass? Why?*

students to draw it out and talk it over with a partner and/or group.

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

Return to whole class conversation by selecting and sequencing some pairs/groups to share their models under the doc cam. This is where you can help students see broad trends or patterns across models in terms of how volume, distance, and energy transfer are represented.

PREPARING FOR FUTURE LESSONS

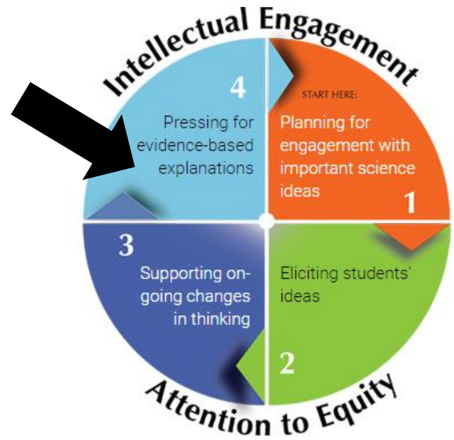
Use the RSST to take notes during the lesson and after the lesson listening to students and looking at student work or notebook entries. Make changes in upcoming lessons based on student thinking and what percentage of the class is thinking about them.

Summary Table

Title of Activity	**Observations**	**What did we learn?**	**Connection to Phenomenon**

[This page intentionally left blank.]

LESSON 5: REVISING MODELS & EVIDENCE-BASED EXPLANATION



OBJECTIVES

This lesson focuses students on how to revise their initial models and write an explanation using evidence from activities so far. Students will:

- Describe how their thinking has changed from the start of the unit.
- Use evidence from activities to justify changes in the model or specific representations.

BACKGROUND & EXPLANATION

(See teacher background content primer)

MATERIALS

For the class:

- Computer with projector and document camera
- Public record of representations of sound
- whiteboard + markers

Per student:

- blank model scaffolds
- explanation checklist
- original models from start of the unit

Step 1. Updating students' explanatory models

1. Have students in small groups update their explanatory models using the blank scaffold. They should incorporate ideas from the summary table into their models. As students revise their models, they will want to compare their models against the explanation checklist and summary table.

2. Have students review their original models and identify places where their thinking has changed. (Pair-Share)

Questions to Ask Students

- *How has your thinking changed?*
- *What idea from the summary table do you want to add to your model? (Can do more than one)*

Step 2. Preparing evidence-based explanations

1. After the updated models have been completed, you ask students to prepare to defend one aspect of their explanatory model by using relevant evidence from a public record such as a summary table.

2. Students use writing scaffold/support to craft a paragraph to support one claim with evidence from the summary table.

3. As students work, teacher(s) select and sequence explanations to have students share out in a specific order. Contradictory explanations or ideas can be fruitful for discussions

BACK POCKET QUESTIONS

- *What idea from your model do you want to choose? Which activity helps support that claim?*

Step 3. Public Comparisons of evidence-based explanations

1. Have selected students share out in particular order. Use talk moves and reinforce norms for students to agree, add on, or disagree using evidence from the summary table. Discussion may result in list of lingering questions or possible activities/experiment that would help settle any disagreements

Back Pocket Questions

- *What additional information would you need to be convinced?*
- *How is your idea similar to X's idea?*
- *Which data from our summary table helps support that point?*

TEACHER DIRECTIONS – CONSTRUCTING EXPLANATIONS

After students have engaged with several investigations, students have gathered evidence from observations about how sound energy is produced (or transformed from other energy), how volume is related to force, how sound energy travels through different materials, and what is going on inside us so we can make sounds. The lessons were chosen from the kit, and some lessons were added, specifically for how their conclusions about properties of sound energy can help explain how the singer was able to shatter the glass with his voice. Students are asked in this lesson to coordinate what they have learned from the different car investigations to apply it back to the singer scenario and explain why the singer was able to shatter the glass.

TIP #1: Divide the Task.

Writing a complete explanation of the singer phenomenon is a huge undertaking for individual students. Let students work in small groups (recommending no more than 3 per group). Talk about group-work norms – sharing talking and writing responsibilities. Check-in with groups on their explanations but also about group work norms.

TIP #2: Watch for vocabulary.

Students may still use a mix of science language and everyday language. If students use words like 'pitch' or 'volume' ask them to add in a sentence to their explanation saying more about what that means and particularly why that affects the singers' ability to break the glass so they don't hide behind science vocabulary.

TIP #3: Sentence Strips: Helpful or not?

Students don't have to use the strips if they feel confused or confined by the phrasing. They can rewrite them in their own words and add in extra sentences about ideas that are important that may not be included. They are a guide to help with writing, but should not impede progress if students can be more productive without them.

TIP #4: Remind Students to Look at the Summary Charts

After each activity, students provided input to create or add-on to a public chart about observations, new learning, and connections. There is a summary chart for each activity. Students can refer to those charts if they read an evidence sentence starter such as, "At recess, we observed…" and can go to the "Recess Activity" chart to remind themselves what evidence they collected during that activity.

Sound Energy Kit – Claim & Evidence Sentence Starter Activity for Constructing an Explanation

CLAIMS – Copy on colored paper (different color than evidence). Cut apart, provide strips to groups or pairs of students. Students can also add their own sentences, too.

The singer taps the glass first in order to…

Sound travels away from the singers' mouth because…

The glass finally breaks because…

The singer can make sound because…

The singer has to be close to the glass because…

The singer has to use a loud volume because …

The glass flexes back and forth because…

Sound energy travels away from the singer's mouth because…

EVIDENCE – Copy on colored paper (different color than evidence). Cut apart, provide strips to groups or pairs of students. Students may use observations from one activity as evidence for two different claims.

We read about…

We saw a video about …

When we did partner whispers in the hall, we observed…

At recess, we observed…

When we knocked on the table…

The ________________ activity showed that …

From the __________________ activity we learned that…

From the __________________ activity we learned that…

OPTIONAL Reasoning *Copy on colored paper (different color than evidence). Cut apart, provide strips to groups or pairs of students. Students may use observations from one activity as evidence for two different claims.*

Based on this evidence, we know …

This evidence shows…

This evidence helps us better understand ________________ __________________________________ because…

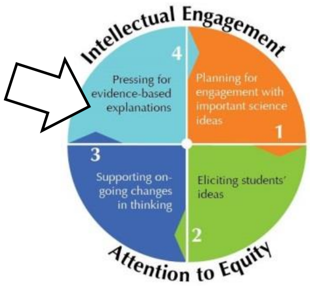
This result can be explained by…

Because of the data from this experiment, we know that…

This evidence supports our claim because…

This evidence supports our claim because…

This evidence supports our claim because…



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 *Student describes what is observable or measureable in a phenomenon.*	☑ Singer flicks glass and listens. ☑ Singer sings at the same pitch the glass makes when he flicked it. ☑ Singer sings loudly near the glass. ☑ The glass wobbles, flexes back-and-forth. ☑ 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. ☑ The glass eventually shatters. The singer stops singing. All of these items are observable from the phenomenon video.
HOW *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. ☑ 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. ☑ The sound energy from the singer is transformed into energy of motion as the glass vibrates. ☑ 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.