

PURPOSE OF THE STUDY OF PHYSICS OF SOUND

Teachers delving into the Next Generation Science Standards (NGSS Lead States, 2013) to inform their STEM curriculum will find light and sound listed together because they are related in their forms of energy – waves. However, young children experience light and sound as very different phenomena. Understanding sound as waves of energy, and conceptualizing sound as a pressure wave of energy transferred to the surrounding air when there is a collision of objects will come later in a child's education. Developmentally appropriate science and engineering expectations for PreK-2nd grade children involve experiences that provoke thinking about the physics of sound in that 1) sound can make things vibrate, and 2) vibrating things can make a sound (NGSS PS4.A).

To assist children in developing a deep understanding of these phenomena, teachers capitalize on their children's unique interests in sound and prepare the environment to enable young children to pursue answers to their questions about sound (NGSS PS4-1). The teacher considers the physical environment (how the classroom is arranged for student investigations), the socio-emotional environment (children feel comfortable to take risks in their learning), the visual environment (how the children's learning process is showcased on classroom walls), and the intellectual environment (activities within the children's studies are rigorous in challenging the children to reason, predict, analyze and question). Such an environment develops science and engineering habits of minds that ask questions, make observations, plan and carry out investigations, construct explanations, and design and test solutions (NGSS PS4-1, 2, 3, 4, and ETS1.A, B, C).

Teachers in pursuit of a rich educational environment may find the Inquiry Teaching Model (Counsell et. al., 2015) helpful in developing, planning, implementing, and evaluating physics of sound experiences. This framework is fundamentally guided and informed by close child observation. Close observation of children's prior experiences, cultural backgrounds, and unique interests in sound related phenomena informs the teacher how to best engage learners, provide opportunities for deeper learning, and make informed decisions to continuously improve the classroom environment and experiences around sound for meaningful learning. For those interested in professional learning on effective teaching and meaningful learning, a citation for the Inquiry Teaching Model is included in the references along with a larger diagram.



4 ASPECTS OF MUSIC TO INTRODUCE TO CHILDREN WITHIN SOUND EXPERIENCES



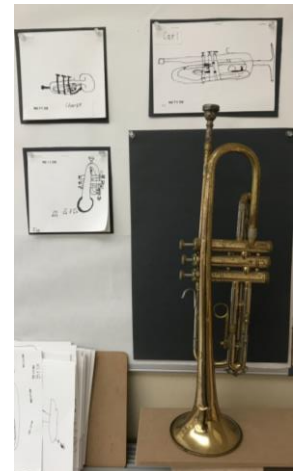
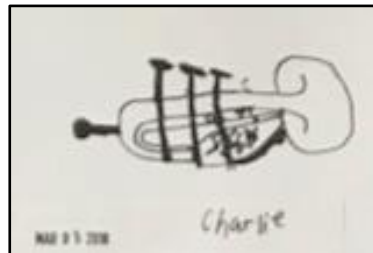
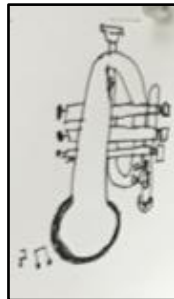
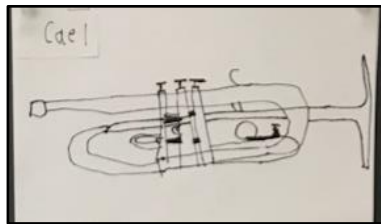
Children enjoy music and are responsive to sounds within music. Children who go on to play musical instruments not only reap the aesthetic benefits of collaboratively producing music with other players (not just listening to music), they actually develop neurophysiological distinction between certain sounds that can aid in literacy and improved academic performance. Research conducted by Nina Kraus, director of Northwestern's Auditory Neuroscience Laboratory found that the active generation and manipulation of sound can rewire the brain to improve the process of speech (Kraus, N., et.al., 2014). Investigating the physics of sound through musical instrument making may support the development of this neural processing.

There are four aspects of musical sounds that can be accessible and meaningful to young children as they experiment with the physics of sound and explore how to manipulate sound in musical instrument making. The first two aspects, **loudness** and **duration**, are relatively easy for young children to grasp. The second two, **pitch** and **timbre** (pronounced TAM ber) are more difficult and require experience and time to understand. The following page provides descriptions along with a visual to help adults understand the sound's relationships to waves. Adults may be successful in teaching young children to match sound wave illustrations to vocabulary, but it is highly unlikely young children will conceptually understand the relationships between sound and waves. A much better use of instructional time is providing young children experiences that challenge them to distinguish differences among sounds, describe those differences, and engineer differences among sounds.

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Teachers can begin to investigate aspects of sound with their young learners by exploring a variety of instruments. Some teachers collect discarded instruments for children to examine and invite them to do observational drawings. Children become intrigued with the intertwining curves. Discussion about how long the instrument would be if it could be all stretched out may challenge spatial thinking (trumpets – 4 ft.10 in.; trombone – 9 ft.; tuba – 18 ft.; French horn – 20 ft.).



Note for Curious Adults: All sound requires vibration that sets off a sound wave through air. This vibration of air can be produced in many ways. Below are four categories of instruments based on how sound is produced through vibration.

CATEGORIES OF INSTRUMENTS BY HOW SOUND IS PRODUCED

Aerophones make sound by vibrating the air inside the instrument. Some aerophones make the air vibrate by buzzing through the player's lips into a cupped mouthpiece. Others make the air vibrate by blowing through a reed. Yet vibrate the air by blowing across the top of an instrument.



Idiophones make sound when they are struck, shaken, rubbed, or plucked. The whole body of the instruments vibrate to produce the sound.



Membranophones make air vibrate by striking or rubbing a tight skin or membrane.

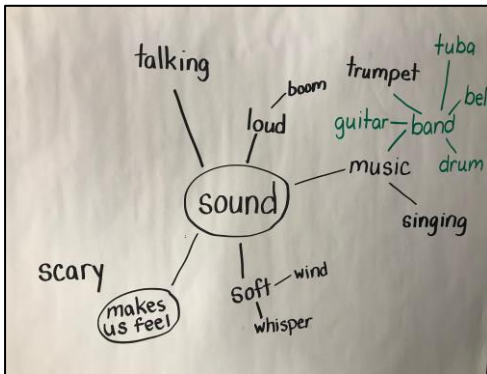


Chordophones make air vibrate by plucking, striking, or bowing strings.



Young children are able to observe vibration most easily in idiophones, membranophones, and chordophones.

INVESTIGATING PHYSICS OF SOUND WITH YOUNG CHILDREN



Teachers can investigate sound as vibration with their children using simple materials, such as rubber bands, tongue depressors, tin cans and glass jars, and drinking straws. Introducing materials in a large group setting enables children to share what they know about sound. Co-create a web of what they know about sound on a large piece of paper in a black marker. This web can be expanded as children learn more throughout the investigation over time. Each time the web is expanded, use a different colored marker. This helps children remember the process of their learning. When children's investigations reveal they had a misunderstanding recorded on the web, model editing by drawing a line through the misunderstanding and then adding the new information.

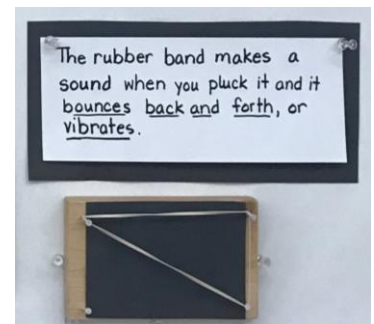
Rubber bands are good materials for beginning exploration of sound as vibration. Start by holding one up as an example to discuss its properties and how to safely handle rubber bands.

- *Where are some places you have seen these?*
- *When I hand one out to each of you to explore, what should we be careful about?*
Hand out one rubber band to each child.
- *What do you notice about your rubber band? What can it do? (stretches, goes back to what it looked like before you stretched it) How does it feel? (soft, bendable, rubbery, stretchy...)*
- *What do you notice with your eyes? (gets thinner as it is stretched longer, and thicker when it is not stretched and is shorter)*
- *What do you notice with your ears? (it makes a sound when you pluck it)*
- *How could you work with a partner safely to listen more carefully?*
Allow children to work in partners with one stretching the rubber band and one plucking it.
- *How does the sound change?*
- *What can you do to make the sound change higher? Lower?*



Invite children to help you set up a place in the classroom to explore this with the question, *What can we do with a rubber band to change the sound?* or, a question the children have. Ask the children to suggest their ideas about how the center could be set up. We advise that you start small so that children can be observed closely as they begin to think about the possibilities. Rubber bands in two sizes can ignite interest in the ways that sound can be made and varied. Starting with one simple material will allow children to make sense of what they are observing in order to make accurate cause-effect relationships. You may also want to include small blocks of wood with two or four nails in the corner to use in stretching the rubber bands.

When the expectations are outlined, the materials introduced, and rules for safety developed, children are ready for open-ended exploration during center time. The goal during exploration is self-directed, unstructured investigation with minimal teacher guidance. This will provide opportunities for children to interact with an object to determine its properties and how the object interacts with other objects. With some guidance and use of productive questioning children have the possibility of observing patterns, identifying variables, and establishing possible relationships. It is important for children to communicate what they have observed and to explain what they have done and found through documentation. To the right, is an example of documentation of first graders' beginning understanding of sound as vibration.



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As interest begins to wane, additional materials can be added to provide more sophisticated challenges. We have found children can begin to understand the role of resonators in musical interests by inviting them to stretch the rubber bands across empty tuna cans cut with a smooth edge can opener and canning jar rings that are added to the center. Both are similar size, and both have the same problem of rubber bands slipping off the edges encouraging comparing only 2 or 3 rubber bands. Over time, children will find the sound of the rubber band is louder when stretched across the tuna can than it is when it is stretched across the jar ring.

Note for Curious Adults: A vibrating string will cause a sounding board and the air inside to vibrate at the same frequency. This makes the sound louder. As more material vibrates (e.g., longer string or tongue depressor), sounds with lower pitch are produced if all other variables are held constant. As tension increases, sounds with higher pitch are produced if all other variables are held constant. This will make more sense to you when you explore the materials yourself. Most young children will not understand sound at this level of complexity, but they will benefit by forming the following relationships between:

- Tightness of the string/rubber band and pitch
- Length of the string/rubber band/tongue depressor and pitch
- Force of the pluck and loudness of the sound
- Closeness to the ear and loudness of the sound
- The use of a resonator and loudness of the sound

We need to provide children opportunities to try out things and to think on their own without interference. But questions may be necessary to provide guidance and to promote understanding. Questions asked in the appropriate sequence can help transition students from the concrete to the abstract. This can be done through the use of productive questions that can be classified as:

- Attention-focusing questions
- Measuring and counting questions
- Comparison questions
- Action questions
- Problem-posing questions
- Reasoning questions

(Martens, 1999)

Possible Questions to Ask Children Investigating Sound with Rubber Bands/ Fishing line

- What can you discover about sound with a rubber band/fishing line?
- What different sounds can you make with your rubber band/fishing line?
- What did you do to change the sounds?
- How can we describe these different sounds?
- Can you change the loudness? How?
- Can you change the pitch? How?
- Can you change the duration? How?
- How can we make our rubber band instruments sound louder?
- What sorts of resonators can we make for our rubber bands/fishing lines?

Possible Questions when Investigating Sound with Tin Cans and Resonators

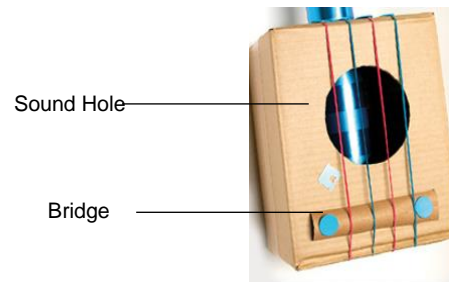
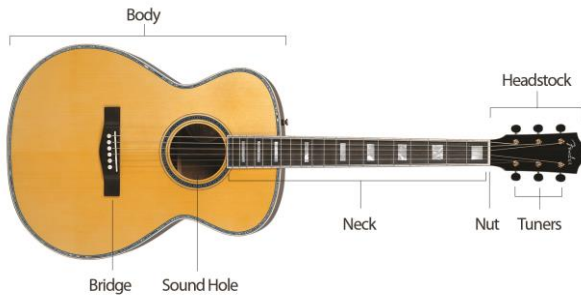
- What did you do to make a sound?
- How can we make our rubber bands sound higher?
- Who can play the highest note on their rubber band?
- How can we tell who played the highest note?
- Did you create different types of sound? How could you describe the differences in sound?

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EXTENDING THE STUDY OF SOUND

Extend understanding of changing the sound pitch of rubber bands by reverse engineering a guitar. Then make a working model using a box or milk carton, rubber bands, cardboard, and tape. Young children can think hard about the purpose of a bridge in addition to the resonator or "Sound Hole." If you leave the neck off of the design challenge children will focus on reasoning about the bridge, tension on the rubber bands, and resonator before going into pretend play.



When children have exhausted the possibilities for engineering the materials initially introduced, their exploration will be may stall. Careful observation will inform you when it is time to add new challenges. When children are ready for a new challenge ask them what materials that could be added to the sound center. Below are some examples:

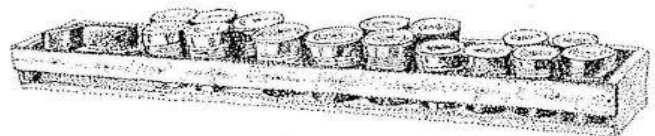
Investigating Membranophones



Cut off the ends of balloons. Stretch balloons over tin cans or jars. How could they make the sound higher? Lower? Does it matter where they strike the drum head?

Investigating Idiophones

Collect cans to make a "tincanarimba."

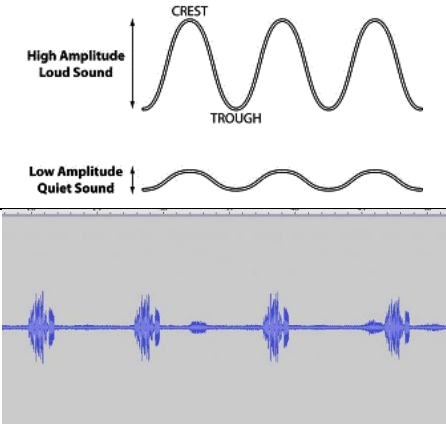

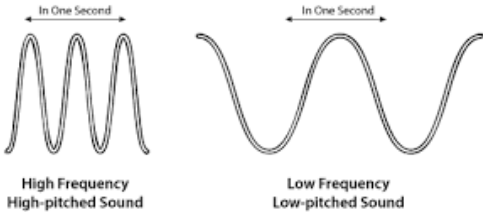
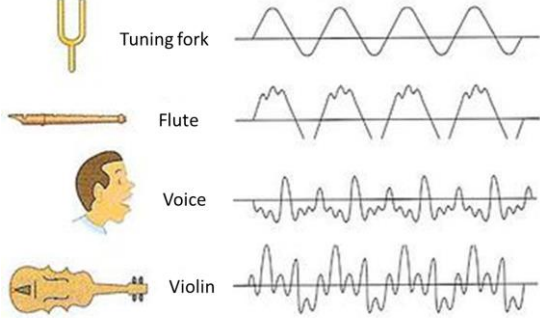


Strike cans and sequence the sounds from low to high.

NOTES FOR CURIOUS ADULTS

Below are descriptions of different aspects of sound that adults use to communicate their learning about sound's relationship to waves. Understanding these aspects as adults helps us think about how to investigate sound with young children.

THESE EXAMPLES ARE NOT MEANT TO BE USED WITH YOUNG CHILDREN.

Aspect of Sound	Illustration to Assist Adult Learning
<p>Loudness is related to the amplitude of vibration, or how large the vibrations are. Sound waves of low amplitude are quiet. Sound waves of high amplitude are loud.</p> <p>Adults can assist children to discern and describe the difference between loud and soft sounds by</p>	
<p>Duration is related to the length of time that a sound-making object vibrates. Duration can be described as long or short, and is an aspect of sound children can discern, compare, and contrast.</p>	
<p>Pitch is related to the frequency of vibration, or the number of times a sound-making object vibrates in a given amount of time. Pitch can be described as <i>high</i> or <i>low</i>. Pitch is often difficult for young children to grasp because cultures describe pitch metaphorically, in terms of space. In English, pitch is described as <i>high</i> or <i>low</i>. The Manza of Central Africa express pitch in terms of size with high pitches being referred to as <i>small</i> and low pitches a <i>large</i> (Stone, 1981). Farsi and Turkish languages describe pitch in terms of thickness, with high pitches described as <i>thin</i> and low pitches scribed as <i>thick</i> (Shayan, Ozturk, & Sicoli, 2011). Discussion within sound experiences over time will help young children assimilate their culture's spatial metaphor for pitch.</p>	
<p>Timbre (TAM ber) is related to the fundamental vibration of a sound-making object (usually the slowest vibration) in combination with other, faster vibrations. It is the sound quality of instruments and voices. Timbre enables you to distinguish the sound of one instrument from another, or the different voices of your friends. Timbre can be described in a number of ways- bright, brassy, twangy, etc.). Children can learn to identify instruments by their timbre, and then investigate how those instruments make those sounds.</p>	

Sound waves can travel through solids, liquids, and gases, but sound moves faster in a solid than a gas. Think about how you see the visual explosion of fireworks but hear the explosion several seconds later. Results from a vibrating object which sends out waves of the same frequency through the medium of air. Sound is a pressure wave that contains regions of high air pressure and low air pressure. This pressure wave causes objects to vibrate including your eardrums.

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CHILDREN'S BOOKS FOR FURTHER INVESTIGATION

Below are some children's books for further study with children.

We recommend reading such books AFTER children have had science and engineering experiences with sound.

- Ardley, N. (1991). *The Science Book of Sound*. Gulliver Books. * P/K and elementary.
- Berger, M. 1994. *All About Sound*. New York: Scholastic.
- Broekel, R. (1983). *Sound Experiments*. Chicago: Children's Press. * P/K, Lower Elementary.
- Bryant-Mole, K. (1996). *Sound and Light*. Rigby Education. * Elementary.
- Chenfeld, M.B. (1995). *Creative experiences for young children* (2nd ed.). Orlando, FL: Harcourt Brace.
- Cobb, V. (2000). *Bangs and Twangs*. Milbrook Press, Inc. * Elementary and above.
- Diagram Group. (1976). *Musical instruments of the world*. New York: Facts on File. *All levels, resource
- Glover, D. (1993). *Sound and Light*. Kingfisher Books. * P/K and elementary.
- Nelson, M. (1995). *You can teach yourself to make music with homemade instruments*. Pacific, MO: Mel Bay.
- Pfeffer, W. (1999). *Sounds All Around*. Harper Collins Publishers. * P/K and Elementary.
- Robinson, F. (1994). *Sound All Around*. Chicago: Children's Press. * P/K.
- Rowe, J., & Perham, M. (1993) *Making Sounds*. Children's Press. * P/K and lower elementary.
- Stille, D. (2001). *Sound*. Compass Point Books. * P/K, Lower Elementary.
- Trumbauer, L. (2004). *All About Sound*. Scholastic Inc. * Toddler and Preschool.
- Ward, A. (1992). *Sound and Music*. New York: Franklin Watts, Inc.* P/K and Elementary.
- Wright, L. (2000). *The Science of Noise*. Raintree Steck-Vaughn Publishers. * P/K and Elementary.

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- Sabbeth, A. (1997). *Rubber-band banjos and java jive bass: Projects and activities on the science of music and sound*. New York: Wiley.
- Seller, M. 1995. *Sound- Noise & Music: Easy to make Science Experiments with Bright Ideas and Why They Work*. New York: Shooting Star Press.