Activity 6

Utensil Music: Teaching Sound Science

Expected Outcome

The middle portion of a string is tied to the handle of a metal utensil. When the two ends of the string are used to swing the utensil up against a hard surface, the collision generates an audible, but unimpressive vibration. However, if the two ends of the string are brought up against a person's two ears and the collision is repeated, a rich symphonic mix of sounds is easily heard.

Science Concepts

Sound travels better through solids (e.g., a taut string) than through air because sound is a mechanical, compression wave that is transmitted via collisions between adjacent molecules. Unlike electromagnetic waves, sound cannot travel through a vacuum. Also, in contrast to our vision where different wavelengths of light are blended to produce the full spectrum of colors, our hearing enables us to separate complex sounds into their component pitches so that we can dissect and discern a mixture of sounds from different sources.

Science Education Concepts

This simple hands-on exploration highlights the fact that hearing, like all human sensory systems, has natural limitations. Even when we try to be fully attentive, human sampling and processing rates and reception and sensitivity ranges capture only a small portion of the sensory data available in the environment at any time.

Perceptual limitations are another contributing factor to some common, persistent misconceptions that run counter to imperceptible (imperceptible, that is, to unaided human senses) yet valid science concepts, such as the nanoscale world of atoms and molecules. This activity is an *auditory participatory analogy* that broadens and refines students' perceptions, conceptions, and appreciation of "reality." Furthermore, it motivates students to stop and look at, listen to, question, and explore with all of their senses (and technological aids) all that nature and their teacher has to teach them.

Materials

- To prepare a musical utensil chime for each pair of learners: Tie single pieces of ~60 cm string to either the handle end of old utensils (forks and spoons are safer than knives) or the hook of a metal coat hanger (which is *not* as safe as forks and spoons). The two ends of the approximately equal lengths of string (~30 cm each) are left free. The string can be wrapped around the utensil for storage.
- For the Extension activities, use tin cans and paper or yogurt cups and nylon thread to make a homemade nonelectrical telephone. Use Slinkies and Newton's Cradles for macroscropic models of sound transmission.

Safety Notes

1. Tin cans can have sharp edges, which can cut the skin. Use extreme caution in handling.
2. Wear safety glasses or goggles during this activity.

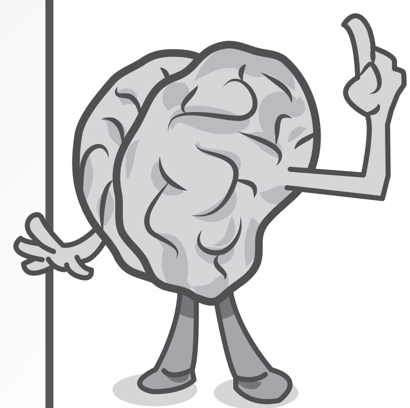
Points to Ponder

There cannot be mental atrophy in any person who continues to observe, to remember what he observes, and to seek answers for his unceasing hows and whys about things…. Don't keep forever on the public road, going only where others have gone. Leave the beaten track occasionally and dive into the woods. You will be certain to find something you have never seen before. Of course it will be a little thing, but do not ignore it. Follow it up, explore around it; one discovery will lead to another, and before you know it you will have something worth thinking about to occupy your mind. All really big discoveries are the result of thought.

—Alexander Graham Bell, Scottish-American scientist and inventor (1847–1922)

The most exciting phrase to hear in science, the one that heralds new discoveries, is not "Eureka!" ("I found it!") but "That's funny...."

—Isaac Asimov, Russian-born American scientist and science fiction writer (1920–1992)



Procedure

(See answers to questions in steps #1 and #2 on pp. 70–71.)

1. Instruct the learners (working in groups of two who alternate using the "chime") to hold the two free ends of the string between their two thumbs and index fingers and swing the object so that it bumps up against their desk (or have a partner tap the suspended utensil with another utensil). Have the learners (a) write at least three adjectives to describe the sound they hear and (b) brainstorm other instances where sound is associated with the vibration of matter. Ask: Does all sound result from the vibration of matter? Do you think we are hearing all the sound that is being produced? If not, how could we better direct the sound energy to our ears?

2. As one possible answer to the last question, have the learners repeat step #1, except this time press and hold the two free ends of the string up against the middle of their outer ears. Have them describe the sound they hear and compare the experience to the previous one. Ask: Did the sound produced really change from the first to the second trial? If the sound produced didn't change, how can we explain the change in our reception and perception of the sound? What other variables in this setup could be changed and how would you predict that changes in these variables would affect the perceived sound?

Debriefing

When Working With Teachers

This hands-on exploration and the quotes from Bell and Asimov can be used to identify and discuss the key attributes of sound science teaching. At the experiential level, teachers can (1) create engaging, aesthetically pleasing experiences that prompt students to feel a sense of wonder and (2) expand students' conceptions of the reality beyond the limited realm of our natural, unaided sensory perceptions. "Sound science" is more than just a play on words; it is a powerful metaphor for the mind-opening and mind-expanding effect of integrated curriculum, instruction, and assessment.

When Working With Students

This activity could be used either in a unit dealing with sound and hearing or as an introduction to the nature of science and the role of experimentation and technological advances in expanding our perceptions and conceptions of reality. Additionally, in life science classes, attention can focus on the different perceptual worlds that different species inhabit and the selective advantages that these differences provide to allow species to occupy unique niches. Specifically, human hearing is limited to sounds with frequencies between 20 and 20,000 Hz (or ~10 octaves on a music scale) and amplitudes of 0 to 85 decibels. (*Note:* Prolonged exposure to 85 dB or even short-term exposure to sounds above 130 dB causes permanent damage.) These frequency and volume sensitivity ranges are reduced with age and occupational or recreational hearing damage.

Animals' sensitivity ranges are different from those of humans (e.g., bats and whales hear in the ultra- and subsonic ranges of humans). Other species may experience a different auditory reality than we do (e.g., consider the concerns about Navy sonar disrupting the worldwide communication network of whales). This difference between humans and other species is also true, for example, with respect to the sensing of electromagnetic frequencies (*sight*—e.g., plant-pollinating bees and birds see in the ultraviolet and pit vipers see in the infrared and *odors*—e.g., dogs can be trained to smell bombs or drugs).

Many advances in science and human history have relied on technological inventions that have extended the ranges of our natural abilities to detect and process environmental information (e.g., the use of infra- and ultrasound instruments to detect mechanical vibrations or compression-type, longitudinal waves propagated through matter; these instruments range from earthquake seismographs to ultrasonic imaging of a pregnant woman's womb).

Activities #7 and #13 in this volume also explore sound concepts.

Extensions

1. *Tin Can (or Yogurt Cup) Telephones*. Have six students line up, three in the front and three in the back (left side, middle, and right side) of the classroom. Give each student in the front of the room a different "secret whisper message" to say to his or her partner across the room. Ask each student to say the message into the open end of a tin can (or yogurt cup) "telephone" that is connected (through a small hole on the bottom) via a taut, strong cotton string (or nylon thread, fishing line, or kite line) to another can (or cup) held up to the listening partner's ear. (*Note:* The two ends of the string can be secured in place in the hole in bottom of the cans by large knots, paper clips, or buttons. This activity again demonstrates that sound travels better through solids than through air.)

   Variations include the following:

   1. Test how the tautness of the string affects sound transmission (if the string is not pulled to a minimum tension, sound will not be transmitted).

2. Test the effect of a third student using his or her index finger and thumb to hold the string at the midpoint (sound transmission will stop).
3. Test which type of line works best (metal wire, nylon, cotton, or even a long piece of rubber band).
4. Test whether you can add a third party to the conversation by tying a single-line extension and cup at the midpoint of the initial line.
5. Challenge the students to come up with a way to ensure that the volume of sound produced in the two trials is held constant (e.g., replace a student in the activity with a portable radio).

Ask students application-level questions related to the transmission of sound through solids:

- In movies about scouts in the Wild West, buffalo hunters and railroad workers are seen holding their ears to the ground or rail track. Why did they do that?
- In old movies and TV shows, snoopy neighbors who live in adjacent apartments are sometimes seen trying to listen in on their neighbors' conversations by holding empty glasses up against their shared wall with the bottoms pressed against their ears. Why do they use glasses?
- Scientists who study earthquakes (seismologists) can easily "hear" and "feel" an earthquake that happens anywhere on Earth with instruments mounted to the ground that pick up sound vibrations, even though the scientists cannot hear the sound of the earthquake through the air unless they are quite close. Why is this?

2. *Macroscopic Models for Sound Transmission*. A toy Slinky can be used to model a longitudinal (or compression) wave such as sound to show how the energy is transmitted through the medium without permanent displacement of the originally affected molecules. Similarly, Newton's Cradle (a device where a row of five steel balls are suspended by nylon threads) or a row of marbles arranged along the groove of a ruler can be used to model the molecule-to-molecule transmission of sound energy. The closer the molecules (or marbles) are to each other the more efficient the sound transmission (i.e., sound travels better through

Safety Note

Metal wire (Variation #3 in Extension #1) can be sharp and cut the skin. Handle with extreme caution.

solids than through air). Students can also research the history and science behind Alexander Graham Bell's invention of the telephone up through modern cell phones.

3. *Research and Careers in Audiology* involve the improvement of the quality of the aural reality for individuals born with hearing impairments, people who have suffered hearing loss from occupational or recreational sound pollution, and people who are aging. A burgeoning area of research, audiology involves biology, neurology, and mechanical and electrical engineering. The question "Do you hear what I hear?" has become "How can I help you hear what I hear?" Students can use the internet to study and report on this exciting research.

Internet Connections

- American Educator (see also: *www.danielwillingham.com* for other articles and videos): "Brain-Based" learning: More fiction than fact: *www.aft.org/pubs-reports/american_educator/issues/fall2006/cogsci.htm* and Do visual, auditory, and kinesthetic (VAK) learners need VAK instruction?: *www.aft.org/pubs-reports/american_educator/issues/summer2005/cogsci.htm*
- Arbor Scientific's Cool Stuff Newsletter: *www.arborsci.com/CoolStuff/Archives3.aspx*
- Dallas Symphony Orchestra: Tin can telephone: *www.dsokids.com/2001/dso.asp?PageID=100*
- HowStuffWorks: Homemade toy telephone: *http://science.howstuffworks.com/question410.htm*
- Learning and Teaching Scotland: Science of sound animations (8): Speed of sound and sound waves in solids and gases: *www.ltscotland.org.uk/5to14/resources/science/sound/index.asp*
- PhET Interactive Simulations: Sound ("see" and adjust the frequency, volume, and harmonic content of sound waves): *http://phet.colorado.edu/simulations/sims.php?sim=Sound*
- Philomel Records: *www.philomel.com/index.html*. (This site sells two CDs of audio-based illusions: "Phantom Words and Other Curiosities" and "Musical Illusions and Paradoxes," both by Diana Deutsch.)

- University of Iowa Physics and Astronomy Lecture Demonstrations [select Acoustics]: *http://faraday.physics.uiowa.edu*
- University of Virginia Physics Department: (1) eight sound activity stations: *http://galileo.phys.virginia.edu/outreach/8thGradeSOL/SoundStationsFrm.htm* (2) Fetal ultrasound: *http://galileo.phys.virginia.edu/outreach/8thGradeSOL/UltrasoundFrm.htm* (3) Doppler effect: *http://galileo.phys.virginia.edu/outreach/8thGradeSOL/SoundfreqFrm.htm*
- Wake Forest University Physics Department: Sound demonstration videos: *www.wfu.edu/physics/demolabs/demos/avimov/bychptr/chptr6_sound.htm*
- Whelmers #67: Bells in Your Ears (variation on the Utensil Music activity [Procedure, step #1] using a pencil): *www.mcrel.org/whelmers/whelm67.asp*
- Wikipedia: (1) Sound: *http://en.wikipedia.org/wiki/Sound#Perception_of_sound* (2) Infrasound: *http://en.wikipedia.org/wiki/Infrasound* (3) Ultrasound: *http://en.wikipedia.org/wiki/Ultrasound*

Answers to Questions in Procedure, steps #1 and #2

1. The perceived sound will appear to be a low-volume, nonmusical, cheap or tinny noise when the string is held away from the ears. All sound involves the transmission of vibrational energy via molecular collisions.
2. The perceived sound is a louder, fuller, almost orchestral sound when the string is held up against the ear. Both the volume and quality (or timbre) are greatly enhanced. The same sound is being produced in both cases. In the first case, part of the sound produced traveled to our ears through air and part was dissipated through vibrations in the string, which were absorbed by our fingers. In the second case more of the energy traveled directly to our ears through the taut string. Sound vibrations travel better in solids than in air. This phenomenon can be related to the relative closeness of the particles in solids versus gases as visualized by the kinetic molecular theory.

Students could explore the effect of changing experimental variables such as the type of string (e.g., cotton, nylon, or thin metal wire) and the length of string. They could also vary the material or the type of utensil (e.g., plastic, wood, or metal; spoon or fork). They also might measure the length of time different students can hear the sound when a string-and-utensil setup is released from a constant angle (there will be some biological variation with hearing sensitivity).