Sound

2014-2-26

Description

In this activity students will explore musical sounds using tuning forks, wooden rulers, boom-whackers, and saxoflute toys. Students practice science and engineering practices by finding patterns, generalizing patterns and applying patterns to design an instrument.

Age Group

All

Estimated Time

20 minutes

Key Question

What physical properties of an instrument determine pitch and loudness of the notes produced.

Content expectations addressed

GLCES

- P.EN.E.3 Sound- Vibrating objects produce sound. The pitch of sound varies by changing the rate of vibration.
- P.EN.03.31 Relate sounds to their sources of vibrations (for example: a musical note produced by a vibrating guitar string, the sounds of a drum made by the vibrating drum head).
- P.EN.03.32 Distinguish the effect of fast or slow vibrations as pitch.

NGSS

These are the relevant sections from NGSS addressed by these materials. Students who demonstrate understanding can:

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

Supporting Practices and science process skills:

- Plan and conduct investigations collaboratively to produce evidence to answer a question. (1-PS4-1),(1-PS4-3)
- Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena. (1-PS4-2)

  Connections to Nature of Science:

- Scientific Investigations Use a Variety of Methods
- Science investigations begin with a question. (1-PS4-1)
- Scientists use different ways to study the world. (1-PS4-1)

Teacher Background

- Sound is a wave, that is a repetitive longitudinal vibration, in air.
- Sound waves can be characterized by amplitude and either wavelength or frequency.
- Typically sounds are made up of many different frequencies, although a single frequency sound can be made. Musical sounds are made up of frequencies that are typically related to each other by integer multiples. in this activity students will not be able to explore the relation of different frequencies within a sound.
- Amplitude is the measurement of the maximum displacement of air particles in wave, in terms of waves at the beach it is how big the waves are.
- Wavelength describes the length between successive repetitions of the wave, in terms of waves at the beach it is how far apart the waves are.
- Frequency is the time the wave takes to repeat itself, in terms of waves at the beach it is the time between waves.

- Wavelength and Frequency are related to each other via the wave speed $wavespeed = wavelength \times Frequency$
- Our perception of sound is based on three characteristics, pitch, volume (loudness), and timbre. Timbre of a sound describes the quality of the sound, it is related to the relative strengths of different frequencies of vibration within a sound. Timbre is not accessible within this activity.
- Pitch is physically related to the frequency and wavelength. Higher frequencies (which have shorter wavelengths) produce higher pitches.
- Volume (loudness) is physically related to the amplitude of the wave. Larger amplitudes produce louder sounds.
- The frequency (therefore pitch) of sound produced by musical instruments depends on the size and stiffness of the vibrating object. In this experiment we ask students to compare pitch of larger and smaller vibrating objects. Students will find longer objects have lower pitch. If students compare different types of objects in size and pitch the rule they find will break down because the stiffness is different between the different objects. We do not intend for students to compare rulers to boom-whackers or tuning forks.

materials

Station 1

Tuning forks and a mallet to strike them with. A bowl or shallow pan filled with water.

Station 2

Wooden rulers.

Station 3

Two sets of boom-whackers.

Station 4

Saxoflute tubes: includes four whistle mouth pieces 2 Organizing boxes, Alcohol wipes or beaker of alcohol to sterilize after each student uses it.

Procedure

The event is designed to work at four stations. Students start with Station 1 and work through in order. Each station can support 4-8 students at a time.

1. Station 1 Tuning forks.

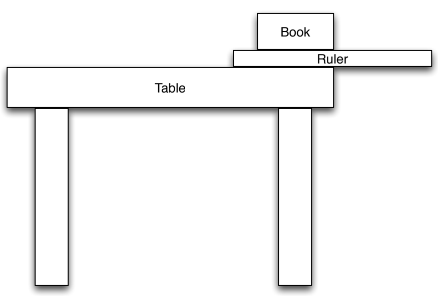
   Students will be looking for evidence that sound is produced by vibrating objects. They may also see that larger objects tend to make lower sounds.

   Students should have a chance to strike several tuning forks and listen to the sound each fork makes. They should strike a fork and look closely to see vibrations. This works best with a larger tuning fork. They should strike a fork and place the end in a bowl of water to see the surface of the water vibrate. Finally they should strike a fork and gently touch the end of the fork to feel the vibrations. This will be easier to do with the larger tuning forks.

   From this evidence they should be able to conclude that vibrating things make sound. They may also begin to make the connection between the length of the object and the pitch of the sound. They will have more direct evidence at the next station.

2. Station 2 Rulers. Students will be examine the sound made by the ruler when they hold it off the desk and pluck the free end. They do not need to hit the ruler very hard, one tendency will be to hit the ruler very hard to make a loud sound. To avoid this we have asked the students when testing the volume "what do you need to do to make the sound quieter", instead of louder.

   The ruler will work best if it is held firmly against the table. Smaller children may want to use a book to help steady the end of the ruler against the table.

   The Students should explore what it takes to make different sounds. The length of the ruler hanging off the edge determines the pitch of the note produced. The force of the plucking action determines the loudness of the note produced.

3. Station 3

   The sound of the boom-whacker depends on what it is hit against. If a surface is too hard or too soft the boom-whacker will not sound as well. Try out different surfaces to find a good one. They work well when hit against each other. I find my head works very well, but that can be a bit risky. Experiment with different surfaces and find something that works well in your classroom.

At this station students should verify the pattern that the found while exploring with the rulers. Longer tubes will make a lower sound. Hitting the tube more softly will make a softer sound.

4. Station 4

   At this station there are parts to make a flute. There are mouthpieces, bells, straight sections, Straight sections with holes, T junctions, and + junctions. The students can make any combination.

   - Everything will make a sound except for blowing backwards through the mouthpiece.
   - The sound of the flute will depend on the length of the tubing used.
   - A hole in the hole piece acts as the end of the pipe if it is uncovered.
   - If there are two paths, with two endings the pitch will be somewhere between the pitch of the long pipe and the short pipe.
   - If there are loops that combine back on themselves the length is the shorter path, unless the child can very carefully blow softly to make a lower sound.

   Clean the mouthpiece by dipping in rubbing alcohol and drying between each child.

1 Tuning Fork Station

1.1 Making Observations

At this station you will find a tuning fork and a mallet. Use the mallet to hit the tuning forks, don't hit the fork against the desk or another hard object. You might damage them. You don't have to hit the tuning fork very hard, the sound is quiet until you bring the fork right up near your ear.

- Strike a tuning fork, hold it near your ear. What do you hear?
- Try listening to several different tuning forks. Do all the forks make the same sound? Which ones sound higher or lower.
- Strike the tuning fork and look closely at the tips of the prongs, what do you see? Try using one of the larger forks.

  You can also try striking the tuning fork and dipping the tips of the prongs in a calm bowl of water. What happens to the surface of the water when you dip the fork in?
- Strike the tuning fork again and gently touch the tips of the prongs. What do you feel? You can touch the prongs gently to your cheek if you can't feel anything with your fingers. Try one of the larger forks.

1.2 Drawing Conclusions

- what do you learn about sound from these observations?

  What can you say about an object that makes sounds?

  What is the object doing when it makes sound?

2 Ruler Station

2.1 Making Observations

At this station you will find a wooden ruler. Hold the ruler so that it hangs off the edge of the table about halfway. Hold the part of the ruler on the table firmly against the table. Pluck the end of the ruler. You should hear a boing sort of sound. That is what we will explore at this section. You don't have to hit the ruler very hard, we don't want to break the rulers.

- Explore what happens as you change the length of the ruler hanging off the table, what happens to the sound?

  Does this have anything in common with the sound from the tuning forks?

- What do you have to do to make the sound quieter?

  Does this have anything in common with the sound from the tuning forks?

2.2 Drawing Conclusions

- What do you learn about sound from these observations?
- Do your conclusions agree with what you found with the tuning forks?

3 Boom-Whacker Station

3.1 Testing your ideas

At this station you will find a bunch of colorful plastic tubes. When you bump the tube against something hard like the floor it makes a boom sound. Each tube makes a different sound. You don't have to hit too hard, and don't hit people with the tubes.

By now you should have some idea about sound, use your idea to predict what will happen and then do a test to see if you are right.

Make these predictions, then test them

- Which tube will make the lowest sound?
- Which tube will make the highest sound?
- What do you do to make a quiet sound with the tube?

4 Saxoflute Station

4.1 Applying your ideas

Now that you have an idea about sound and you have tested it out you are ready to put it to work. Use your ideas to make a flute from the pieces in the bins.

- What do you think the job of the mouthpiece is? Why does it go first?
- How long did you make your flute? Why did you choose that length?
- Did you use a piece with a hole in it? What does the hole do when it is covered? What does the hole do when you uncover it?
- Did you use a junction like the T or the +? What does the junction do?

Do You Hear What I Hear?

A 5E lesson combines music, science, and students' backgrounds.

By Krista L. Adams, Jon Pedersen, and Nicole Narboni

Ask many elementary school teachers or principals, and they will tell you that science and music are not the top priority in their classrooms. From a teacher's perspective, if we simply provide the "evidence" that more science, music, and other arts needs to be taught in the classroom, we are doing little to foster change. Teachers need to know *how* they can incorporate the necessary mathematics and reading goals and objectives while still engaging students in the critical and aesthetic thinking developed through science and music.

It was this concern that brought us—science educators and a music educator—together to develop a lesson to integrate our subjects for classroom instruction. A natural link between science and music—sound—also provided a nice backdrop to highlight students' backgrounds. To integrate science, music, and culture may seem complex. However, one way that this may be accomplished is through a systems approach to teaching. A systems approach allows for a single system to be more fully examined in isolation. *A Framework for K–12 Science Education: Practices, Crosscutting Concepts and Core Ideas* (NRC 2012) defines the "Systems and System Models" as a small group of related components that is isolated from the larger system. The focus of a systems approach is on the relationships and connections between the parts as applied to a specific context while moving away from focusing on the individual parts (Llewellyn and Johnson 2008). Taking a systems approach allows scientists and students to investigate a small portion of a concept to understand the forces acting on that system. In the case of this lesson, sound waves can be seen as a subsystem of musical acoustics or the physics of music (Sullivan 2008). Within this system, sound waves are analyzed in terms of the pitch (high and low), loudness (loud or soft), and timbre (quality of sound). However, music is more than individual notes played in isolation. Music is organized notes in sequences that tell a story about the feelings and ideas the composer wants to invoke in the listener. It is this nature of music that makes it a cultural experience; each culture shares its own beliefs, ideas, and experiences through a variety of instruments and sounds. When we considered what it would take to understand and teach the idea of sound as a system, we decided that we needed more than just science to fully explain the complexity of sound, even at an elementary level.

The objectives of this lesson was for fourth-grade students to learn about sound waves as created by a variety of musical instruments in order to develop a model of sound waves by recognizing the similarities and differences in patterns caused by a series of sounds. We wanted our students to develop a model of the relationship between loudness and pitch with respect to a stringed instrument (e.g., guitar) in order to apply this knowledge to building their own instrument. With regards to the National Standards for Music Education (MENC 1994), we wanted our students to listen to, analyze, and describe music by identifying the properties of sounds created by a variety of instruments using appropriate terminology (i.e., *timbre* and *sound quality*) in explaining the sounds heard as well as develop perceptual skills about music from various cultures. We also wanted to capitalize on the cultural diversity of students by highlighting each individual's unique experiences and knowledge of music. Building on the students' everyday context is important for providing a meaningful experience by celebrating the diversity among students in the classroom.

Music Terms

Pitch and Frequency

Musicians use the term *pitch* to indicate how high or low a sound actually is, but scientifically this is referred to as the frequency. Frequency is defined as the number of vibrations in one second. Pitch (we will use this term throughout) can be altered by changing the rate of vibrations that can be accomplished by varying the tension or by changing the length of a string.

Loudness (Volume) and Amplitude

Loudness, or volume, is related to the height of a wave, amplitude. Differences between soft and loud sounds can be seen by plucking a string either lightly or heavily to produce small and large waves.

Sound Quality and Timbre

Sound quality, or timbre, is the distinguishing characteristic that allows the ear to identify a sound with the same pitch and loudness. This correlates to the science of sound as different types of vibrations produce different qualities of sound. For example, the student would be able to distinguish a clarinet and piano playing the same note.

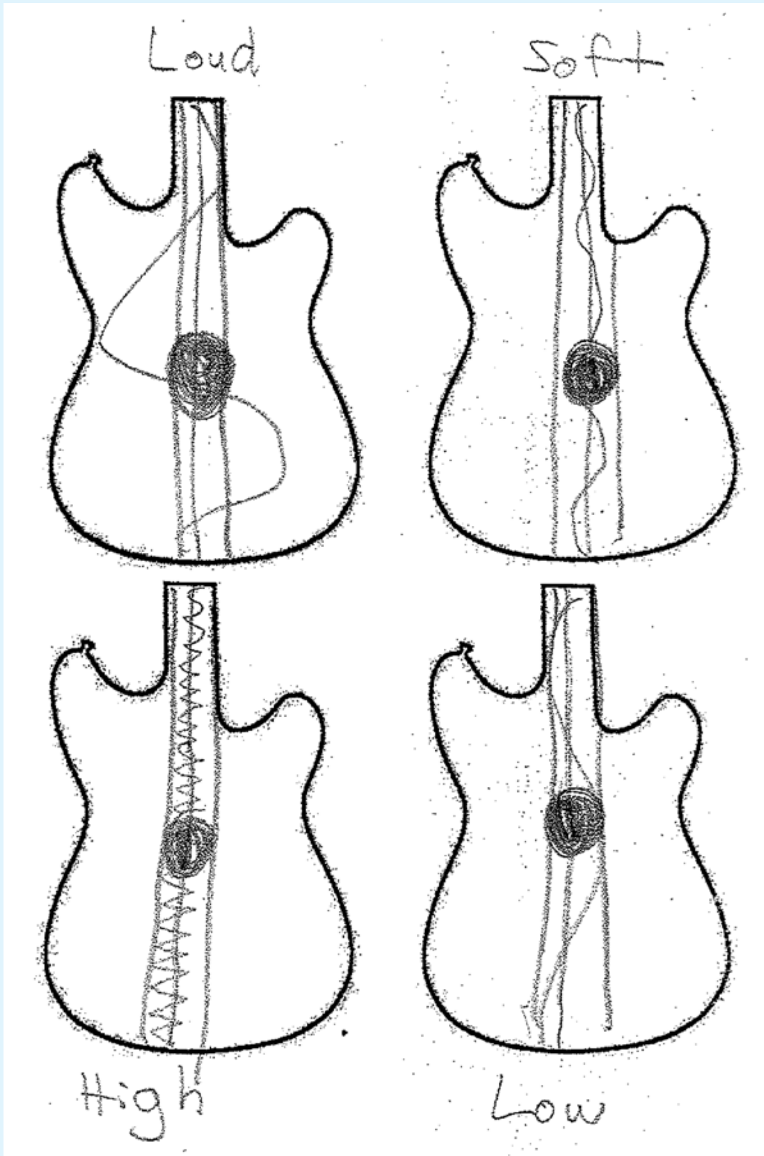
Where To Start

We used a 5E (Bybee et al. 2006) learning cycle to engage the children in a guided process of collecting data, analyzing data, and applying their new understandings about the concept of sound. The big ideas involve pitch and frequency, loudness and amplitude, and sound quality and timbre (see "Music Terms" sidebar). The 5E lesson was implemented across five days of instruction to allow fourth-grade students time to develop and test their model of sound waves.

Prior to starting these lessons, you will need access to tuning forks, a piano or guitar, drums, and a computer or listening device (e.g., CD player or MP3 player) with external speakers along with a variety of music CDs or digital audio files featuring world music from various cultures. For this lesson, the tuning forks were obtained from a science kit on sound but can be purchased through various online sources. We collaborated with the music educator in the building to access the piano, drum, and guitar. We used both a piano and guitar for instruction, but using only a guitar or video of someone playing a guitar would be sufficient for demonstrating a stringed instrument. Another resource for instruments would be to encourage students and parents that play an instrument to participate during the Elaborate section by bringing the instrument to share with the class. We also used the local library's music collection and our own personal MP3 files to provide a variety of music from around the world. Consider asking parents to share examples of music they listen to at home. Building on a culture's music is a great way to validate the student and their family's unique experiences in the learning process (Ness, Farenga, and Joyce 2003).

FIGURE 1.

Student data sheet.



Engage

We began the first lesson by asking students to quietly think for 10 seconds about their favorite song or musical artist. After a lively discussion of favorites from a variety of genres such as hip-hop, rap, and country, we asked how the music made them feel (e.g., happy, sad) or what the music made them want to do while listening (e.g., dance, sing). Students began to describe the music as making them feel like "dancing" and "jumping around" while others talked about feeling "happy" or some other emotion. To engage students in discussing their family's culture, we asked the students to describe the type of music their family listened to or played at home. At this point, students added a few more examples from a variety of genres like Latin and jazz. One student asked if "singing" was considered an example. At this point, we encouraged students to discuss where the music originated and the significance of those songs. Was their song religious? Played only at family gatherings? For special occasions such as a wedding? Did it have a special meaning? Students responded with more information about what their family's choices in music, but some began to discuss differences in experiences saying, "Is there different music to play at weddings?" and "We like to listen to the oldies." To build connections to the idea of significance, we also played several audio recordings of world music (e.g., Maori) and asked students to describe what they thought the music was about and made them feel—the color of sound. While listening to Maori singers perform "Whakahoro raku" by Te Matarae I Orehu, students were dancing and "beating" the desk along with the

FIGURE 2.

Using a tuning fork.

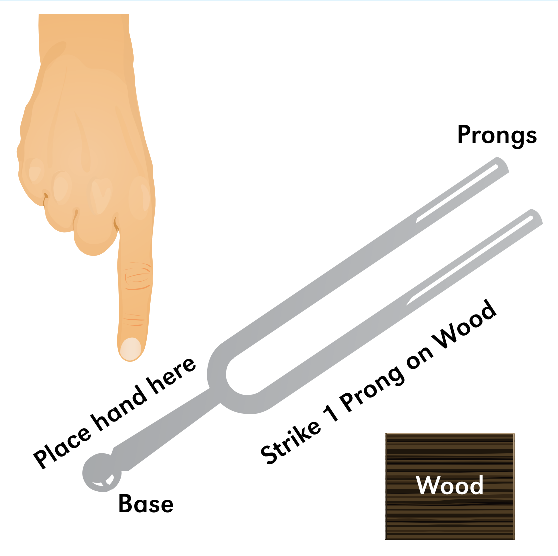


FIGURE 3.

Sound scoop.

music. Students wondered if the song was performed "before going into war" or "used for everyone to row a boat [keep time]." The emphasis was on the individual and shared cultural experiences of the students as expressed through music.

On the second day of the lesson, we asked students to think quietly for 10 seconds about what they heard when listening to the various music examples. In the whole-group discussion, students initially suggested "words," "singing," and "types of instruments," without discussing sound waves, pitch, or loudness. To connect music to science, we probed students about the different types of sounds they had heard, how they were similar, and how they were different. In the discussion, students began to identify the differences in the pitch and loudness of sounds. To determine what students already knew about how these different sound waves are created, we asked them to take two minutes to draw a string onto a picture with four blank guitars to depict each type of sound: high pitch, low pitch, a loud sound, and a soft sound (Figure 1; see NSTA Connection for the guitar handout and answer key). The students' initial drawings were then placed in the students' science journal for reference during the subsequent activities.

Next, we asked students to share with their table partners the similarities and differences they found in their drawings (the room is set up with four students at one group of desks). The students were then asked to use a different colored pencil to make modifications to the drawings based on new ideas about sound waves after talking with their peers. After giving students a few minutes to share the drawings, we engaged in whole-group discussion about the common elements students had observed among the pictures. The students noticed that their drawings of loud and soft sounds were similar, with most showing a string with large (for loud sounds) and small (for soft sounds) waves. However, the students were perplexed about how to depict the high and low pitches. Some students drew similar models as drawn with loudness; only one tried to rationalize a shorter string for pitch but could not incorporate this idea of a shortened string with respect to an actual guitar; and one student discussed how the thickness of the strings impact the pitch. We instructed students that they were going to test their ideas about how sounds are created in a string instrument through a series of activities. Students were also encouraged to ask their own questions about sounds and record these in their science journal.

Explore

The next day we began to collect data about the science of sound using a tuning fork and a sound scoop. First, we demonstrated for students how to strike a tuning fork against a block of wood (see Figure 2). Paired students were then given a tuning fork (any frequency will work),

PHOTOGRAPHS COURTESY OF THE AUTHORS

Sound scoops were used to explore sound transmission.

a small block of wood, and a cup half-filled with water. The students were instructed to hold the fork about 5 cm from their ear and record observations into their science journals. Next, students were instructed to strike the tuning fork once more and gently feel the tuning fork. After letting the tuning fork "rest" for about 3–5 seconds, the students then were asked to hold the tuning fork next to their ear and then touch it. Students then were asked to strike the tuning fork again but immediately place the "forked" ends into the water and instructed to collect data about what they saw and what they heard. Care should be taken while working with water by using a paper towel to capture any spillage and to dry the tuning fork before the next exploration. Students naturally want to tap tuning forks on random surfaces. Instruct students on the proper technique for using tuning forks and only use the wood block provided for striking unless otherwise instructed. Students also need to be mindful of not touching the ear while listening to the tuning fork. After the series of tasks, students were asked to summarize findings into the science journal. To help students with what to record, we asked them to describe what they heard when striking the tuning fork and what they saw when placing the tuning fork into the water.

In the second exploration, students were asked to use a sound scoop created by attaching a 20 cm string (preferably fishing line) to a paper clip and threading it through a pre-punched hole in the bottom of a plastic cup (see Figure 3, p. 59). To punch the hole, we used a nail and hammer to create a small opening in the base of the cup.

To use the sound scoop, paired students were instructed to designate one student as the "ear" and place the sound scoop over the ear. Their partner would then hold the end of the string taut and "strum" the string like someone playing the guitar. Students were instructed to record in their science journal what they saw and what they heard using pictures to show the data they collected. After one student had acted as the ear, the students switched roles and continued to make observations about what was occurring with the sounds they heard. They were also encouraged to explore other ways to manipulate the sound scoop using additional materials (e.g., yarn, dental floss, and thread) to serve as the string and record their findings in their science journal. Questions for students to consider while exploring included "Did the sound you heard when you plucked the string sound different from when your partner plucked the string?" "What happens to the sound if the string is not held tight?" "What happens to the sound as you change material?" After exploring with the sound scoop, students wrote down observations about the effect of various materials and ways of strumming the sound scoop into their science journal. Stress to students the importance of proper use of the sound scoop. Remind students that use in a way other than the sound scoop's intended use could cause harm to themselves or classmates.

Explain

As the students finished the explorations, we had them discuss in table groups the results of the activities in terms of the nature of the sound waves. We interacted with the groups by listening, providing feedback, and asking probing questions. For example, we ask questions such as "Why did you hear different sounds as you strummed the string?" "Why did you see waves with the tuning fork and water?" "How were the tuning fork and sound scoop similar?" "Why did you see similarities and/or differences in your observations? Why do you think that?" and "What if the sound scoop and tuning fork produced the same note would there be any differences to the model of waves?" Students started making connections between sound waves and how instruments are struck in order to create variations in timbre, pitch, and loudness. Once groups had come to some form of consensus, we passed out another sheet with the blank guitars in which the students were each asked to draw a new model of how the sound waves behave in terms of loudness and pitch. After completing the new drawing, students were then instructed to compare this model with their initial drawings in their journal (from the Engage phase). The students were then asked to write a brief description in their science journals about the differences between the first and second drawings of sound waves to show student growth in understanding.

CAUTION

Elaborate

In order to elaborate, we wanted to make sure that we brought students to understand the broader concept of "sound" by using music to understand the complexity of sound. We began by creating three stations where one group of students explored tuning forks again by striking them and placing them—"handle" (base) first—on the table or desk at which they were sitting. Students were instructed to listen and collect data by describing the quality of the sound in the science journals. Students were then encouraged to explore the room with their tuning forks in the same way, striking them and holding them against an object such as a door, desk, or white/blackboard. We asked students questions like "How is this different from just holding the tuning fork in the air?" and "If there is a difference, what differences do you hear?" While walking around, we heard discussions that addressed the quality of the sound as the tuning fork rested on different surfaces along with why some sounds seemed to hurt ears (e.g., high pitches).

The second station had students explore a drum with an intact drumhead along with a drumstick and a drum key (this is the tool that "tunes"—loosens and tightens—the drumhead). Students were asked to explore the drum and the sound that it makes by striking it with the drumstick. As previously indicated, students were given an opportunity to explore how the drum sounds "different" when struck differently or without the drumstick and only a hand. During this activity, data were collected and students were asked to consider the differences in the quality and characteristics of the sound produced as compared to the tuning forks. At this point, students shared their data and used the concept developed in the first half of this lesson—discuss pitch, loudness, and the production of sound. As students discussed their data, we guided the development of the idea of sound quality, which can include pitch (highness or lowness of a sound); timbre (quality of sound); and the color of sound (the quality and "feeling" that sound produces). Bringing in music education standards provides a path for students to develop a broader and deeper understanding of the idea of sound as more complex than just vibrations and begin to relate this idea directly to their day-to-day lives through music. If a drum, drumstick, and drum key are not available, using plastic wrap, a rubber band, and an empty oatmeal container can be used for an inexpensive version of this demonstration. The rubber band stabilizes the plastic wrap (or "drumhead") that is pulled taut over the container to varying degrees while students tap the drumhead.

At the final station, students explored a piano to bring together the ideas behind science, music, and culture by discussing the concepts of pitch, timbre, and colors. With this station in mind, engage students and parents ahead of time, asking them to bring in various instruments to help the class understand the complexity of sound waves. Students were asked to build on the totality of the experience from the beginning—(1) vibrations produce sound, (2) the quality of sound is enhanced by connecting vibrations to other solid objects, and (3) sound is complex and includes the elements of pitch, timbre, and color—by closely examining the components of the piano, observing the parts of the piano in action, and listening to various musical pieces. Upon completing the three stations, students compared the different instruments they observed in terms of the quality of sound produced.

> Bringing in music education standards provides a path for students to develop a broader and deeper understanding of the idea of sound as more complex than just vibrations.

Evaluation

We assessed student mastery in several ways. First, we gave students multiple opportunities to reassess their model of sound waves through observations and drawings in their science journals. Students' description of the change in models over time showed that students became aware of what is involved in producing a sound by adding a hand to the guitar as well as recognizing the different string diameters and lengths to produce a variety of sounds. Specifically, we used a science journal rubric (see NSTA Connection) to assess students' ideas about science and music. The science journal rubric included students' understanding of specific science and music concepts, ability to make connections between activities and models, and use of proper terminology.

For the final evaluation, table groups were asked to create their own instrument and describe how the sound is produced (what is vibrating and where?); describe the component parts of the instrument and their role in the production of sound; and provide their interpretation of the pitch, timbre, and color of their own instrument. Students were also encouraged to create a musical piece for their instrument. After creating the instrument, each group orally presented information about it as they displayed and performed with the new instrument to the class. Throughout the presentations, we examined and discussed patterns students had found between sound production, sound waves, and performance using an oral presentation rubric (see NSTA Connection).

Students answered a final set of questions: What have you learned about sound waves? Why is it important for a child or family member to be able to describe the music to which they listen? In what ways do musicians use the information they collect about sound? In what ways do scientists use the information they collect about sound? Last, students were challenged to determine all the ways the quality of sound is used in culture, professions, media, and entertainment. This was an expansion of the Engage stage discussion on the types of feelings created by listening to music.

Conclusion

Teachers in elementary schools are consistently put under pressure to "cover" those disciplines that are tested and limit—at best—their efforts to teach those areas that are not traditionally tested (science, social studies, art, music). Through a guided inquiry approach to teaching in the elementary school like the 5E Learning Cycle, teachers can incorporate multiple disciplines (science and music) by having the students examine a concept or big idea from a broad encompassing perspective that builds on students' background. Guided inquiry can effectively engage children in learning science from an interdisciplinary perspective and enhances students' understanding of the integrated nature of science. Using both science and music to study sound, we can say that scientifically students will hear what we hear, but musically it may be another story altogether. ■

Connecting to the Standards

Standard 4-PS4 Waves and Their Applications in Technologies for Information Transfer

Performance Expectations:
4-PS4-1 Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.
4-PS4-3 Generate and compare multiple solutions that use patterns to transfer information.

Science and Engineering Practice:
Developing and Using Models

Disciplinary Core Idea:
PS4.A Wave Properties

Crosscutting Concept:
Patterns

NGSS Table: 4-PS4 Waves and Their Applications in Technologies for Information Transfer
www.nextgenscience.org/4ps4-waves-applications-technologies-information-transfer

Connecting to the Music Standards

Standard: Listening To, Analyzing, and Describing Music

K–4 Achievement Standard:
c. Use appropriate terminology in explaining music, music notation, music instruments and voices, and music performances.
d. Identify the sounds of a variety of instruments, including many orchestra and band instruments, and instruments from various cultures, as well as children's voices and male and female adult voices.

National Standards for Music Education
www.philorch.org/sites/default/files/13-14-Nat-Arts-Achievement-Standards.pdf

Krista L. Adams **(kadams12@unl.edu)** ***is an assistant professor at the University of Nebraska–Lincoln in Lincoln, Nebraska. Jon Pedersen is an associate dean for research, also at the University of Nebraska–Lincoln. Nicole Narboni is a private music instructor in San Antonio, Texas.***

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NSTA Connection

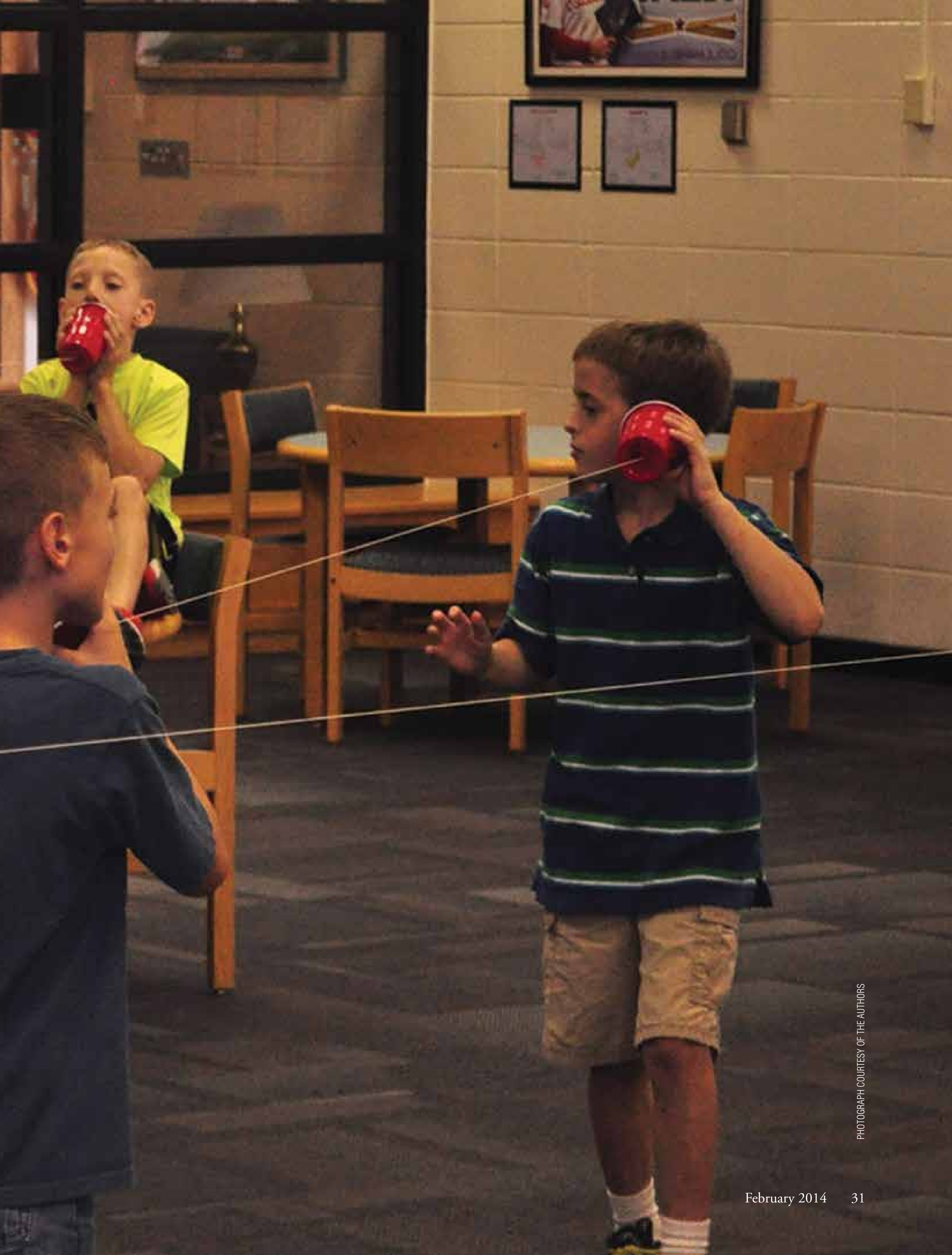
Visit *www.nsta.org/SC1402* for the guitar handout and answer key and the science journal and oral presentation rubrics.

The Sound of Science

AN ENGINEERING DESIGN CHALLENGE TEACHES STUDENTS ABOUT SOUND.

By Venkatesh Merwade, David Eichinger, Bradley Harriger, Erin Doherty, and Ryan Habben

"A more engaging way to teach the science of sound"



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Sound plays a critical role in our life. It is by sound that we can express our thoughts with speech, educate ourselves through broadcast media, and through natural and human-made noise, gain a sense of our surroundings. While the science of sound can be taught by explaining the concept of sound waves and vibrations, we focused our efforts on creating a more engaging way to teach the science of sound—through engineering design. In this article we share the experience of teaching sound to third graders through an engineering challenge that involves designing a stringed instrument. The activity, which corresponds to first- and fourth-grade *Next Generation Science Standards*, was implemented for third graders to satisfy grade 3 Indiana Science Standards. However, it can be easily modified for higher grades by incorporating more open-ended inquiry or design activities. The engineering challenge is divided into four discrete activities that took place over two sessions of 1.5 hours: inquiry, design, build, and test/evaluation. Each activity is designed to build on students' understanding of the characteristics and properties of sound. By using what they learn about sound from these activities, students are then encouraged to apply what they know about sound to complete the engineering design challenge.

Inquiry: How Is Sound Created and Transmitted?

We designed an inquiry-based activity to enable students to learn that sound is created through vibrations and that these vibrations move through media to transmit the sound from one location to another. We began by initiating an interactive discussion on sound and asking key questions such as: "How is sound created?" "What causes sound to travel?" "How does sound travel?" and "What is needed for sound to travel?" This discussion revealed that several of the students were able to identify that vibrations are a key component for the creation and transmission of sound, indicating that this concept was a part of their prior knowledge about sound.

After this discussion, the class was divided into five groups, with five members in each group. Each group was given one tuning fork and a string that was approximately 1.5 meters long. The students in each group were then asked to tap the tuning fork on their desk or chair to sense the vibrations by positioning it near their ear to listen to the subsequent sound generated through these vibrations.

Each student in the group was given a chance to tap the tuning fork and to observe the results. A few students tried this while holding the tuning fork by its tines rather than by the base, resulting in little or no vibrations. If held correctly, the vibrations can be sensed by either touching the tuning fork after tapping or by bringing the tuning fork closer to the cheeks or any other body part. Similarly, the sound from these vibrations can be heard by bringing the tuning fork closer to the ear after tapping.

Once the students understood the idea that sound is generated through vibrations, the concept of transmitting these vibrations through a medium was introduced by using a string with the tuning fork. The students in each group were instructed to pass the string through the tuning fork as shown in Figure 1. Next, one of the students in each group was asked to wrap each end of the string onto the forefingers of each of their hands, and then place their forefingers in their ears (see Figure 2). Then the students were asked to hit the tuning fork against a hard surface. We asked the following questions to the class: "What is happening and why is he/she hearing the sound?" and "Why is it different than the sound you get just by hitting the fork without any string?"

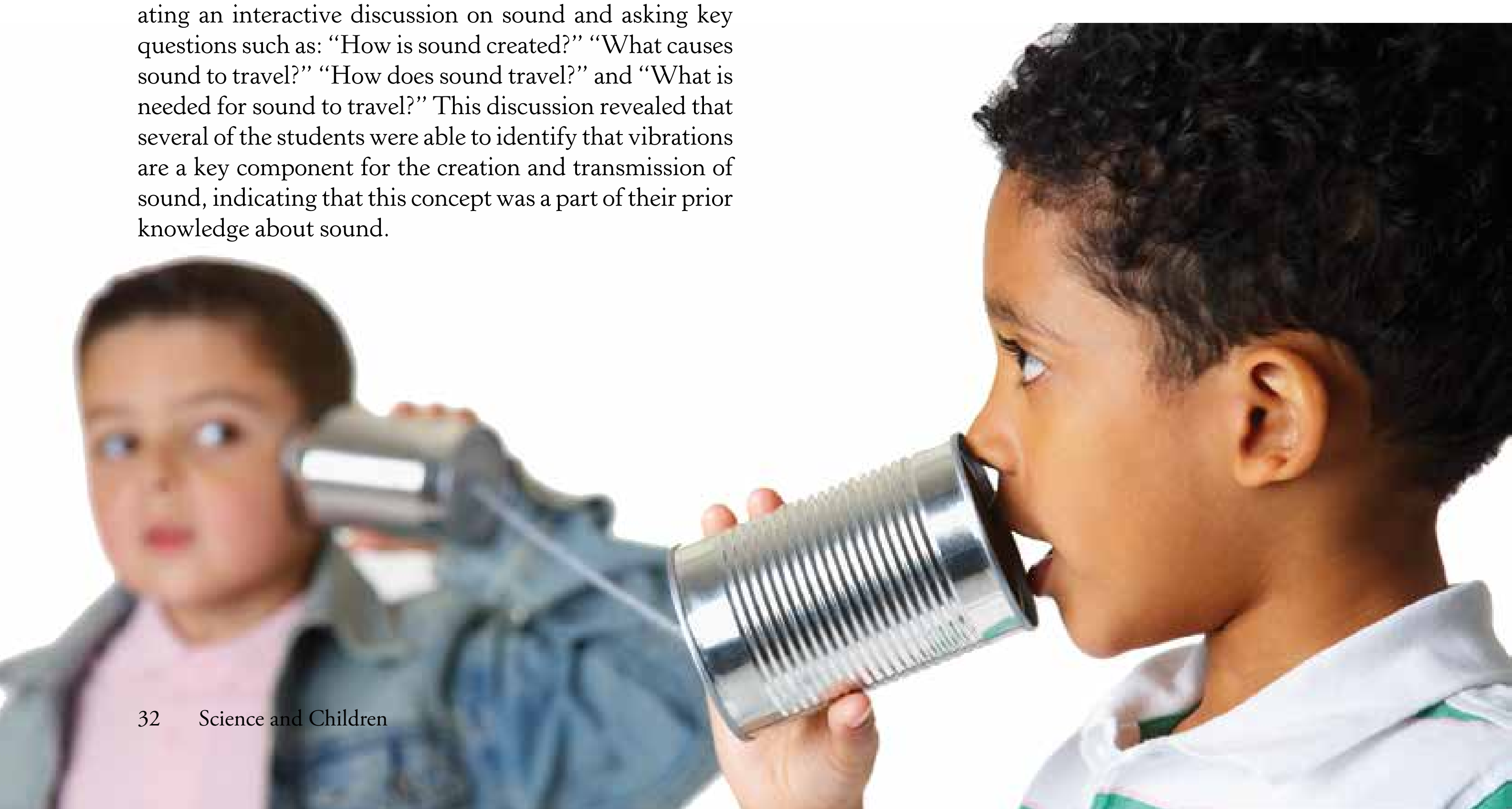

FIGURE 1.

Demonstration of passing the string though a tuning fork.

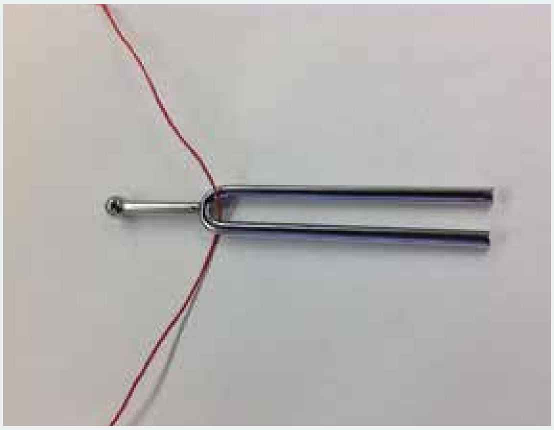

FIGURE 2.

A student hitting the tuning fork against a hard surface to hear the sound.

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When the tuning fork is connected to a string, the vibrations are transmitted from the fork to the string and to the ear drums through the forefingers. In this case the string is acting as a medium to transmit the sound or the vibrations from the fork to the ear. In most other cases (e.g., when we speak or play music), the air acts as the medium to transmit the sound from the source to our ear drums. All of the students noticed that when using the string, the sound of the tuning fork was louder and had a different pitch than when used alone. Many of them compared it to the sound of a church bell.

The next activity involved the use of a homemade string phone to further explore the concept of sound vibrations traveling through a medium. The string phones can be made by using any type of disposable cups connected by a length of string. Strings that work best for a string phone include sewing thread, fishing line, or kite string. Two phones were made using the same type of sewing thread with different lengths. The objective of this activity was to help students understand sound vibrations and to investigate the effect of the distance of travel on the transmission of these vibrations by using string phones of different lengths made from the same material. While creating a string phone itself can be a fun activity to do with students, it may detract students' attention from the actual activity. In our application, these phones were prepared in advance. Instructions for creating a string phone can be found online (see Internet Resource).

The students explored the effects of the distance of travel for sound vibrations by using the string phones. Students worked in pairs to use one of the premade string phones. Students soon realized that the sound transmission was better when the string was pulled taut between them than when the string was slack. After allowing students to use the phones for several minutes, we had them summarize some of the things they learned from this activity. Students mentioned the effects of the taut versus slack string. Several students explained that when they stretched their string taut and then stood such that their strings touched and overlapped at a 90° angle (forming an X with their strings), then one person could speak into his/her phone and all three of the other students could hear his/her voice.

Introducing the Design Challenge

In the design challenge, students were asked to address the design problem based on the knowledge they gained from the inquiry activities. The students were presented with the following challenge:

> Your school is on a field trip to the city to listen to a rock band concert. After arriving at the concert, you

were told that the band's instruments were damaged during travel. The band needs your help to design and build a stringed instrument with the available materials. Your design must satisfy the following criteria and constraints.

Criteria:

- Produce three different sounds (pitch)
- Your instrument must include at least one string

Constraints:

- Only available material should be used
- The instrument should be no longer than 30 cm (or 1 ft.)

The challenge was introduced as a narrative depicting a particular problem that required a solution in the form of an artifact or a process (Capobianco, Nyquist, and Tyrie 2013). Any engineering design process is undertaken to respond to a particular problem. At the start of the design activity, it was necessary to introduce the students to the appropriate terminology involved. After the challenge was introduced, we asked students the following questions: "What is the goal?" "Who is the client?" and "What is the design?" The students were able to answer the first question relatively easily. Many students knew the meaning of *client* and were able to correctly identify the rock band as the client. It was difficult for them to separate the goal and the design, so we explained the difference. We also explained that the design is usually guided by certain criteria and constraints. The criteria and constraints were then discussed with the class (see NSTA Connection for a copy of the design brief).

After the challenge was clear to all students, the class was again divided into five groups. The students were then introduced to the materials available for the challenge (see Figure 3). Each group of students was then asked to create a plan or drawing of the proposed design for their instrument that showed each component with labels. We specifically encouraged students to create individual designs first, and then discuss their individual designs with other group members. The objective of this discussion was to encourage a collaborative approach where the students discuss the pros and cons of each design to come up with one single design for their group. Our main observations from this design activity included: (a) Not all students in all groups started with their individual design, but they participated in the discussion to finalize the design for their group; (b) All groups paid special attention to the available materials in preparing their design; and (c) Some of the students did not correctly interpret the meaning of a stringed instrument. After each group came up with a final design, they were allowed to collect the materials to build the stringed instrument.

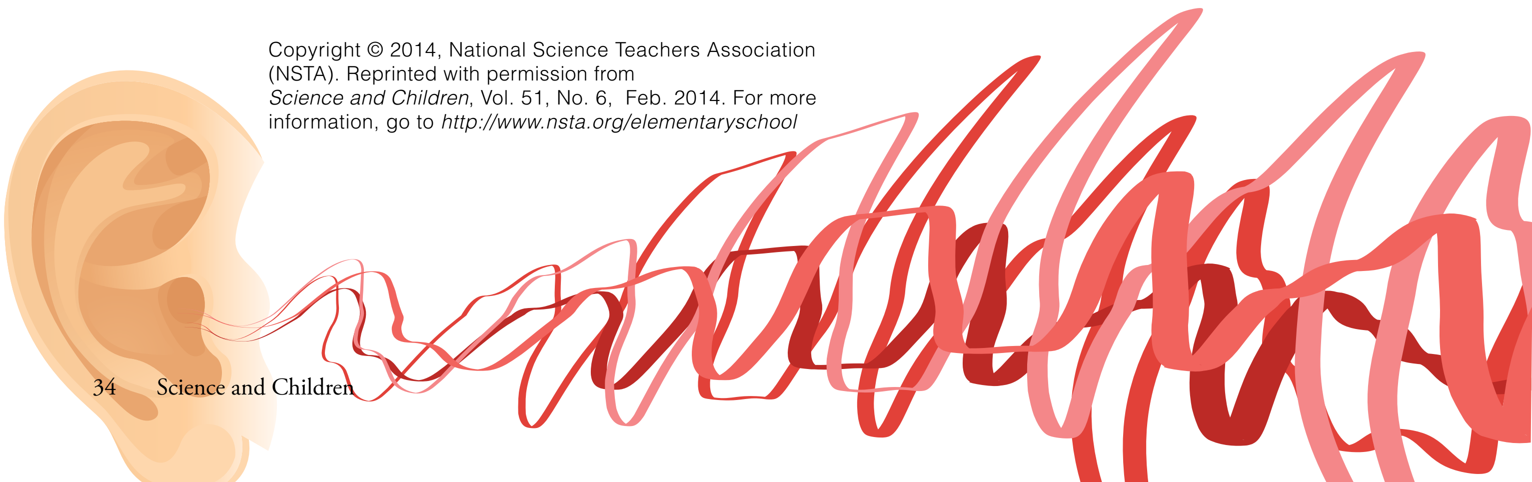
FIGURE 3.

Material list for the design activity.

- Boxes of various sizes
- Balloons
- Different kinds of strings (e.g., fishing line, sewing thread, thin metallic wire, and rubber bands)
- Glue
- Duct tape
- Masking tape
- Scotch tape
- Disposable cups (paper, plastic, foam)
- Plastic wrap

Build and Demonstrate

Each group had one or two members collect the materials required for their design. The team dynamics within each group were different. One group was certainly led by two members who created an instrument based on their designs, while the other members in their group showed minimal participation. Two groups showed participation



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from all members at varying levels. The remaining two groups realized that their design was not going to work as planned. As a result, each member in these two groups began constructing his or her own instrument. The students were given approximately one hour to complete their task. During the building activity, it was apparent that the students needed some clear instructions or even an additional activity that could reinforce teamwork or team building concepts. We think that doing a team-building activity before the design and build will address some of the issues we encountered with teamwork among the students.

After completing the construction of their instruments, one member from each group was asked to demonstrate their team's instrument to the whole class by producing at least three sounds or pitches. While two groups had more than one instrument, they were asked to present the one that was closest to their original design. The students were able to produce three different sounds. They were also asked to mention some of the drawbacks of their design or design process and how they could improve upon that. All teams mentioned that the use of appropriate strings and paying attention to its tightness could improve their overall sound. One of the dysfunctional teams also mentioned the issues within their team and how that led to construction of more than one instrument. See NSTA Connection for examples of student designs.

Evaluate and Conclusions

After finishing the activity, students created their own "exit ticket" on a piece of notebook paper. To complete the exit ticket, they were required to write one thing they learned about sound. Many made general statements such as "I learned that vibrations of string can make sound" or "Wrapping a string around your finger and placing the finger in your ear can act like headphones." Others mentioned things that didn't work in their group such as "Balloons cannot be used to make string instruments" or "Our group couldn't get along so my project didn't work, but I got to see how other groups created sound using the materials." This type of formative assessment helped us realize that this project aided the students in learning how sound is created and what materials students could use to design instruments that produce sound outside of the classroom.

While our activity stopped after the design demonstration and evaluation, this activity may be extended to have each group fix the flaws or shortcomings of their own instrument and come up with an improved design. Similarly, the use of proper vocabulary in a write-up may show students' understanding of all the technical terms associated with the sound. Innovative use of provided materials to develop multiple pitches or enhance the pitch can also be used for assessing students' learning.

Overall, we observed that the students walked away with a better understanding of how sound travels and what tools they could use to create sound and different tunes. More importantly, they were able to learn about the behavior of the types of the strings and their overall effect on creating the sound through the design process. ■

Venkatesh Merwade **(vmerwade@purdue.edu)** ***is an associate professor of civil engineering at Purdue University in West Lafayette, Indiana. David Eichinger is an associate professor of science education, and Bradley Harriger is a professor of computer integrated manufacturing technology, both at Purdue University.***

Erin Doherty is a sixth-grade teacher at Lafayette Sunnyside Intermediate School in Lafayette, Indiana. Ryan Habben is a fourth-grade teacher at Mintonye Elementary in Lafayette, Indiana.

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NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

Internet Resource

Constructing a String Phone
www.sciencekids.co.nz/projects/stringphone.html

Connecting to the Standards

Standard 4-PS3 Energy

Performance Expectation:
4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

Disciplinary Core Idea:
PS3.B: Conservation of Energy and Energy Transfer

Science and Engineering Practices:
Asking Questions and Defining Problems
Planning and Carrying Out Investigations
Constructing Explanations and Designing Solutions

Connections to Nature of Science:
Science Is a Human Endeavor

NGSS Table: 4-PS3 Energy
www.nextgenscience.org/4ps3-energy

Standard 1-PS4 Waves and Their Application in Technologies for Information Transfer

Performance Expectation:
1-PS4-1 Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.

Disciplinary Core Idea:
PS4.A Wave properties

Science and Engineering Practices:
Planning and Carrying Out Investigations
Constructing Explanations and Designing Solutions

NGSS Table: 1-PS4 Waves and their application in technologies for information transfer
www.nextgenscience.org/1ps4-waves-applications-technologies-information-transfer

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NSTA Connection

Download the design brief and see examples of student instrument designs at *www.nsta.org/SC1402*.

CREATIVE SOUND DRAMATICS

DRAMATIC MODELS OF SOUND TRAVEL EXTEND INQUIRY LEARNING FOR FOURTH GRADERS.

By Rebecca Hendrix and Charles Eick

"I feel like real particles and not dots in a book!"

Sound propagation is not easy for children to understand because of its abstract nature, often best represented by models such as wave drawings and particle dots. We wondered how science inquiry, when combined with an unlikely discipline like drama, could produce a better understanding among our fourth-grade students of how a sound wave travels through matter. Creative dramatics uses children's imagination, emotions, and movement to act through improvisation to learn academic material in the classroom. Creative dramatics helps children both retain academic ideas and learn them more deeply (Johnson 1998). We used creative dramatics as extensions in support of our children's ongoing inquiries in the Full Option Science Study (FOSS) module on the physics of sound (see Internet Resource). We found that children performed better on end-of-unit module tests when performing these extension activities integrated into their inquiry studies (Hendrix, Eick, and Shannon 2012). We used an adaptation of the Glasson Learning Cycle Model (Glasson 1993) to plan our sequence of drama activities for maximum effect into four phases or steps: Preliminary, Focus, Challenge, and Application. These steps mirror the 5E Learning Cycle steps of Engage, Explore, Explain, and Elaborate but with an emphasis on student dialogue on new learning in each phase. We will describe a series of creative drama activities that we used with the module section How Sound Travels, including how the teacher facilitates the process (see Table 1).

Preliminary Stage: Exploring Sound Travel

Before beginning the drama activities, students conduct a practice exercise that helps them learn how to feel comfortable with their bodies and use their bodies appropriately (see Figure 1 for tips for keeping students on task). This practice exercise helps to reduce the initial novelty of drama and related off-task behavior and silliness that can interfere with the learning experience. In the preliminary phase of the drama integration, we begin with a 15-minute body warm-up in which the teacher leads the children to imagine, invent, and mimic the movement of a sound vibration traveling through matter. The children are aware of sound vibrations and the nature of sound waves after completing the the first three modules in their FOSS curriculum. In previous investigations on how sound travels, students develop the concept that the energy of a vibrating sound wave can move from one place to another because it travels through a medium. The teacher provides the science setting: That sound is energy in the form of a vibration that travels through all matter. The teacher also coaches with prompts such as, "Pretend you are an air particle too small to be seen near the sound source of a plucked string of a violin. How would you move?" and "How would you cause the other particles to vibrate?" The activity gives children permission to enact and experience a model of a sound vibration as they conceive it. We use the music of Vivaldi's "Four Seasons" to help motivate and encourage individual body movement as a sound wave or vibration. Varying the genres of music used can add a more multicultural emphasis in the lessons. Children use the movement of their bodies to suggest the back-and-forth movement of a vibration coming from a sound source. They imagine they are sound waves traveling through the medium of matter. They use their head, arms, torso, and legs to model the wavelike motions of a moving sound wave. For example, they wave their arms and bodies away from the sound source to bump into another particle (student) who continues the motion.

The preliminary phase activity is a motivational and thought-provoking activity because children must get out of their seats and engage in initially thinking about the science that they are learning through movement. After the drama experience, children write and draw in their science journals their understanding of how air particles vibrate. Their initial ideas inform us of their understanding of the cause-and-effect nature of vibrating particles traveling through matter. With this initial understanding, we are

FIGURE 1.

Drama practice exercise and behavior management.

We use stop and start signals for the dramatic action. Children are asked to imagine that they have a bubble surrounding them. If they get too close to another person and into their space, then that bubble will burst. Then, playing some slow music, children move around the room to the music. The slow music is followed by another tune with a more rapid beat. These short experiences with movement help set the tone for expectations in the upcoming lessons. Any behavior problems that arise in this initial exercise are addressed with the children. In particular, we explicitly address the issue of respecting other children's physical bodies by not crashing into them or using limbs to accidently hit them. Running is also forbidden. While carrying out drama, we provide an adequate playing place or area in the classroom by moving the desks to the side. This rearrangement opens up the area in a classroom and sets the perimeters for the playing space to be used for about 15 children. Teachers with larger numbers of children and/or smaller classrooms can use the space in a cafeteria, gymnasium, or outdoor playground (with a whistle). Children are instructed not to run or inappropriately touch or push each other in their dramas.

TABLE 1.

Adapted Glasson learning cycle for creative drama activities for the FOSS module's section on "How Sound Travels."

	Teacher Activity	Student Activity
Preliminary	Explores student views on how sound is produced through creative dramas. Provides the motivational experience of integrating music and creative body movement to science concepts. Coaches children to visualize the rapid back-and-forth movement of a sound vibration.	Engages in creative movement activity to mimic the wave motion of a sound vibration. Values music and movement to learn about air particles, sound vibration, sound transfer, and sound mediums.
Focus	Teaches the tools of creative drama to act out scientific models of molecular motion. Guides children by asking open-ended questions of the effect sound vibrations have on particles.	Uses improvisation and pantomime to explore molecular motion. Uses literary personification to understand molecular motion. Records ideas in science journal.
Challenge	Introduces Compression and Rarefaction Guides the exchanges of views. Checks to ensure that all views are considered about air particles in a sound wave. Keeps discussion open. Presents the evidence from the accepted science point of view.	Seeks validity of concepts of how sound travels through additional reading in the science text about compression and rarefaction in a sound wave. Compares the accepted science view with the view of other children. Evaluates own view. Cites evidence of view based on science readings.
Application	Assists children to clarify views and to understand concepts from reading and investigations. Help children to apply the science concepts to build accurate models of sound science through dramatic improvisation, pantomime and literary personification.	Discusses and debates the best approach to present the group model of compression and rarefaction. Solves problems in model construction with collaboration of peers. Presents solutions as to the best way to construct the science model of compression and rarefaction in a sound wave. Presents models to the class. Engages in evaluation of models.

ready to introduce the tools of creative drama in the Focus Phase in order to construct still deeper understandings of how a sound source affects particles in different mediums as it travels.

Focus Phase: Building Models With the Tools of Creative Drama

In the focus phase, we begin with the concept of how a vibration from a sound source affects particles in different mediums: solids, liquids, and gases. In Module 3, students compare and record how a sound wave moves through different mediums, including solids, liquids, and gases. This is the phase where we first introduce, explain, and use the creative drama tools of improvisation, pantomime, and literary personification (Table 2). Before students can use these tools on their own, the teacher first leads the children through whole-class and small-group exercises where they learn through practice how to use each drama tool. We place the names of each drama tool on our word bank of terms that we keep from our previous FOSS lessons. The word bank is particularly important for our English language learning children. We use the tools in practice to communicate our notions of the vibrating motion of air particles previously explored.

We then seek to further combine language with the pantomime to understand sound travel through the invention of drama scenarios. The teacher introduces the drama scenarios for the class based on the targeted science concepts learned from the FOSS inquiries. Children working in groups of four to six write out their dialogue for their dramas to perform before the class. The prior introduction to the tools of creative drama serves as a catalyst for their use in planning and acting out models of understanding (see Table 3). In this way, children are meeting the scientific practice of Developing and Using Models to represent events (NGSS Lead States 2013). As groups plan

TABLE 2.

Creative drama tools used with practice examples.

Creative Drama Tool	Definition/Description	Activity examples
Improvisation	The art of creating dialogue on the spot through group interaction in order to create a sense of story or character without the use of a scripted play. (Can be applied to both animate and inanimate objects in science.)	**Improvisation Circle Activity** Children form a circle. Teacher guides an improvisation on moving particles in air through "I" statements that are completed by each child around the circle: Example: Teacher: I am a very small air particle and ... Child 1: I can cause other particles to vibrate and ... Child 2: I pass my energy of motion on and ...
Pantomime	The art of conveying ideas without words in which the body engages in physical movement much like dance to challenge the imagination and sharpen the senses. Note: Pantomime for science concepts is also the art of making the invisible seen through movement and invention.	**What Are You Activity** Children select action slips from the pantomime box for miming the physical action to the class individually or in small groups for others to guess: Example: Pretending to be a vibrating air particle striking a nearby still air particle
Personification	Giving human characteristics to animate or inanimate objects.	**If I Could Talk Activity** Children write first-person "I" statements in science journals about what an object [or concept?] (e.g., particle, vibration) might say if it could talk as a monologue. The activity is extended to include a dialogue between particles.

their dramas, the teacher listens closely to each group and facilitates thinking in helping link their dramas to the science concepts learned in the corresponding FOSS activity.

As groups perform, the class also listens to each group's thinking and construction of events in the scenario to assess elements of sound travel through the mediums of air, liquids, and solids. Some examples of children's performance statements include, "Spread out men! Let's move to the ear! Get ready go!" and "Excuse me fellow gas molecules but you need to vibrate!" The expectation in performance and class dialogue is that a new idea or expression of science meaning will occur from prior knowledge in the settings we have created. Our purpose is to interact, assess, and exchange dialogue with the children about how sound travels through all matter.

Challenge Phase: Introducing Compression and Rarefaction

The Glasson Learning Cycle stresses the exchange of ideas in science discourse and the importance of oral language in framing conceptions. In the Challenge Phase, we decide to dig deeper in learning about particle movement and sound vibrations by reading about compression and rarefaction in our science text. In this phase, children use informational text as evidence to support their thinking in linking learning from the science investigations and creative drama activities. In using these multiple modes of learning, the children also meet the following language literacy standards from the Common Core (NGAC and CCSSO 2010):

- ELA-Literacy RI.4.1 – Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.
- ELA-Literacy RI.4.9 – Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably.
- ELA-Literacy SL.4.5 – Add audio recordings and visual displays to presentations when appropriate to enhance the development of main ideas or themes.

The teacher poses the question: "What has to happen to particles to make sound travel to sound receivers in a medium like air?" We ask the children to particularly analyze the textbook picture diagram of compression and

TABLE 3.

Drama scenarios for enacting targeted science concepts in small groups with student examples.

Drama Scenario	FOSS Science Concept	Example Student Dramas
A mixture of air particles are gathered together when suddenly the music of a violin causes a stir of vibrating particles.	Sound vibrations travel through the gases in the air to a sound receiver.	Group invents the pantomime by swaying back and forth to mimic movement of air particles in vibration. Invents what the air gas particles would say: "I am an oxygen particle causing other particles to vibrate on the way to the sound receiver."
A group of submarine captains are traveling on a secret mission underwater to find the lost city of Atlantis. Suddenly, there is a sense of danger as the sub's crew hears the sonar ping of a distant submarine.	Sound vibrations travel through water.	Group invents the pantomime by traveling in two submarines underwater. Enemy submarine sends out a sound wave to the other submarine. Invents dialogue: "I hear the sonar ping, Captain! There is another ship." The submarine hearing the sonar ping sends back two pings to the enemy ship.
A group of solid particles make up the surface of a marching bass drum.	Sound vibrations travel through solids.	Children use classroom drum to march as particles of a solid that make up the surface of the drum. The striking of a classroom drum becomes the inspiration for moving particles that vibrate the drum's surface. Moving outward, the children pretend to make nearby air particles also vibrate through the air in all directions.

rarefaction. They learn from the informational science text how air particles are initially compressed nearest the sound source and then relaxed in rarefaction through oscillations that then travel in a sound wave away from the sound source through the nearby air particles.

The teacher encourages all the children to participate in expressing their views in a class discussion based on evidence from the text on how the particles in compression and rarefaction are arranged in a sound wave. They evaluate the accuracy of each other's thinking by comparing what is stated and the picture diagram in the science text. They try to evaluate their thinking in light of the ideas and model described in the text and whether their views make sense based on the given scientific knowledge. In this way, they use the textbook along with previous FOSS activities as evidence to support their thinking. The teacher guides the children to consider the accepted view of compression and rarefaction that is described in the text. We then write agreed-upon student statements about compression and rarefaction on large sheets of white paper tacked to the wall (see NSTA Connection). These sheets of paper provide a visual representation of statements for everyone to see as well as scaffolding for the next part of the lesson. The children will return to these statements to use as cited evidence in the Application Phase. This is particularly helpful for our English language learners. As a class we collaborate to compare and synthesize thinking through this phase in order to build (and later revise) a model of compression and rarefaction that can be acted out through drama in the next phase activity. In this portion of their learning, students are utilizing multiple scientific practices of: (1) engaging in argument from evidence as they communicate with one another and (2) developing and using models as they construct explanations (NGSS Lead States 2013).

Application Phase: Creating Compression and Rarefaction Models

In the Application Phase, children apply their refined understanding of sound travel by working in groups to create their own sound models using creative drama. We direct the children to collaborate with their group partners to develop a model of compression and rarefaction to perform for the class. The teacher instructs groups to use the agreed-upon ideas from the wall charts from the previous lesson in developing their models for greater accuracy. Groups also receive a rubric of essential components to include in their dramas and that will be used for peer evaluation of performances (see NSTA Connection). The teacher circulates, observes, and acts as the science and drama coach to facilitate group thinking on the science learned and its application to the dramas. After drafting and practicing their created drama models, student groups perform the models for the class to observe. The use of videotaping for each performance is helpful in allowing the class to review each performance for deeper analysis, discussion, and learning purposes.

Groups come up with many different creative ways to use the drama tools that they have learned to more accurately model the compression and rarefaction principles of sound travel. In one drama, a group of children led a particle conga line adapting the conga song rhythm to show particles vibrating and traveling in compression and rarefaction to the point of slowly fading out. Pretending to be vibrating air particles of oxygen, nitrogen, and water vapor, the children sang, "Everybody Conga," followed by a pause to drop the head, while pulling inward their arms and hands to shape the body as an air particle in compression, followed by saying "compression." The children follow this same method for the second verse but in this instance the chest lifted and expanded as particles spacing apart in rarefaction followed by saying "rarefaction."

FIGURE 2.

Creative drama group in their orange stretchy costumes.

The arms and fingers were spread out as far as the body would allow for a model of rarefaction in a sound wave.

In another drama, the children decided to use orange stretchy "particle" costumes available in our science classroom (see Figure 2). The children bunched together to mimic the compression of air particles and then spread apart to mimic the rarefaction in a sound wave. Their movements were set to their favorite songs that served as a sound source. Decision making and collaboration were evident as the children explored the best way to communicate their model and maneuver the orange material. Although costumes are not necessary to implement creative drama, their use provides our children with an additional motivation and excitement in their dramas.

Using the drama model rubric (see NSTA Connection), all children assess if each creative drama model implementing improvisation, pantomime, and literary personification is in keeping with accepted science views of compression and rarefaction. We discuss their assessments as a class. For example, in assessing the conga line drama, we discussed how the model was weaker on science accuracy because the performing group had the same particles traveling through space. The open-ended questions at the end of the rubric provide further self-reflection about sound from each performance. We observe that the rubric helps to sharpen their thinking on the accuracy of the science model created when compared with accepted science thought. For grading purposes, rubric scores are collected and averaged for half of the grade given for each group's work, with the other half being the teacher's rubric score.

Conclusion

Children enjoy getting out of their seats to learn science. Children greatly enjoy movement and action as they learn across academic disciplines through the use of creative dramatics. To the teacher of science, this simply means that children improvise science models through movement of the body that mimics accurately the science concept. Creative drama performs well as an extension to the abstract nature of concepts in sound travel. In addition, moving electrons or the biology of circulating red blood cells all become inspiration for building models of understanding through creative drama to make difficult concepts more concrete. This metacognitive strategy provides a great extension to inquiry-based science learning for concepts that are too small or not possible to see! ■

Rebecca Hendrix* (rebecca.hendrix@opelikaschools.org) *is a teacher in Opelika City Schools in Opelika, Alabama. Charles Eick* (eickcha@auburn.edu) *is an associate professor of curriculum and teaching at Auburn University in Auburn, Alabama.

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Hendrix, R., C. Eick, and D. Shannon. 2012. The integration of creative drama in an inquiry-based elementary program: The effect on student attitude and conceptual learning. *Journal of Science Teacher Education* 23 (7): 823–846.

Johnson, A.P. 1998. How to use creative dramatics in the classroom. *Childhood Education* 75 (1): 2–6.

National Governors Association Center for Best Practices and Council of Chief State School Officers (NGAC and CCSSO). 2010. *Common core state standards.* Washington, DC: NGAC and CCSSO.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press.

Internet Resource

Full Option Science System (FOSS) *Physics of Sound*
www.deltaeducation.com/productdetail.aspx?Collection=Y&prodID=1074&menuID=

Connecting to the Standards

Standard 4-PS4 Waves and Their Applications in Technologies for Information Transfer

Performance Expectation:
4-PS4-1 Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.

Science and Engineering Practice:
Developing and Using Models

Disciplinary Core Idea:
PS4A Wave Properties

Crosscutting Concept:
Patterns

NGSS Table: 4-PS4-1 Waves and Their Applications in Technologies for Information Transfer
www.nextgenscience.org/4ps4-waves-applications-technologies-information-transfer

NSTA Connection

Download a model evaluation rubric and see student statements at *www.nsta.org/SC1402*.

0 *Discovering STEM* Program

Sounds like Fun!

Materials:

Station 1

- Tuning forks
- A mallet to strike them with
- A bowl or shallow pan filled with water

Station 2

- Wooden rulers.

Station 3

- Two sets of boom-whackers.

Station 4

- Saxoflute tubes: includes four whistle mouth pieces
- 2 Organizing boxes
- Alcohol wipes or beaker of alcohol to sterilize after each student uses it