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.

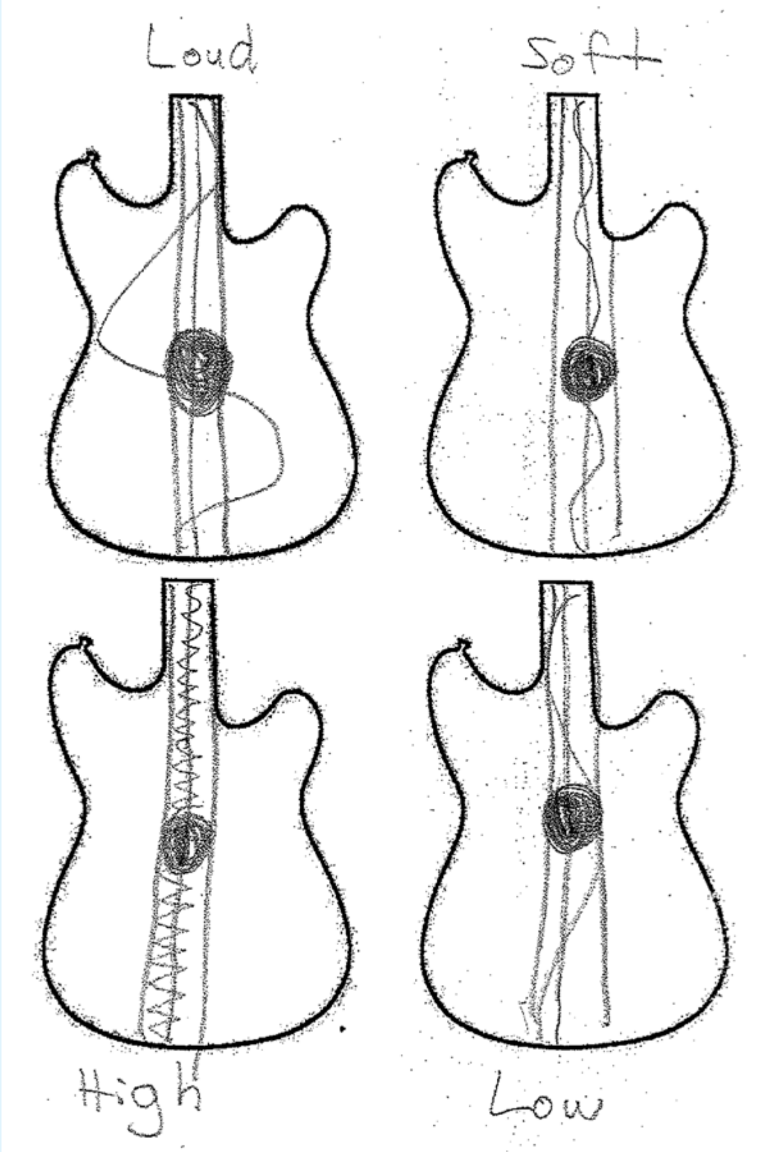
Where To Start

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.

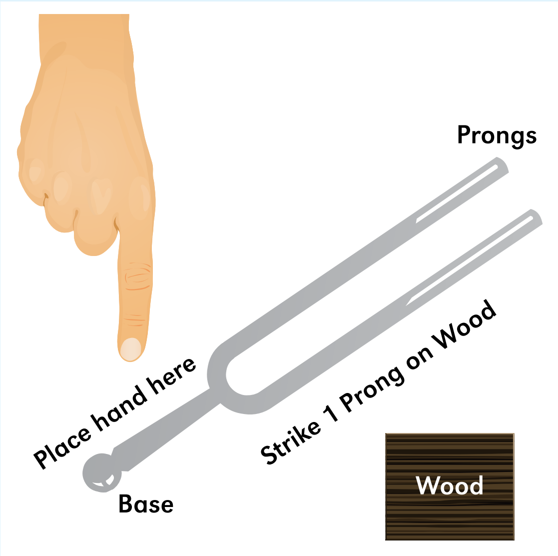


FIGURE 3.

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),

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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.

CAUTION

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.

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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*

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References

Bybee, R.W., J.A. Taylor, A. Gardner, P. Van Scotter, J.C. Powell, A. Westbrook, and N. Landes. 2006. *The BSCS 5E instructional model: Origins, effectiveness, and applications.* Colorado Springs: BSCS.

Llewellyn, D., and S. Johnson. 2008. Teaching science through a systems approach. *Science Scope* 31 (9): 21–26.

Music Educators National Conference (MENC). 1994. *The school music program: A new vision.* Reston, VA: Music Educators National Conference.

National Research Council (NRC). 2012. *A framework for K–12 science education: practices, crosscutting concepts and core ideas.* Washington, DC: National Academies Press.

Ness, D., S.J. Farenga, and B.A. Joyce. 2003. After the bell: Balancing the equity equation—The importance of experience and culture in science learning. *Science Scope* 26 (5): 12–15.

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

Sullivan, M. 2008. Career of the Month: An Interview with Musical Acoustics Scientist James Beauchamp. *The Science Teacher* 75 (2): 64.

NSTA Connection

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