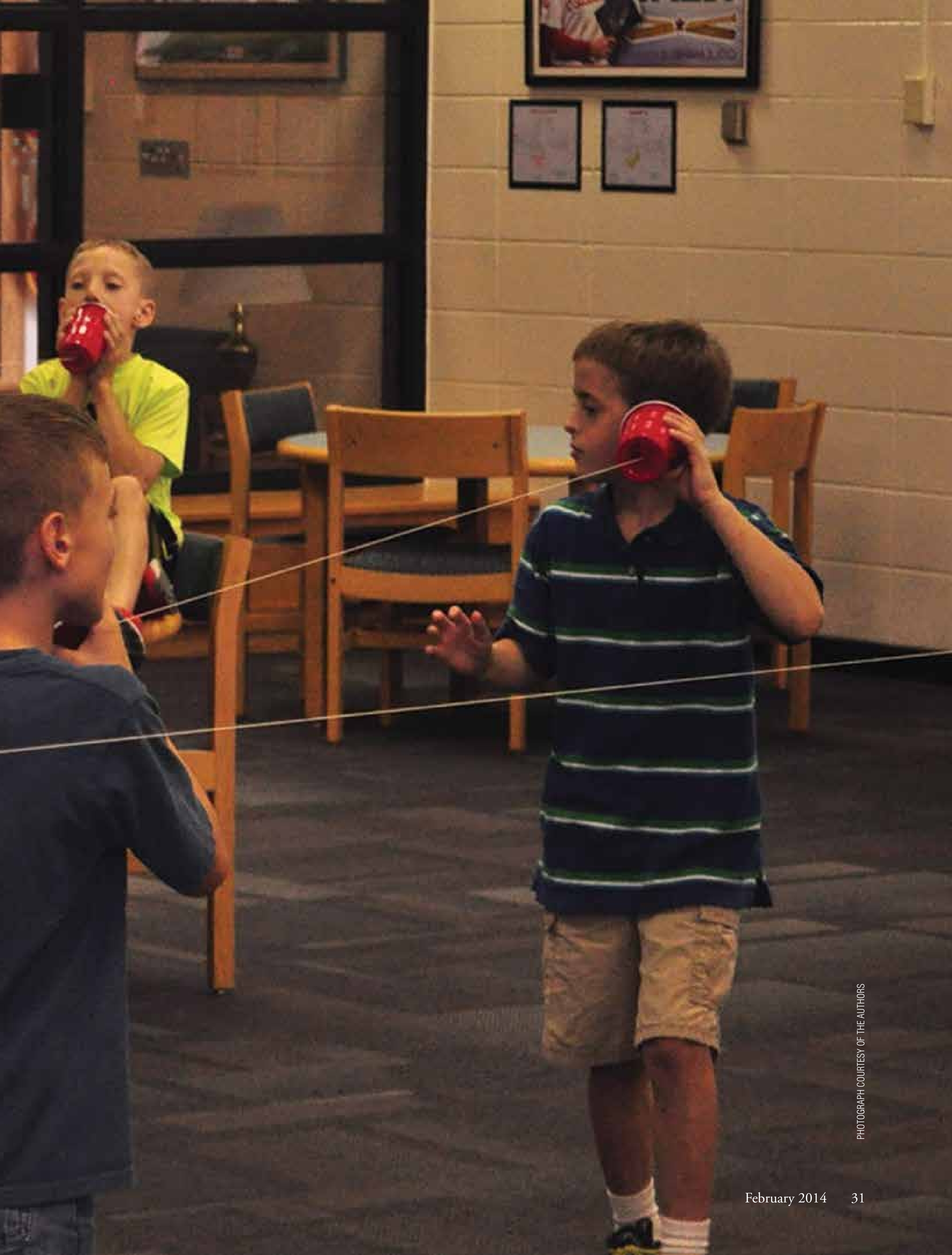
The Sound of Science

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?"

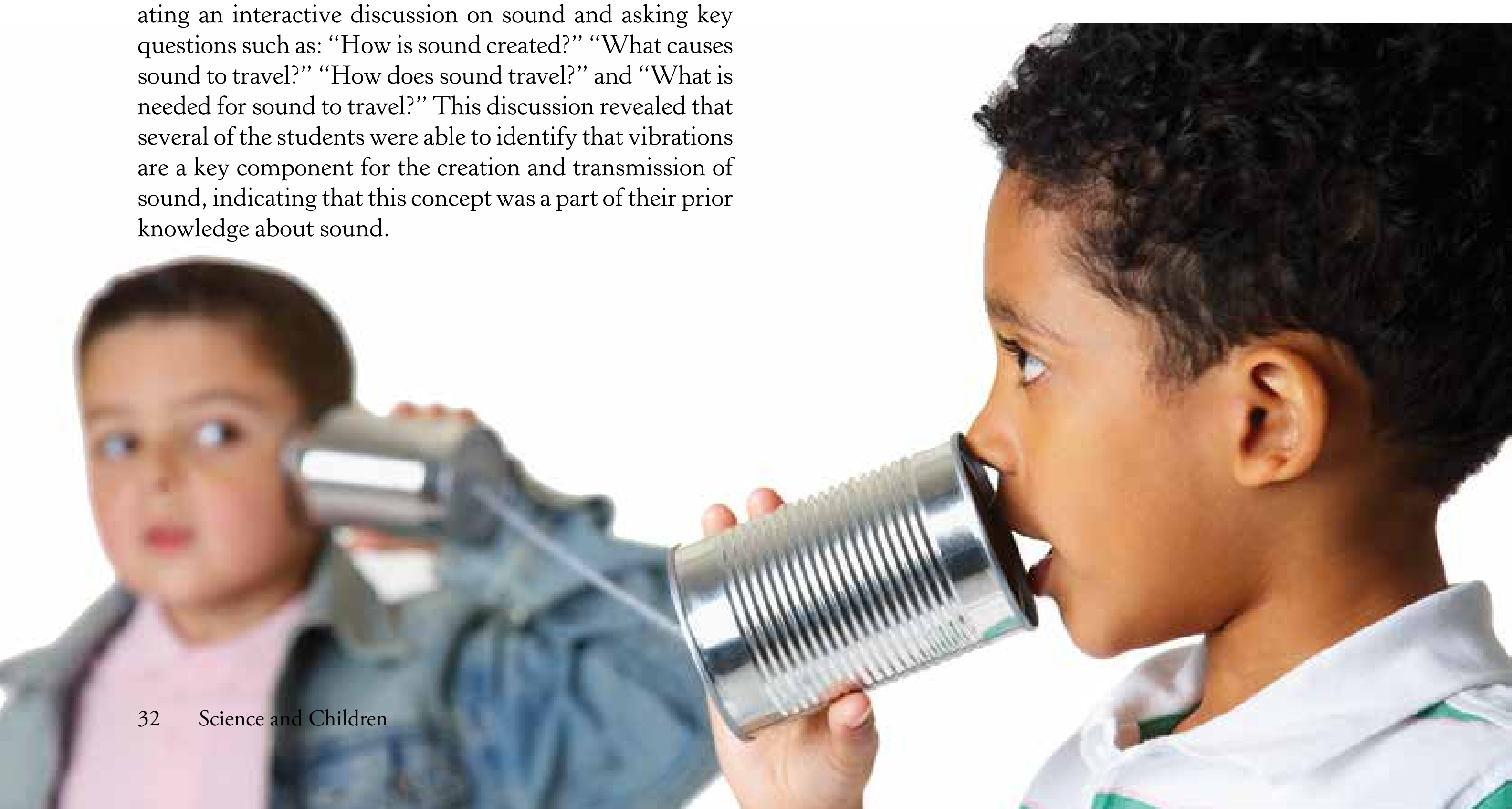

FIGURE 1.

Demonstration of passing the string though a tuning fork.

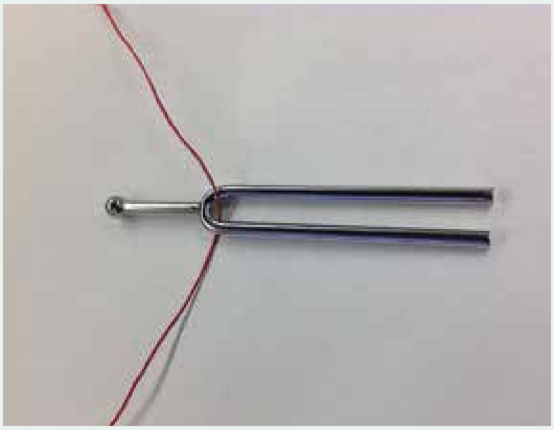

FIGURE 2.

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.

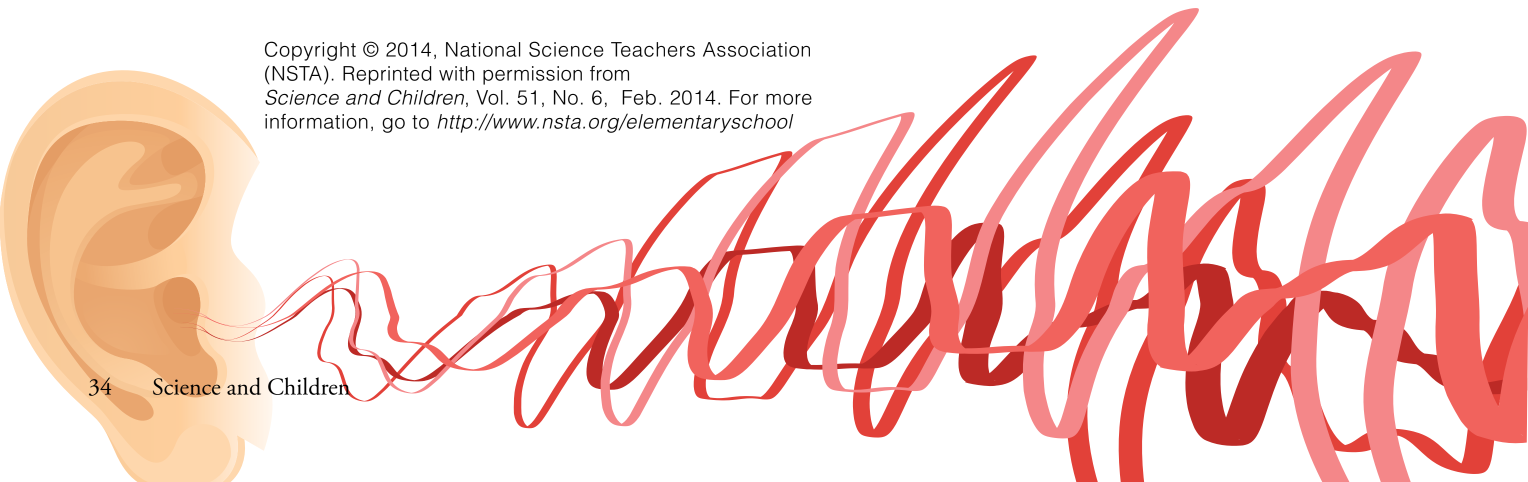
FIGURE 3.

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. ■

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References

Capobianco, B.M., C. Nyquist, and N. Tyrie. 2013. Shedding light on engineering design. *Science and Children* 50 (5): 58–64.

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*.