UNIT 2: SOUNDS GOOD

IN THIS UNIT, students explore sound by making stringed instruments and headphones and then playing tunes.*

UNIT TABLE OF CONTENTS

- **Overview:** Students change a virtual string's tension, length, and gauge to create different pitches and write a melody—just what they do in a "non-virtual" way in *Build a Band*.
- **Learning outcomes:** Use *String Thing* to: a) introduce the unit by defining relevant terms and giving students experience manipulating the variables they'll work with in *Build a Band*, or b) end the unit, as a culminating activity, review, or assessment of the unit's concepts.

- **Overview:** Students stretch four rubber bands around, over, or across a shoebox and tune them to different pitches by adjusting the strings' tensions and lengths. To maximize volume, they design an instrument that transmits vibrations well whenever a string is plucked. Finally, they work in pairs to tune their instruments and play a melody.
- **Learning outcomes:** Students will be able to design and build a tunable instrument and discuss how a string's tension, length, and gauge affect pitch. They will also be able to describe how they used the design process to design and build their instruments.

- **Overview:** Students apply what they learned about sound in *Build a Band* to design and build a headphone system. They choose either a string-telephone system or a tube-based option to carry the sound waves from the instrument to their ear. Then they determine the best place to attach the string or tube—where the instrument vibrates a lot when a string is plucked.
- **Learning outcomes:** Students will be able to explain how sound waves travel and describe how they used the design process to design and build a headphone.

- **Overview:** Students present their instruments and discuss the science and engineering behind their designs. They also watch two short videos: They meet a young engineer who uses sound to navigate a submarine, and they see how the *Design Squad* teams use the design process to refine their instruments.
- **Learning outcomes:** Students will be able to identify the science concepts exhibited in their work (e.g., sound energy, pitch, waves, amplitude, frequency, and wavelength), explain how the design process encourages them to think creatively to tackle a challenge, point out how they are thinking and working like engineers, and cite examples of how engineering is a profession centered on designing and building things that matter to people.

PLANNING YOUR TIME

Only have one class period available? Do *Build a Band*.

Two class periods? Do *Build a Band* and *Making It Real*.

Three? Do *Build a Band*, *Headphone Helper*, and *Making It Real*.

When should I do *String Thing*? Use *String Thing* to introduce or end a unit—or both! For details, see page 17.

"Solving a real problem is a turn-on, especially for kids with learning problems."

Rosemary B.
Fairgrounds Middle School
Nashua, NH

* For specific STEM standards, see Appendix, page 48.

STRING THING ONLINE GAME

String Thing is an interactive online game on the *Design Squad* Web site. In the game, students change a virtual string's tension, length, and gauge to create different musical pitches. These are the same kinds of changes they'll be making in the *Build a Band* challenge.

A class can complete *String Thing* in as little as 20 minutes, or the game can fill an hour. Use the game as an introduction to define relevant terms (e.g., frequency, pitch, gauge) and as a way to give students experience manipulating the variables they'll work with in *Build a Band.* Alternatively, use it at the end of the unit as a culminating activity, a review, or as an assessment of concepts and factors related to sound.

Preparation

- ☐ Decide if you'll do *String Thing* to introduce or end your sound unit—or both.
- ☐ Bookmark *String Thing* (Visit pbs.org/designsquad and click on "Play Games.")
- ☐ Copy the *String Thing* handout (one per student).
- ☐ Provide one computer per student pair, or project *String Thing* onto a screen to do as a class.

Procedure (20–50 minutes)
Distribute the handout and have students complete it, either in pairs or as a class. Review the terms ***tension, gauge,*** and ***length*** on the handout. If students are playing *String Thing* in pairs, give them 10–15 minutes before you start reviewing the questions together as a class.

Answers to questions on the student handout:

3. List three ways to lower a string's pitch. *(Lengthen it; reduce its tension; or increase its gauge.)*
4. Drag a long string and a short string onto the grid. Change the tension or gauge of these strings so they play the same pitch. Describe what you did. *(To raise a string's pitch, increase the tension, decrease its gauge, or both. To lower a string's pitch, decrease the tension, increase its gauge, or both.)*
5. Which changes the pitch more: increasing the gauge of a string by one click, or the length of a string by one fret? *(Gauge changes the pitch more than length does.)*
6. How do you play the highest note possible? *(Use a short, thin, tense string.)*
7. List some reasons why adult voices are usually lower than kids' voices. *(Pitch depends on the length and thickness of vocal chords. Long, thick vocal chords are lower pitched than short, light vocal chords. That's why adults have lower ranges than kids do—125 hertz [vibrations per second] for men, 210 hertz for women, and 300 hertz for boys and girls.)*

USING STRING THING WITH STUDENTS

Depending on computer access, *String Thing* can be done as homework, in small groups on classroom computers, or as an activity with the whole class using an interactive whiteboard or computer projector.

***"Design Squad* is the full package. This program brought cohesiveness to my unit."**

Doug S.
Concord Middle School
Concord, MA

THE STRING THING GAME

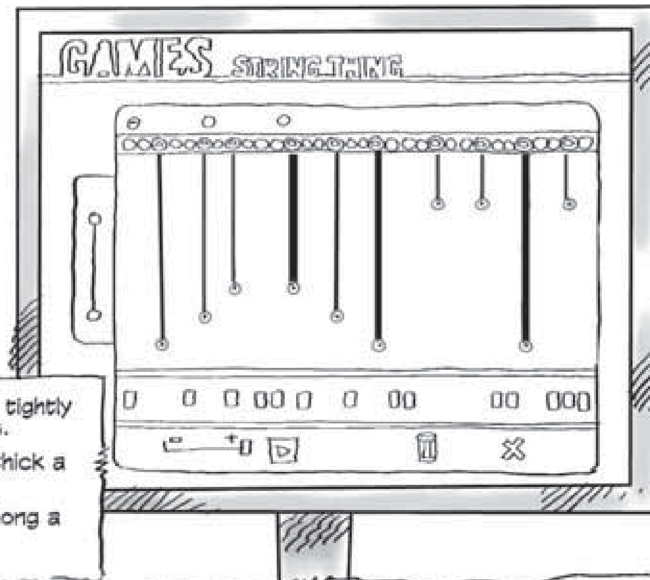
DESIGN SQUAD

as built on TV

pbs.org/designsquad

1. Open the String Thing game. If you need to go online, go to *pbs.org/designsquad* and click on "Play Games."

2. Drag strings onto the grid. Click on them to change their properties.



Tension is how tightly pulled a string is.

Gauge is how thick a string is.

Length is how long a string is.

3. List three ways to lower a string's pitch.

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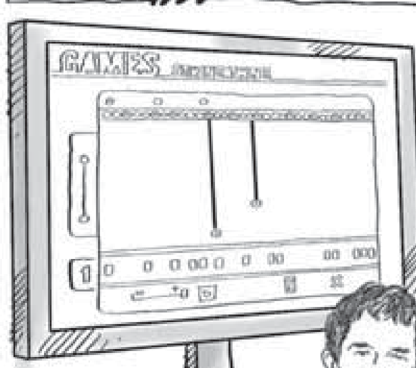

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6. How do you play the highest note possible?

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7. List some reasons why adult voices are usually lower than kids' voices.

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Major funding for *Design Squad* provided by

NSF intel Education the Lemelson foundation improving lives through invention

Additional funding for *Design Squad* provided by

NOYCE FOUNDATION NCEES National Council of Examiners for Engineering and Surveying ASME IEEE Celebrating 125 Years NORTHROP GRUMMAN Foundation

BUILD A BAND CHALLENGE

The Challenge: Build a four-stringed instrument that can play a tune.

Preparation

- ☐ Copy the *Build a Band* handout (one per student).
- ☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Sound Energy*** (30 seconds) and ***Pitch*** (1 minute). Be prepared to project them.
- ☐ Gather the materials (per student):
  - duct tape
  - scissors
  - 2 pencils
  - 4 craft sticks
  - 4 rubber bands (2 medium, 2 thin)
  - shoebox (both lids and boxes can be used to make an instrument)

1 Introduce the challenge (10 minutes)

- Have students touch the front of their throats and say something. Ask: How is what you feel related to sound? *(Students will feel their vocal chords vibrate. The vibrations cause sound waves that travel out through the mouth and into the air.)*
- Have them first make a high-pitched and then a low-pitched sound. Ask: How do your vocal chords feel as you change the pitch? *(Vocal chords tighten to produce higher-pitched sounds and relax to produce lower-pitched ones. They also vibrate at a higher frequency for higher pitches.)*
- Show ***Sound Energy.*** Discuss sound, vibration, and how our ears process sound.
- Ask students to list different kinds of stringed instruments. *(Guitar; ukulele; violin; cello; bass; mandolin; banjo; harp; piano; zither; dulcimer, etc.)* Tell them that today's challenge is to design and build a four-stringed instrument that can be used to play a tune.
- Who might be interested in a low-cost, low-tech instrument? *(Kids, parents, schools, recreation centers, camps, afterschool programs, people interested in new kinds of sounds. The message is: Music matters, because people love music and there will always be a demand for instruments and sound systems.)*

2 Brainstorm (10 minutes)

Brainstorm sound and pitch

- Remind students that instruments produce the sounds and pitches we call music. Then show the ***Pitch*** video to explain why we hear faster vibrations as higher pitches.
- What causes different pitches? *(Things vibrating at different frequencies)*
- What can affect a string's pitch? *(Its length, tension, and gauge)*
- How will a rubber band's thickness affect its pitch? *(With tension and length equal, a thicker rubber band will produce a lower pitch than a thinner one will.)*
- How is what you did with your vocal chords related to pitch? *(Throat muscles change the vocal chords' tension and thickness [i.e., gauge], producing different pitches. A vocal chord's length depends on the size of a person's throat and changes as a person grows. That's why adults' voices are lower than kids' voices.)*

Students build a four-stringed instrument and investigate how a rubber-band string's length, thickness, and tension affect pitch.

Students use duct tape to hold the rubber-band strings in place and tune each one to a different pitch.

Students tune their instruments by adjusting the length and tension of the rubber bands.

Finally, students pair up and play a tune together.

Brainstorm the design process

- You can slip rubber bands around a box or cut the rubber bands open, making strips that you tape down. Brainstorm ways to keep a rubber-band strip securely in place. *(Tape down one end. Then drape the other end over the box edge and tape it down so the rubber band pulls against the edge of the box. Students can also pass rubber bands through holes they poke in the box.)*
- Brainstorm ways to keep the box from interfering with how the rubber-band strings vibrate. *(Make a "bridge" by slipping pencils or craft sticks under the strings to raise them off the surface.)*
- Brainstorm some ways to tune a rubber-band string to a different pitch. *(Stretch or loosen it or make it longer or shorter.)*

3 **Summarize the problem to solve** (5 minutes)

- Break the larger challenge into its sub-challenges. Ask: What are some of the things you'll need to figure out as you make your instrument? *(What box to use; what side of the box to put the rubber bands on; how to make strings out of rubber bands; how to attach the strings; how to tune the strings; how to make the instrument loud)*
- To promote creative thinking and foster a sense of ownership, have students pair up and brainstorm their own ways of turning these materials into a four-stringed instrument. Distribute the handout and have them sketch their ideas.

4 **Build, test, and redesign** (25 minutes)

Here are some strategies for dealing with issues that may come up during building:

- **Trouble hearing:** Keep the room as quiet as possible and have students remove anything that interferes with the strings' vibrations traveling through and then out of the instrument, such as excess tape.
- **Trouble with tuning:** To lower the pitch a little, stretch out the rubber band, making it just slightly longer. Also, raising or lowering the height of the bridge will change the tension and increase or decrease the pitch. Finally, students can adjust a rubber band's tension by sliding it a tiny bit one way or another across the bridge or box edge. The friction between the edge and the rubber band will hold the rubber band in its new position.
- **Trouble playing a melody:** Remind students that fretting a string, either by pushing it down against the box or by pinching it, will give them different pitches from each string. Have them try: *We Will Rock You*, *Happy Birthday*, or theme songs from TV shows and movies, such as *Pink Panther* or *The Addams Family*.

BUILD A BAND

DESIGN SQUAD
PBS
as built on TV
pbs.org/designsquad

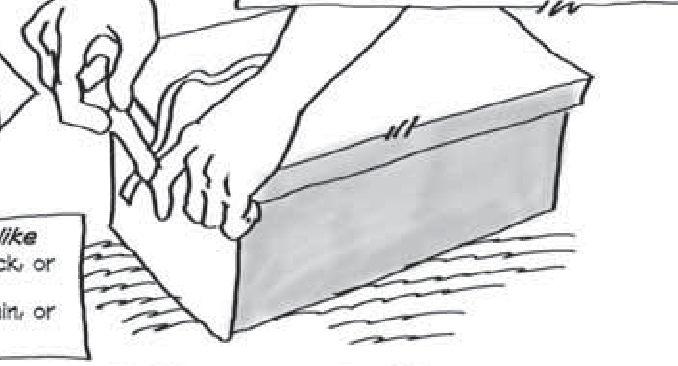
DESIGN AND BUILD

Tip: Taping down rubber bands

Put tape over the end of a rubber band. Then run your fingernail along the rubber band to firmly connect the tape and rubber band.

Attach your strings

- Wrap one end over a box edge and tape it. This way it pulls on the box, not just on the tape.
- Stretch the other end to where you want it, and tape it.



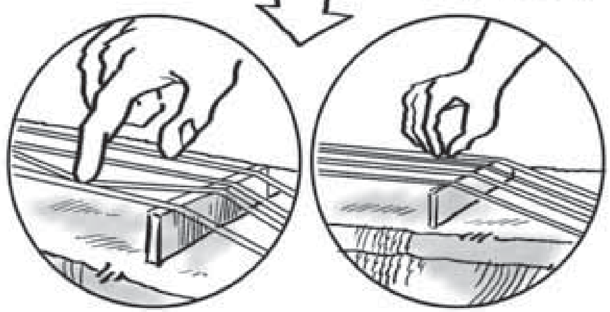
Find 4 pitches you like

- Low pitch = Long, thick, or loose strings
- High pitch = Short, thin, or tight strings

TEST AND REDESIGN

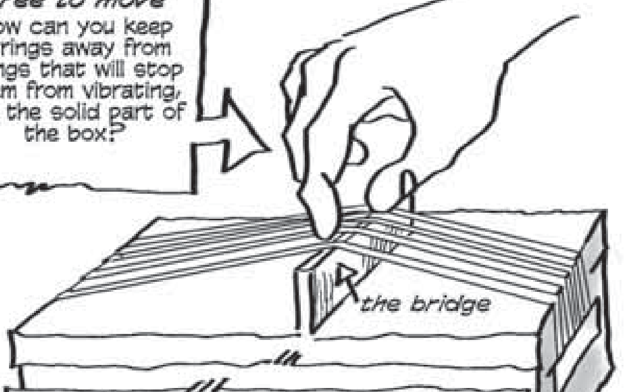
Tip: Get extra notes

Press fingers along a string or pinch it. That changes its length. Mark the notes you like.



Free to move

How can you keep strings away from things that will stop them from vibrating, like the solid part of the box?



More vibrations = louder!

Get the string's vibrations to go cleanly from the strings to the box material. Too much tape, loose parts, or a bulky bridge will reduce the vibrations.

Music is important to almost everyone, so there will always be a demand for musicians, not to mention the instruments and sound equipment they need! Rock on!

SHARE

Find a partner, tune both instruments, and play a song.

Watch DESIGN SQUAD on PBS or online at pbs.org/designsquad.

Major funding for *Design Squad* provided by

Additional funding for *Design Squad* provided by

HEADPHONE HELPER CHALLENGE

The Challenge: Add a headphone to your instrument to make it easier to hear.

Preparation

- ☐ Copy the *Headphone Helper* handout (one per student).
- ☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Rock On Challenge*** (1 minute) and ***Design Process: Teamwork Issues*** (3 minutes). Be prepared to project them.
- ☐ Make a simple string telephone (two cups connected by a string).
- ☐ Gather these materials (per student). See page 44 for suppliers.
  - *Build a Band* instruments
  - 2 paper cups (6 ounce or larger)
  - thin string (e.g., kite string)
  - large paper clips
  - scissors
  - duct tape
  - paper-towel tube or, even better, a 3-foot section of a wide plastic hose (e.g., sump pump discharge hose, which is 24 feet long, flexible, inexpensive, and readily available at hardware and home supply stores)

1 Introduce the challenge (5 minutes)

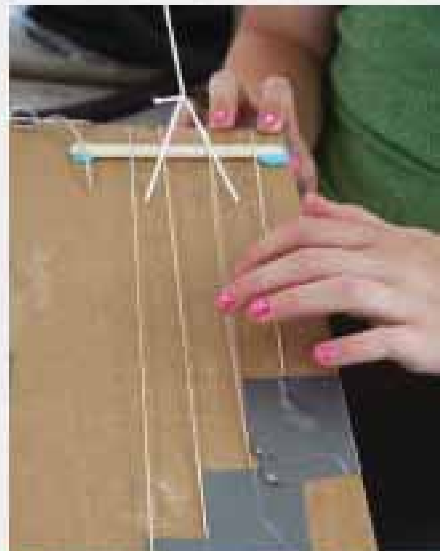
- Show ***Rock On Challenge.*** Ask: How is what you're doing similar to what the *Design Squad* teams do? *(Both groups have to build original stringed instruments out of everyday materials that can be tuned and play a range of notes.)*
- Ask students: What are some ways to improve the instruments you built in *Build a Band*? *(Answers will vary, but increasing the volume will likely be mentioned.)*
- Tell students that today's challenge is to add a headphone to their instrument to make it easier to hear it.

2 Brainstorm (10 minutes)

Brainstorm sound energy

- What could you use to help carry sound waves from your instrument up to your ear? *(A tube; a string telephone with one end attached to the instrument; a stethoscope; an electronic system with a pickup; a radio system with a transmitter; etc.)*
- Explain that headphones work by picking up an instrument's vibrations. Hold up a student's instrument and have the class trace the path that sound travels from the string to the ear. *(Some of the string's vibrations travel directly into the air. They also go through the bridge and into the box, table, and air. These vibrations then travel through the air to the ear. Mention that materials and designs that absorb or dampen vibrations, like a bulky bridge or excess tape, reduce the volume.)*
- Show students your string telephone, and point out that sound waves travel through a solid—the string. Have students trace how the sound travels. *(The voice produces sound waves that travel into a cup and get the string vibrating. The string carries these vibrations to the second cup. This cup begins vibrating and moves the air in and around it, reproducing the original sound, which can be heard by the person holding the second cup.)*
- Show students a length of tubing and ask: How does sound travel through an air-filled tube? *(Sound energy vibrates the column of air trapped in the tubes. The vibrating column of air vibrates your eardrums, reproducing the sound.)*

Students pinpoint where their instrument vibrates a lot and attach a tube or string telephone to carry the sound waves directly to their ear.



One team used a string telephone with a double string to capture twice the number of vibrations.

A tube can carry sound waves. Students can attach it to the surface or insert it into the box.

In *Making It Real*, students discuss the science and engineering behind their designs and describe how they are thinking and working like engineers.

Brainstorm the design process

- Show ***Design Process: Teamwork Issues.*** Ask: What are some strategies you can use to make sure all team members are included? *(Ask for ideas; agree on a plan; choose roles; assign tasks; use people's strengths; etc.)*
- Brainstorm ways that enable a string telephone or tube to trap as many vibrations as possible. *(String telephone: Use more than one string; use string that vibrates well; attach the strings firmly to the box. Tube: Add a cup to one or both ends as a sound collector. Both: Attach to a place on the instrument where there's lots of vibration, such as next to or under the bridge; keep the string or tube length as short as possible, because sound diminishes with distance.)*

3 Summarize the problem to solve (5 minutes)

- Break the larger challenge into its sub-challenges. Ask: What are some of the things you'll need to figure out as you design your headphone system? *(What kind of headphone to make; where and how to attach it; how to get the headphone to pick up the instrument's vibrations; whether to add a headband or an earpiece, such as a cup at the end of the tube; etc.)*
- To promote creative thinking and foster a sense of ownership, have students pair up and brainstorm their own ways of turning the materials into a headphone system. Distribute the handout and have them sketch their ideas.

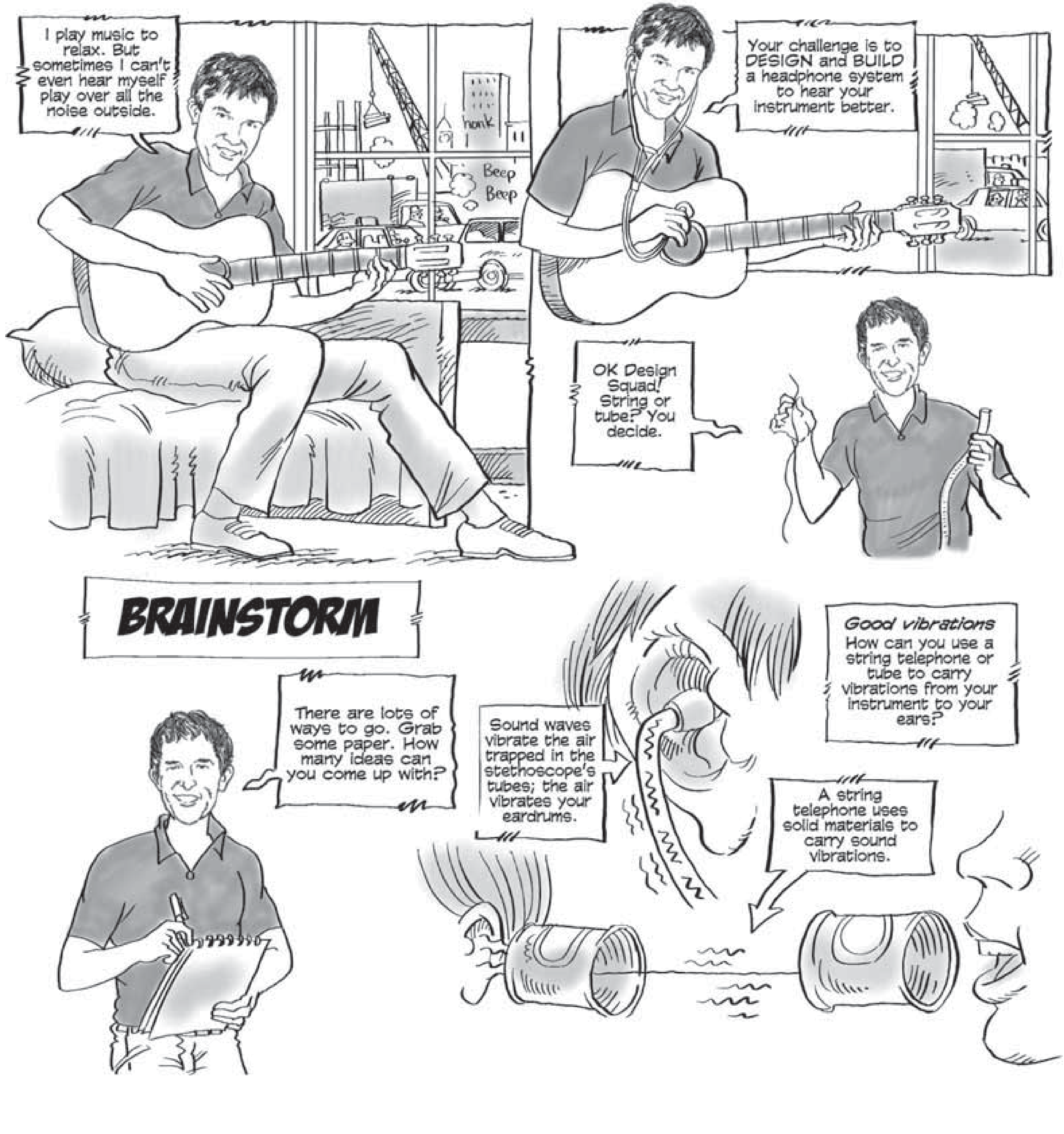
4 Build, test, and redesign (30 minutes)

Here are some strategies for dealing with issues that may come up during building:

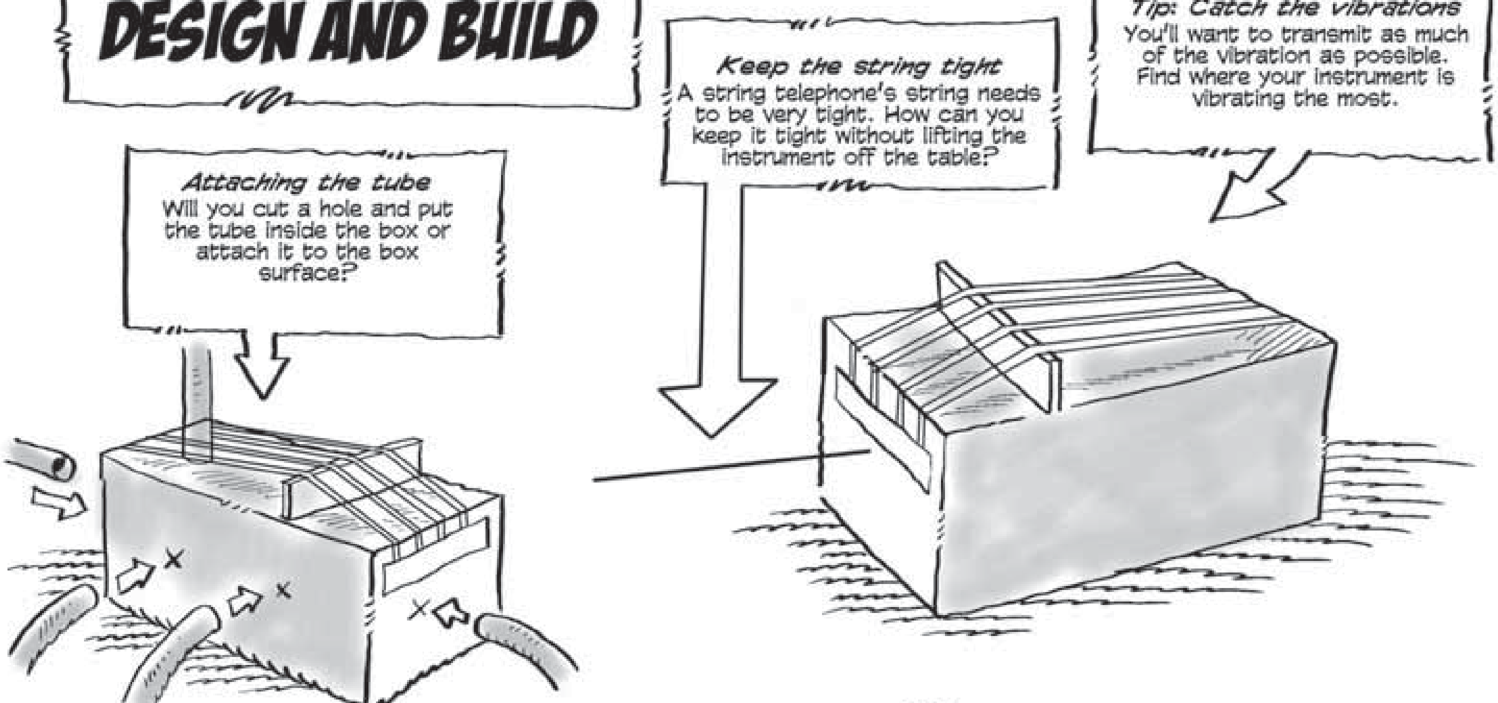
- **Reattach strings:** Give students time to retape the strings on their instruments if the tape let go overnight.
- **Maximize vibrations:** To avoid dampening the vibrations, encourage students to use as little tape as possible, avoid using a bulky bridge, and keep the headphone from interfering with the strings' movements.
- **Keeping the string telephone's string tight:** Students can add weights or have a partner hold down the instrument to keep it in place.
- **Attaching the tube:** Students can tape the tube to the box or cut a hole in the box and insert an end into the air space.

HEADPHONE HELPER

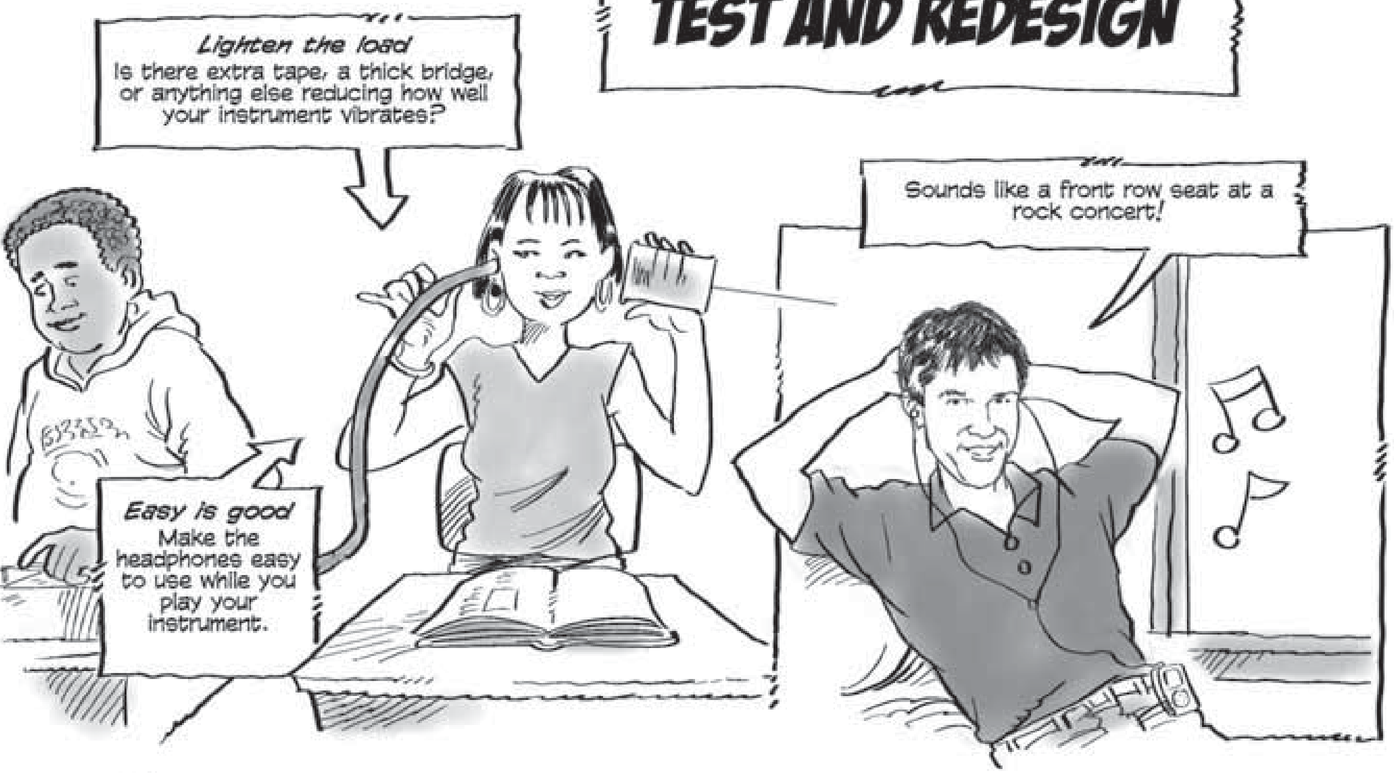
as built on TV
pbs.org/designsquad



DESIGN AND BUILD



TEST AND REDESIGN



PBS. **Watch DESIGN SQUAD on PBS or online at pbs.org/designsquad.**

Major funding for *Design Squad* provided by

the Lemelson foundation
improving lives through invention

intel Education

Additional funding for *Design Squad* provided by

NOYCE FOUNDATION

NCEES National Council of Examiners for Engineering and Surveying

ASME

IEEE Celebrating 125 Years

NORTHROP GRUMMAN Foundation

MAKING IT REAL:
DRIVING HOME THE SOUNDS GOOD UNIT

Overview: Students take their work beyond the walls of the classroom, using a combination of presentations, videos, and discussion. They present their instruments, discuss how they demonstrate the unit's science concepts, explain how the design process encourages them to think creatively, and discuss how engineering is a field centered on designing and building things that matter.

Preparation

- ☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Rock On Judging*** (2½ minutes), ***Design Process: Brainstorming About Pitch*** (3½ minutes), and ***Darrin Barber*** (1½ minutes). Be prepared to project them.

1 Raise student awareness of engineering (5 minutes)

Our world is molded by the engineering that surrounds us. Yet, many students are unaware of what engineers do. Probe students' ideas about engineering. Ask:

- What do engineers do? *(List students' ideas.)*
- Then ask: What things in this room were probably designed or made by engineers? *(There is very little in the room other than the people, plants, and dirt that does not bear the mark of an engineer.)*

2 Relate students' work to science and engineering (20 minutes)

Show ***Rock On Judging***, in which the band evaluates the instruments that were designed and built by the *Design Squad* teams and selects a winner. Then ask: How is the process you followed similar to the one the kids on *Design Squad* did? *(Both the students and the* Design Squad *teams brainstormed lots of ideas, then built, tested, and revised their instruments, and presented their designs to others.)*

Show ***Design Process: Brainstorming About Pitch***, in which the *Design Squad* teams discuss the variables affecting pitch and brainstorm designs. Have students present their instruments and headphones. Use the following questions to explore key points in the video and unit:

- How did your design transfer the strings' vibrations through and out of the instrument? *(Students should talk about how their designs and materials effectively transmitted vibrations and how they eliminated things that absorbed vibration, such as excess tape.)*
- How did you produce different pitches on your instrument?
- How did what you learned about sound in *Build a Band* help you when you designed and built your headphones?
- What were some of the problems you solved as you built, tested, and redesigned your instrument and headphones?
- If you could improve one thing about your instrument or headphone, what would it be?
- Tell students that their instruments and headphones are ***prototypes***—models for testing and improving an invention. Ask: What would you look for in an ideal stringed instrument? (*Loud; easily tunable; easily playable; wide range of pitches; parts vibrate well together; affordable; cool design; etc.)*

SHOW KIDS THE RELATED TV EPISODE

Show students *Rock On*, the full-length *Design Squad* TV episode related to the *Sounds Good* unit, where the *Design Squad* teams design and build original instruments for an avant-garde rock band. Watch it online at: **pbs.org/designsquad.**

"The discussion, animations, and videos had my students linking the concepts to the engineering process."

Harini A.
Belle Haven Elementary School
Menlo Park, CA

Students develop a working knowledge of sound in *Build a Band*, take their understanding further in *Headphone Helper*, and explore the relevance of the science and engineering in *Making It Real*.

3 Meet an engineer (10 minutes)

- View the ***Darrin Barber*** video to introduce students to an engaging young engineer who uses sonar—traveling, bouncing sound waves—to navigate a submarine. Darrin also talks about how engineering is one of the "coolest" jobs he can imagine.
- After watching, review how sonar works. *(A device sends sound waves out into the water. When they hit an object, they bounce back. Listening devices on the submarine pick up these reflected waves. By analyzing the patterns of the returning waves, people can determine where the object is. Note that bats use a similar system to detect their prey.)*
- Darrin mentions that every day he uses the math and science he learned in high school. Ask: How might the math and science you learn in school be important on board a submarine? *(It would help you understand how the equipment works, what the signals mean, how to navigate around the ocean, and how to explain to others what's going on.)*

4 Make the engineering real (10 minutes)

Use the following questions to help students see how the work they did relates to engineering and see that engineers design things that matter and improve people's lives. Ask:

- Who might be interested in a low-cost, low-tech musical instrument? *(Kids, parents, schools, recreation centers, camps, afterschool programs, people interested in new kinds of sounds [like* White Noise, *the band in* Rock On*]. Instrument manufacturers would be interested in a prototype instrument. The message is: Music matters—people love music and there will always be a demand for instruments and sound systems.)*
- Engineering opens the door to many interesting careers, such as navigating a submarine. What are some challenges that an engineer might tackle? *(Designing instruments and amplification and recording systems; making pitch-correction systems for singers; applying new materials and technology; writing programs for computers and electronic instruments; developing personal music players; figuring out ways to integrate sound and video; designing cutting-edge telephones; developing sonar and radar systems; etc.)*
- In what ways did you think and work like an engineer as you made your instrument and headphone? *(Followed the design process; applied science concepts; made something people want; used creativity; tackled interesting challenges)*

TELL US WHAT YOU THINK

Take our quick online survey, and we'll send you a *Design Squad* class pack (while supplies last—see back cover for details).

Extension Ideas

- Share photos of your students' designs and see what others have made. Visit DS XCHANGE, *Design Squad*'s online community at **pbs.org/designsquad**.
- Tell students about inventions that produce high-frequency pitches. Teens can hear them, but most adults can't. Storeowners use these devices to annoy and drive away loitering teens. Teens use the high-pitched tones as cell phone ring tones that adults can't hear! Ask students to think of other applications. Take this high-pitch hearing test and listen to the related National Public Radio podcast at: **npr.org/templates/story/story.php?storyId=5434687**.
- Watch *Design Squad* host Nate Ball demonstrate a pen that plays music as it draws: **youtube.com/watch?v=mG6tkthHH2A.**

Interdisciplinary Connections

- *Music:* Work with a music teacher to identify tunes the students may be familiar with and to get larger groups playing together.
- *Music:* Compare the design features (form and function) of various stringed instruments: violin, guitar, banjo, harp, washboard bass, zither, and piano. Focus on how they achieve pitch and amplitude, the number and type of strings, the size and shape of the sound boards, the methods of producing vibrations and projecting sound, and other design features.
- *Technology:* Use computer-based recording software to record one or more instruments. Students can multitrack, add effects, add percussion, loop their compositions, make a ring tone, and even burn a CD.
- *Shop*: Students can make an instrument out of wood. It could have a neck (like a guitar), be a frame (like a harp), or be a box (like a dulcimer, zither, or autoharp). They can experiment with different string materials, sound holes, sound boxes, soundboards, and tuning systems.

In their presentations, students talk about how sound travels through an instrument and how eliminating things that absorb vibration increases the volume.

The design process encourages students to think creatively about tackling a challenge.