Science and Innovation

A Boeing/Teaching Channel Partnership

DESIGN A QUIETER CABIN

Teacher Handbook

Tch Teaching Channel

Design a Quieter Cabin

Day 3: Shake, Rattle, and Roll (Optional Extension)

Grade Level	Early Middle School (Grade 6)
Lesson Length	One 50-minute session

Lesson Overview

In this optional Day 3 extension, students further explore the idea that energy can flow from one form to another as they continue to build their understanding of sound generation and transmission in preparation for their final design challenge of designing a quieter airplane cabin. As part of this extension, students examine sound waves created with simple electromagnetic tools. Eventually, they create a very simple speaker using a paper plate. Connecting energy flow and transfer to students' experiences building a speaker out of a paper plate deepens the conceptualization of energy transfer and flow for students.

Helpful Tip

The Day 3: Shake, Rattle, and Roll (Optional Extension) can be used to help students develop an understanding of the concepts of energy transfer and wave amplitude. Consider including this day if students need extra support understanding waves. It can also be included to provide students with experience engaging in a design "build." This may help students with their design solution builds throughout the unit.

Connecting to the Next Generation Science Standards

On Day 3, students make progress toward developing understanding across the following three dimensions:

- Science and Engineering Practices: Planning and Carrying Out Investigations
- Disciplinary Core Ideas: PS4.A Wave Properties
- Crosscutting Concepts: Energy and Matter: Flows, Cycles, and Conservation, Structure and Function

In the following table, the specific components addressed in this lesson are underlined and italicized. The specific connections to classroom activity are stated.

Performance Expectations

This lesson contributes toward building understanding of the following *physical science* performance expectations:

MS-PS4-1. Use mathematical representations to *describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.*

MS-PS4-2. *Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.*

Specific Connections to Classroom Activity

This lesson can be used as an optional lesson to reinforce the ideas of energy transfer and wave properties. Students design a speaker to show that electrical energy can be transferred to sound energy. Students also realize that sound waves can be transmitted through materials, such as paper plates. Finally, students explore the relationship between wave amplitude and energy by pouring sand on their paper plate speakers.

Dimension	NGSS Element	Connections to Classroom Activity
Science and Engineering Practices	**Planning and Carrying Out Investigations** • *Collect data about the performance of a proposed object, tool, process or system under a range of conditions.*	Students generate a speaker model to test differences in wave amplitude. Students collect qualitative data on the performance of the speaker under a range of conditions.
Disciplinary Core Ideas	**PS4.A: Wave Properties** • *A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.* • *A sound wave needs a medium through which it is transmitted.*	Using the speaker and sand poured on a paper plate, students explore what happens when they turn up the volume of a speaker. Through this investigation, students recognize the relationship between energy and amplitude. Students also realize that sound waves can be transmitted through various materials, such as a paper plate.
Crosscutting Concepts	**Structure and Function** • *Structures can be designed to serve particular functions by taking into account properties of different materials and how materials can be shaped and used.* **Energy and Matter: Flows, Cycles, and Conservation** • *Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).* • *The transfer of energy can be tracked as energy flows through a designed or natural system.*	As students build paper plate speakers, they recognize the relationship between structure and function of the speaker. In this lesson, students consider how energy is transferred from one form to another. Students construct a device (the speaker) that is capable of demonstrating energy transfer.

Basic Teacher Preparation

Before students can design and build their quieter airplane cabins, they need to understand how sound is generated and travels, and how energy can be transferred from one form to another. During Day 3, students gain an understanding of how energy is converted from one form to another by building paper plate speakers. This allows students to see the actual wave action.

Preparation needs to be done prior to class. Review the Speaker Build video prior to instruction. Check the following Materials List for necessary components and preparation guidelines.

Helpful Tip

The Speaker Build video is 15 minutes long. Preview it before class, and choose sections to show, or demonstrate the build for students yourself. Consider making a student handout with build instructions.

Required Preparation	Links/Additional Information
❑ Gather or purchase the required materials for the lesson	Refer to the Materials List below
❑ Review suggested teacher preparation resources	Refer to the Suggested Teacher Resources at the end of this lesson

Materials List

Item	Description/Additional Information	Quantity	Where to Locate/Buy
Paper plates	Used to build speakers	1 or 2 per team	Local store
Styrofoam plates	Used to build speakers	1 per team	Local store
Plastic plates	Used to build speakers	1 per team	Local store
AAA batteries		1 per team	Local store
AA batteries		1 per team	Local store
C batteries		1 per team	Local store
D batteries		1 per team	Local store
Plain paper	For speaker mount	A few sheet per team	Available in schools
Rare earth magnets	For speakers, 20 in a pack	1–3 per team	General option online [Web Link]
.5-inch wood dowel	Can be cut into several sections	1 per team	Wood dowel [Web Link]
Colored sand	Used to show sound waves on paper plate speaker	Small amount (1 tablespoon) per team	Colored sand [Web Link]

Headphone extension cable	Cut cables in half	Half a cable per team	Headphone extension cable [Web Link]
Simple DC motors	Can use to explore and/or harvest materials	1 or 2 per team	DC motor [Web Link]
Hot glue gun and glue	To assist with speaker build and other activities in the module	1 per class	Hot glue gun and glue [Web Link]
Audio source	Phone or mp3 player to provide signal to speaker; small PA system (audio amplifier) makes for a much more impressive effect (as depicted in the Speaker Build video)		Small PA system available in some schools, or bring phone or mp3 player from home
Decibel meter		1 per class, or more if there will be multiple testing sites	Decibel meter [Web Link] (used Day 1)

Day 3: Shake, Rattle, and Roll (Optional Extension)

Introduction (5 minutes)

Pose the following question to students. Engage in a whole class discussion to answer the question.

- *Pretend you are listening to a radio that is plugged into the wall. Model the flow of energy from the wall outlet to your ear. How many changes occur in this system?*

Explain to students that today's activities will help them refine their response to this question. Tell students that in previous lessons, they explored the movement of sound waves. In this lesson, they will focus on the energy aspects of sound.

Investigation: How to Build a Paper Plate Speaker (15 minutes)

Explain to students that they are going to work with their design teams to create a speaker to learn more about how sound travels. To begin, demonstrate the steps.

Next, give each team the following supplies, and then guide students through the process:

- Ruler
- Plain paper
- Rare earth magnet
- Pin or dowel slightly larger in diameter than the magnet
- Paper or polystyrene plate
- One of each battery: AAA, AA, C, D

Video Link

All of the demonstrations and builds in this section can be seen in the Speaker Build video.

▶ Speaker Build [YouTube Link]

First Steps

1. Cut a strip of paper approximately 5 inches x 1 inch.
2. Roll the paper to form a tube. The paper tube needs to be wide enough to slip over the magnet easily (not tight).
3. Tape the paper tube together. As noted in the video, the dowel can be used for support. (See the Speaker Build video.)
4. Mark the center of the backside of the paper plate with a dot.

Second Steps

1. Wrap wire around the paper tube near one end of the tube, leaving approximately 6 inches of wire leads at both ends, as shown in the video.
2. Tape the coil to the paper tube. The type of tape doesn't matter, but clear tape lets you see the coil within.
3. Put a magnet on a table, and slip the coil on top of the magnet.
4. Trim the paper tube so it is just a bit taller than the magnet, about 1 inch above the coil. The video provides a clear demonstration of this step.
5. Use a hot glue gun to attach the paper tube (with the attached wire coil) to the center of the paper plate.

Third Steps

1. Be sure the paper tube is over the magnet and connected to the paper plate speaker.
2. Touch one of the wires from the paper tube and coil to a battery. The plate will either stay in place or jump off the magnet—depending on the polarity.
3. Reverse the polarity, and the plate will either stay in place or jump off the magnet.

Helpful Tip

Reversing the polarity demonstrates the electromagnet and the permanent magnets interacting and in some cases "fighting" each other. This is an example of the energy in an electromagnet.

Fourth Steps

1. Connect the speaker plate to an audio source, like a phone or PA system amplifier. Several options for connections are modeled in the demonstration video. The paper plate acts like a speaker. If you use an amplifier as part of the connection, you will hear the music even better and see the plate vibrate.
2. Hold the speaker up slightly and at different alignments or angles. Find the angle that makes the speaker play loudest. This changes how well-aligned the magnetic field is with the battery. It also changes how much friction is between the magnets and the paper tube.
3. Put the coil next to the magnet to vary the distance between the magnet and electromagnetic field.
4. Put a small spacer (such as a cardboard disc) under the magnet to raise it a bit higher inside the coil. See how it changes the performance.

Investigation: View Sound Waves on the Speaker (20 minutes)

Now that students created speakers, they can use them to develop a better understanding of the energy aspects of sound. Students use their paper plate speakers as a way to view sound waves.

Sound Wave Viewer

- Have one student from each team tightly cover their paper plate speaker with plastic wrap. Be sure the speaker is hooked up to a music source.
- Give each team a tablespoon of colored sand.
- Have students pour the sand on the wrap. Students should be able to see the sand bounce—helping students understand that this is mechanical energy.

NGSS Key Moment

When students test what happens to the sand when they turn up the volume, they develop an understanding of the relationship between energy and amplitude (PS4.A).

- Allow students to experiment with turning up and down the volume to determine what happens to the sand Students should be able to see the sand bounce higher when the volume is louder, helping students relate amplitude to energy.
- Have students develop an explanation to describe the transfer of sound from the electrical current, to the speaker, and to the bouncing sand.

Extension

To extend this investigation, incorporate the Science and Engineering Practice *Planning and Carrying Out Investigations.* Have students develop ways to test the relationships among electrical energy, sound energy, and movement of sand. Have students report their findings in a consensus discussion.

Lesson Close (10 minutes)

Relate the investigation to the design problem of designing a quieter cabin. Lead a class discussion aimed at understanding how the speaker investigation can help students with the design problem.

At this point in the module, you might want to recap information about sound waves. The Transmission of Sound—Designmaster and ScienceMan Digital Lesson—How Sound Waves Travel videos provide grade-level appropriate information about sound waves. Preview and choose one to show to the class, if time permits. After viewing the video—summarize some key points from all the activities students have experienced thus far in the module.

Video Links

- Transmission of Sound—Designmaster [YouTube Link]
- ScienceMan Digital Lesson—How Sound Waves Travel [YouTube Link]

Key points:

- Energy can change forms. Examples of various kinds of energy can include mechanical energy, electric energy, and sound energy—all forms explored in this module.
- Energy can flow from one form to another. Can students provide some examples of how various forms of energy flowed from one form to another form, such as wind turbines, motors, generators, and sound systems?
- Other types and forms of energy exist that we have not explored in this module (such as light energy, heat energy, gravitational energy, atomic energy, chemical energy, and so forth). Do students think these forms of energy can be transferred into a different form? If yes, could that be put to good use?

Assessment

Several opportunities for formative assessment exist in this lesson:

- Consider gathering evidence of student progress through small group and whole group discussions.
- Consider adding an exit ticket for students to demonstrate their understanding of how energy flows from one form to another and to provide an opportunity to ask any unanswered questions.

Use the identified assessment opportunities to monitor student progress on disciplinary core ideas, science and engineering practices, and crosscutting concepts. Provide appropriate supports or extensions when necessary.

Reference Appendix B for suggestions for meeting the needs of all learners.

Community Connections

Students may have family members who work with sound or sound systems. Ask students to bring in anecdotal examples about how their family member's understanding of sound energy impacts their work.

Suggested Teacher Resources

Meeting the Needs of All Learners	Design a Quieter Cabin Teacher Handbook, Appendix B
Speaker Build	[YouTube Link]
Transmission of Sound—Designmate	[YouTube Link]
ScienceMan Digital Lesson—How Sound Waves Travel	[YouTube Link]