Science and Innovation

A Boeing/Teaching Channel Partnership

DESIGN A QUIETER CABIN

Teacher Handbook

Tch Teaching Channel

Design a Quieter Cabin

Days 4 and 5: How Sound Travels through Cabin Walls

Grade Level	Early Middle School (Grade 6)
Lesson Length	Two 50-minute sessions (if possible, consider adding another day)

Lesson Overview

On Day 4, students engage in a modeling activity and an investigation to determine how sound waves travel through solids. Through the investigation, students realize it is easier for sound waves to travel through solids than through air. Students test a variety of solids to determine which solids best transmit sound waves.

On Day 5, students build on the ideas developed on Day 4 to design, test, and redesign a tin can telephone. Students consider the science ideas behind their design choices and modifications.

Connecting to the Next Generation Science Standards

On Days 4 and 5, students make progress toward developing understanding across the following three dimensions:

- Science and Engineering Practices: Developing and Using Models, Engaging in Argument from Evidence
- Disciplinary Core Ideas: ETS1.B Developing Possible Solutions, PS4.A Wave Properties
- Crosscutting Concepts: 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 *engineering* performance expectations: MS-ETS1-4. *Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.* **This lesson contributes toward building understanding of the following *physical science* performance expectations:** 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 On Days 4 and 5, students engage in an investigation exploring how sound waves travel through solids as compared to gases. Students compare various materials to show how sound waves travel through each material. As a mini-design challenge, students design, test, and redesign tin can telephones. By testing different materials to use in the telephone, students develop an understanding of which materials best transmit sound waves. Further, students develop an understanding that design solutions must be built, tested, and revised. Both understandings will be essential for the final design challenge of designing a quieter cabin.

Dimension	NGSS Element	Connections to Classroom Activity
Science and Engineering Practices	**Developing and Using Models** • *Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.* • *Develop and use a model to describe phenomena.* **Engaging in Argument from Evidence** • *Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon.*	Students engage in two types of modeling in this lesson. First, students model, with their bodies, how a sound wave might travel through solid, liquid, and gas. Second, students develop written models to explain how a sound wave travels through an airplane cabin wall. When students initially consider the idea of a sound wave traveling through a solid, liquid, or gas, students develop a hypothesis about whether it will be easier for the sound wave to travel through a solid. Students argue their side before testing their hypothesis.
Disciplinary Core Ideas	**ETS1.B: Developing Possible Solutions** • *A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.* **PS4.A: Wave Properties** • *A sound wave needs a medium through which it is transmitted.*	When students design the tin can telephones, they test, modify, and retest their design solutions. On Days 4 and 5, students engage in a series of investigations and modeling activities to develop the idea that sound can be transmitted through different mediums and sound waves behave differently in different mediums.
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.*	Students experiment with structure and function relationships when they design their tin can telephone. Students consider the intended functions of the phone in order to determine the materials used for the structure.

Basic Teacher Preparation

Ensure all supplies are laid out. Students need to have access to the proper measuring equipment and other supplies. Review the Talk Science Primer to prepare for leading class discussions.

Refer to the Design a Quieter Cabin Student Handbook ahead of time so you can address any questions students might have. All Day 4 and 5 documents can be found on pages 5–8 in the Design a Quieter Cabin Student Handbook. The documents used in this lesson are:

- How Sound Travels through Materials (page 5)
- How Sound Travels from an Airplane Engine to *Inside* the Cabin (page 6)
- Design Challenge: Can You Hear Me Now? (pages 7 and 8)

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
Tin cans	Standard 12-inch	2 per team	Have students bring from home or buy online [Web Link]
Disposable plastic cups		2 per team	Plastic cups [Web Link]
Disposable polystyrene cups		2 per team	Polystyrene cups [Web Link]
Masking/duct tape		1 roll per team	Hardware store
Nail		1 per team	Nails [Web Link]
Hammer	Lightweight	1 per team, or 1 for instructor use	Hammer [Web Link]
Yarn		1 skein of yarn per class	Craft store
Kite string		1 roll per team	Kite string [Web Link]
Fishing line		1 spool	Fishing line [Web Link]
Aluminum foil		1 roll	Local store
Plastic wrap		1 roll	Local store
Wax paper		1 roll	Local store
Corkboard		1 pack per class	Cork tiles [Web Link]
Rubber liner		1 roll	Rubber liner [Web Link]
Heavy duty trash bag		1 box	Local store
Cotton washcloth or T-shirt fabric			Local store or thrift shop
Cotton balls		1 bag	Local store
Duct tape		1 roll	Local store
Masking tape		1 roll	Office supply store
Playdoh® or modeling clay		1 large tub	Local store

Day 4: How Sound Travels through Cabin Walls

Introduction (5 minutes)

Reference the Driving Question Board. At this point in the module, students should have a good sense of how airplane engines produce sound and how sound travels to the cabin wall. Tell students that their goal now is to figure out how sound travels through the cabin wall.

Remind students that we know that sound waves travel through air because the sound waves vibrate air particles. Also remind students that solids and liquids are also made up of particles, but the particles are more closely packed. The particles in solids are very tightly packed, and the particles in liquids are not packed as tightly as solids but are packed more tightly than air (or gas). The goal in today's lesson is to figure out how sound moves through various materials.

Whole Group Discussion: How Sound Travels through Cabin Walls (10 minutes)

Using their bodies to represent particles, have students model how a sound wave travels through air. To do so, students should stand with about an arm's length apart from other students. The teacher should model the source of the sound. As the sound wave travels, students should model the spread of the vibration. Because students are standing far apart from one another, it should be difficult (but still possible) to pass the vibration along.

Next, have students move closer together to represent a liquid. Ask students what they think will happen when a sound wave travels through a liquid. Students may say it is easier for the sound wave to travel in the liquid because the particles are closer together. Students may also argue it is harder for a sound wave to travel through a liquid (likely based on personal experience or developing conceptions). Some students may argue that the sound wave stays the same. Draw out all three stances and encourage students to support their stances.

Continue the modeling activity by modeling how a sound wave passes through a solid. Again, encourage students to present arguments for all three stances (easier, harder, or stays the same). In the upcoming investigation, students investigate what happens when sound travels through solids and gases.

NGSS Key Moment

Students should present their ideas for how sound waves travel through different materials because it motivates the next investigation. In the next investigation, students experiment with various materials to determine how sound waves travel. By presenting arguments and testing them, students engage in the practices of modeling, argumentation, explanation, and investigation.

Investigation: How Sound Travels through Cabin Walls (10 minutes)

Tell students they are going to investigate what happens to sound waves when they pass through various materials. At this point, some students might feel strongly that it is harder for sound waves to pass through a solid than a gas, some might believe it's easier for sound waves to pass through a solid, and some might believe that there is no difference between a solid and a gas.

Tell students that to test their hypotheses, they will tap on different materials, such as a desk, and listen with their ear pressed against the material (to hear a sound wave traveling through a solid) and then with their ear in the air (to hear a sound wave traveling through a gas). Prompt students to consider what kinds of evidence they might find to indicate whether it's easier for sound waves to travel through a solid or gas.

Have students test how sound travels through solids. Instruct students to work in pairs. One student closes his or her eyes while the other taps lightly on the material or desk. Next, the listening student places his or her ear against the material or desk while the other student taps lightly again. Students then switch roles.

Ask students to discuss what they heard. Students should notice that they heard the sound more easily when their ear was pressed against the material or desk. This provides evidence for the stance that sound waves travel through solids more easily than through gases. To reinforce the point, have students model (with their bodies) how sound waves move through solids.

Investigation: How Sound Travels through Various Materials (20 minutes)

Allow students time to explore how sound travels through different types of materials. Provide students with the materials that will be available to them in the design challenge (cotton balls, corkboard, and so forth). Instruct students to conduct tests to compare the materials to each other. Students can manipulate variables as they see fit. For instance, students can tap on the materials or place a speaker behind the material. Students should record notes the on How Sound Travels through Materials on page 5 in their Design a Quieter Cabin Student Handbook. Encourage students to include notes that explain why they think sound travels through some materials better than others.

NGSS Key Moment

This investigation is a key investigation for helping students develop an understanding of PS4.A. Students explore the ways different materials transmit sound waves and develop ideas about why some materials may be better than others. This investigation is also key because it helps students link the science ideas embedded in PS4.A back to the design problem.

Remind students their goal is to find a material that can prevent sound from entering the cabin.

Now that students have developed an understanding for how sound travels through solids, instruct them to develop a revised model for how sound travels from an airplane engine to inside the cabin. Direct students to How Sound Travels from an Airplane Engine to *Inside* the Cabin on page 6 in their Design a Quieter Cabin Student Handbook. Have students incorporate components of their previous models in the current model.

Lesson Close (5 minutes)

Reference the lesson question on the DQB, *How does sound travel through cabin walls?* Ask students if they think they made progress in answering the question.

Tell students to record their progress on sticky notes. They should answer the question with as much evidence as they can.

When students are finished, have some read their sticky notes out loud to the class and post them to the DQB.

Listen to students read their sticky notes or read the sticky notes posted by students to assess their progress in answering the questions on the DQB.

Day 5: How Sound Travels through Cabin Walls

Introduction (5 minutes)

Begin today's lesson by having students share their models on page 6 in the Design a Quieter Cabin Student Handbook with their design teams. Students should revise their models based on their team's feedback.

Prompt students to discuss how their models inform their understanding of designing a quieter cabin, which is their ultimate design challenge.

Tell students they are going to engage in an engineering design challenge that builds on their understanding of how sound travels. Have students sit with their teams as they watch the Man vs. Wild: Big Sky Country Tunnel video. Discuss the following question:

- *How can people tell that a train is coming by touching a railroad track with their hands before they can hear the same train with their ears?*

Video Link

Show the portion from 1:15-2:15.

▶ Man vs. Wild: Big Sky Country Tunnel [YouTube Link]

Investigation: How to Design a 20-Foot Telephone Line (10 minutes)

Explain to students that they are to create a simple speaker/microphone system. Their goal is to choose the best available materials to use for the speaker/microphone along with a 20-foot telephone line. Display the available materials for students (tin can, plastic cup, polystyrene cup, fishing line, kite string, and yarn). Direct students to draw their Individual Design on page 7 in the Design a Quieter Cabin Student Handbook. As part of their individual design, students must justify their choices. Justifications must include science ideas developed on Days 1 through 4. Students should specifically reference evidence from Day 4. Remind students to include labels and measurements with their drawings.

Have students take turns in their design teams to share their designs and reasons for their selected materials. Design teams must then come to consensus on a team design.

Each student must draw the Team Design (with labels and measurements) and record the team rationale for their choices of materials on page 7 in their Design a Quieter Cabin Student Handbook. Each team must have the teacher sign off on their design before beginning construction.

Important Note

Ensure that each student has a safe and uninterrupted environment in which they can share their designs and justifications.

Design Work: Build and Test a String and Cup Telephone (10 minutes)

Students construct their initial telephone solutions. This is done by using a nail to poke a small hole in the center of the bottom of each cup or can. Students then use their choice of "telephone wire" to thread through each hole and tie a knot on each end.

Have students pull the telephone wire taut. Then, one student speaks into one of the cups while the other student listens through the cup on the other end of the wire. Students then reverse roles. Instruct students to record their Initial "Telephone Solution" Observations on page 8 in their Design a Quieter Cabin Student Handbook.

▲ String and Cup Telephone

Helpful Tip

- You might want to use the hammer and nail prior to class to puncture the cups and cans.
- Students might want to use the nail to help thread their choice of "wire" through their cups or cans.
- Students might need to use tape over the knot to ensure the wire does not slide through the hole.

Design Work: Team Discussion and Redesign (10 minutes)

Have students take turns with their team members and share their observations from the previous test. Ask students to think about which materials they might change and why. Remind students to manipulate only one variable at a time so they can determine the impact of the change on the effectiveness of their telephone. The new material selection for one of the components should then be discussed with team members, using the same process as before.

Once the team has reached a consensus, they should diagram and explain the Team Redesign "Telephone Solution" on page 9 in their Design a Quieter Cabin Student Handbook. Teams must have their redesigns signed off by the teacher before beginning construction.

Design Work: Rebuild and Test a Second Telephone (10 minutes)

Have students construct a second iteration of their telephone solutions. Once students have completed constructing their second iterations, have them test their redesigns. Students pull their telephone wires taut and take turns speaking and listening through the cups. Instruct students to record their Redesign "Telephone Solution" Observations on page 8 in their Design a Quieter Cabin Student Handbook. As part of the observation, students should compare their two designs and make note of how the material change and/or modification altered the performance of their design.

NGSS Key Moment

Students need to have the opportunity to rebuild and test a second (or even a third) telephone solution. By iteratively testing and revising their designs, students build an understanding that models must be built, tested, and revised in order to reach an optimal design (ME-ETS1-4).

Lesson Close (5 minutes)

As a class, have students share the modifications and results they recorded in their Design a Quieter Cabin Student Handbook. Have students identify common observations that occurred throughout these informal presentations. Relate the observations to the science ideas developed during Days 1–4 and to this module's design challenge.

Assessment

Several opportunities for formative assessment exist in this lesson:

- Design a Quieter Cabin Student Handbook entries can be used to monitor student progress throughout the module. Focus specifically on the Design Challenge: Can You Hear Me Now? on pages 7 and 8.
- Student models and notes on pages 5 and 6 can be used to track student progress on the key physical science performance expectations.
- Consider gathering evidence of student progress through small group and whole group discussions.

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

If any student's family members have a background in engineering or an audio/visual field, invite them into the classroom to assist as a volunteer or to share their work experiences related to sound generation and/or transmission.

Suggested Teacher Resources

Meeting the Needs of All Learners	Design a Quieter Cabin Teacher Handbook, Appendix B
Design a Quieter Cabin Student Handbook	[Resource Link]
Man vs. Wild: Big Sky Country Tunnel video	[YouTube Link]
Talk Science Primer	[Web Link]