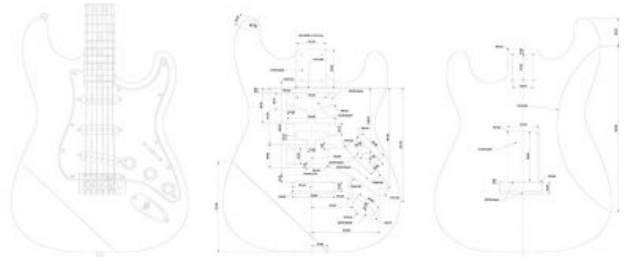
The Guitar: A Musical Transducer

OVERVIEW

ESSENTIAL QUESTION

How can the guitar help us understand the scientific principle of transduction?



OVERVIEW

We are surrounded every day by a myriad of signals moving around us, unseen. Our brains constantly receive electromagnetic signals and sound waves, allowing us to make sense of our surroundings. Electrical signals hum around us, powering our lives. Digital signals floating in the air connect us to the rest of the world.

But we are not receiving, interpreting, and using this barrage of signals on our own. We are aided by thousands of different types of transducers—devices that translate one type of signal into another. For example, an antenna is a type of transducer that converts invisible electromagnetic or digital signals into images and sounds. Light bulbs transduce electricity into light, and electroacoustic transducers such as microphones, speakers, and pickups make the music we love possible.

In this lesson, students understand the principles of transduction and the role of transducers by looking at the history of the guitar. They begin by examining how an acoustic and electric guitar function, and then construct their own "digital" guitar from cardboard, conductive tape, and a Makey Makey circuit board. After performing their own "riffs" on their digital guitars, they discuss how each type of guitar transduces sound waves, electrical currents, and/or digital signals.

Materials required for this lesson:

- Cardboard
- Box cutter/exacto knife
- Art supplies (markers, colored pencils, etc.)
- Copper Tape
- Makey Makey kits
- Laptops, computers, or chromebooks
- Acrobat Flash Software

OBJECTIVES

Upon completion of this lesson, students will:

1. KNOW (KNOWLEDGE):

- The concept of transduction, and what a transducer does
- Differing types of signals, including sound waves, electrical signals, and digital signals
- How acoustic and electric guitars differ in construction and operation
- How to create a "digital guitar" circuit that produces sound
- How to perform a simple melody with the handmade "digital" guitar
- The definition of a "riff"

2. MASTERY OBJECTIVE:

- Students will be able to make a musical transducer by building their own playable guitar.

ACTIVITIES

PREPARATION

1. Cut out a variety of cardboard guitar shapes using **Handout 1 - Electric Guitar Templates** as a model.
2. Ensure each computer that will be used for the lesson has Adobe Flash installed.
3. (Optional) Have students first complete the **Designing an Electric Guitar with Shapes** lesson.
4. (Optional) To create a "digital" guitar with six operational "strings," it is necessary to go to https://makeymakey.com/pages/remap and remap the "click" area on the Makey Makey circuit board to the letter "a."

MOTIVATIONAL ACTIVITY

1. Tell students that in class they will be learning about transducers, and the process of transduction. Show **Image 1, Transduction Definitions**. Ask students:
   - Can you find anything in this room that might be a transducer? (*If necessary, provide the example of the lights in the classroom, which convert electricity to light.*)
   - Can you think of something in your house that is a transducer? What kind of energy goes into it, and what does it convert that energy into? (*For instance, a microwave transduces electricity to heat.*)
   - Can you think of any ways transducers might be used to make or listen to music?

PROCEDURE

1. Pass out to each student **Handout 2 - Transduction Pathways**. Explain that they will be looking at three different kinds of guitars, to see whether each acts as a transducer.

2. Direct students' attention to the first guitar in the handout, at the top left hand corner. Ask students:

    - Do you recognize this? What is it?
    - What makes the sound on an acoustic guitar? (*Encourage students to recognize that the vibration of strings creates the sound.*)
    - How many strings are on the guitar? How might the strings be different? (*Draw students attention to the tuning pegs at the top of the guitar, which are each attached to a string.*)
    - What might turning the pegs on the end of the guitar do?
    - The acoustic guitar is hollow on the inside. Why might this be? (*Emphasize that the cavity within the guitar acts as an echo or reverberation chamber, which heightens the volume of the strings when they are played.*)

3. Display **Image 2, Types of Signals**. Ask students:

    - What do you think the three symbols in the picture mean? What is meant by "signals?"
    - What are sound waves, and how are they transmitted? (*Help students recognize that sound waves are vibrations in the air, which are captured by the ears and translated in the brain*).
    - What are electrical signals, and how are they transmitted? (*Electricity is created by relocating electrons by mechanical processes, such as turbines or solar panels to create energy.*)
    - What are digital signals, and how are they transmitted? (*Digital signals provide a string of information, usually made up of 1s and 0s, that give instruction to programs created to interpret the signals.*)
    - What type of signal do you think an acoustic guitar sends?
    - Do you think an acoustic guitar is a transducer? Why or why not?

4. In the space between the acoustic guitar and the ear, ask students to draw in the symbol for the type of signal they think the acoustic guitar creates. (*For instance, if students think the signal produced by the electric guitar are sound waves, they will draw curved lines to represent sound waves. See* **Image 3, Completed Handout** *for an example of a filled-in handout.*)

5. Ask students to volunteer their answers. Explain to students that the vibrating strings on a guitar produce sound waves in the air, which are picked up by the ear. (*For a lesson further detailing sound waves, see the* **Sound Waves, Analog Synthesis, and Popular Culture** *lesson.*)

6. Direct student's attention to the next guitar on the handout, below the acoustic guitar. Ask students:

    - What is this instrument called? (*Note to teacher: this is an electric guitar.*)

- What similarities do you see between this electric guitar and the acoustic guitar we saw previously?

- What makes the sound on an electric guitar? Is it similar to an acoustic guitar? (*Note to teacher: Just like an acoustic guitar, the sound of an electric guitar is created by vibrating strings.*)

- What differences do you notice between this guitar and an acoustic guitar?

- Is this guitar hollow, like an acoustic guitar?

- What does this guitar have instead of a soundhole? (*Point out to students that electric guitars have small pieces of metal in the place of the soundhole.*)

7. Point students to the pictures to the right of the electric guitar. Ask students:

   - Why are there so many more pictures between the guitar and the ear for this guitar?

   - What kind of signal does the electric guitar first make, when you strum the strings? (*Encourage students to recognize that the signal is sound waves.*)

8. Tell students that like the acoustic guitar, the electric guitar first produces sound waves, but those waves are transduced into different types of energy. Returning to the handout, tell students they will look into how the sound waves of the guitar strings are transduced. Ask students:

   - Look at the picture of the speaker. What kind of signal do you think comes out of a speaker? What kind of signal goes in? (*It may be helpful to discuss speakers more practically: what "comes out" of a speaker? How does the music "go into" the speaker?*)

   - What is the device to the left of the speaker? Based on the signal coming out of the electric guitar and the signal needed to go into a speaker, what does this transducer need to do?

9. Tell students that the device to the right of the guitar is called a pickup, a transducer embedded into the electric guitar that uses magnets to convert the vibrating strings into electric signals. Display **Image 2, Types of Signals** once again, and have students draw the respective signal types between each image in the worksheet for the electric guitar (see **Image 3, Completed Handout.**)

10. Play students **Clip 1, "Guitar Sound Comparison."** Ask students:

    - How do the acoustic and electric guitar sound different? How would you describe the sound of an acoustic guitar, and the electric guitar?

    - Why might these two types of guitars sound different? How might transduction effect the sound of the electric guitar?

11. Tell students that the third guitar on the handout could be called a "digital" guitar, which they will be constructing themselves in class. If students have completed the **Designing an Electric Guitar with Shapes** lesson, allow them the opportunity to transfer their design using art supplies directly to the cardboard guitar. Otherwise, hand out a cardboard guitar to each student, and allow them to decorate it. (*Note: if there are not enough Makey Makey kits for each student, have students decorate their electric guitars in a group.*)

12. Help students apply 3-6 strips of copper tape to each guitar, positioning them where the strings would normally be. (*For early elementary classrooms, 3 strips is recommended. Students in higher grade levels might wish to add additional strips.*)

13. Hand out the Makey Makey kits and computers. Ask students to unpack their kit and set aside the circuit board, colored wires, and USB cable. Have students clip one end of a colored wire to the "Earth" section of their Makey Makey circuit boards and leave the other end unclipped to anything.

14. Tell students that using the wires provided, they need to find a way to connect each of their metal strips of tape to one of the arrow or circular pads on the Makey Makey circuit board. (*See* **Image 3, Connected Digital Guitar** *as an example of what the final assemblage could look like.*)

15. Connect each Makey Makey circuit board to a computer or laptop via the provided USB cord. Go to **https://scratch.mit.edu/projects/266322620/** on an internet browser. Once the program loads, click on the green flag to begin.

16. Tell students that the wire that remains unclipped to anything (the one coming from the "earth" section) will be their pick—what they use to play the guitar. Ask them to pull back the rubber sleeve of the wire so the metal tip is exposed, and touch the metal tip to one of the copper tape strips. A sound should be heard from the computer, and the Makey Makey circuit board should light up. (*If no sound is coming out of their computer, make sure the volume is turned up, the program is running properly, the usb cable is firmly attached, and all the clips are securely fastened to the Makey Makey circuit board and the tape strips.*)

17. Once students have played with their guitars for a few minutes, ask them to carefully unclip their wires from the Makey Makey circuit board and clip them to new direction arrows or circles on the Makey Makey circuit board (anywhere except the "Earth" area). Ask students:

    - What happened when you attached the wires from the guitar to different parts of the Makey Makey circuit board?

    - Why might have the sound changed when you rearranged the wires? (*Each area of the Makey Makey circuit board corresponds to a different function, which in the scratch program produces different notes.*)

18. Have students experiment more by making their guitar "strings" ascend in order. Ask them to rewire their connections so that the piece of tape closest to them produces the lowest note, the one furthest away produces the highest, and the ones between produce notes in the middle.

19. Tell students they will now be creating a "riff" with their guitars to share with the class. A riff is a short melody that is played repeatedly. Many Rock and Roll songs are based on guitar riffs.

20. Have students perform their riffs for their classmates.

SUMMARY ACTIVITY

1. Return to **Handout 1**, and tell students they will be filling out the final portion for their "digital guitar". Ask students:

    - What do you think happens when you touch the clip to the metal tape on your guitar? Do you think it would work if the tape was plastic or paper? Why or why not?

    - Why did the Makey Makey circuit board light up when it was plugged into the computer? Why does it light up when you touch a metal strip of tape with the metal clip? Why do different parts of the board light up when you touch different pieces of tape?

2. Through classroom discussion, the classroom should arrive at the conclusion that they have created a circuit, which channels electricity along different routes. The USB cable provides the Makey Makey board with electricity. When the metal clip is placed on a piece of tape, electricity flows through the tape and wire into a certain part of the Makey Makey board, lighting it up. Ask students:

    - Are you making any sound waves directly from the "digital" guitar? If not, what signal type are you creating?

    - What kind of signal do you think the Makey Makey board sends to the computer? Do you think it is electrical, or something else? Why do you need to run a special program to make the sound?

3. Through classroom discussion, students should discover that the Makey Makey circuit board is a transducer that converts electrical signals into a digital signal sent to a computer. Digital are most often made up of information coded in 1's and 0's. When this information is picked up up by the right program, certain things occur. In this case, the Makey Makey board is telling the computer program to play samples of guitar strings when certain areas on the board are electrically activated.

4. Display **Image 2, Types of Signals**. Based on the classroom discussion and what they learned already about speakers, have students return to **Handout 1**, and fill in the third line.

EXTENSION ACTIVITY

1. Bring in a local guitar player to perform on acoustic and electric guitars.

2. Instead of developing a short riff, have students create a 4-measure melody on their cardboard electric guitars. (For this activity, it may be beneficial to create guitars with 4-6 pieces of tape.)

3. Have students notate a simple melody (pitch and rhythm) that they perform when they demonstrate their guitar. Students can use color to coordinate pitch with the color of the alligator clip attached to each piece of copper tape.

4. Have students notate a simple melody first, and then perform it with their constructed guitars.

STANDARDS

NEXT GENERATION SCIENCE STANDARDS (NGSS)

4-PS4-3: Generate and compare multiple solutions that use patterns to transfer information.

COMMON CORE STATE STANDARDS

College and Career Readiness Anchor Standards for Reading

Integration of Knowledge and Ideas 7: Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.

College and Career Readiness Anchor Standards for Language

Language 1: Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

Vocabulary Acquisition and Use 6: Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when encountering an unknown term important to comprehension or expression.

NATIONAL STANDARDS FOR MUSIC EDUCATION – NATIONAL ASSOCIATION FOR MUSIC EDUCATION (NAFME)

Core Music Standard: Creating

Imagine: Generate musical ideas for various purposes and contexts.

Plan and Make: Select and develop musical ideas for defined purposes and contexts.

Present: Share creative musical work that conveys intent, demonstrates craftsmanship, and exhibits originality.

RESOURCES

VIDEO RESOURCES

- Guitar Sound Comparison

HANDOUTS

- Handout 1 - Electric Guitar Templates
- Handout 2 - Transduction Pathways