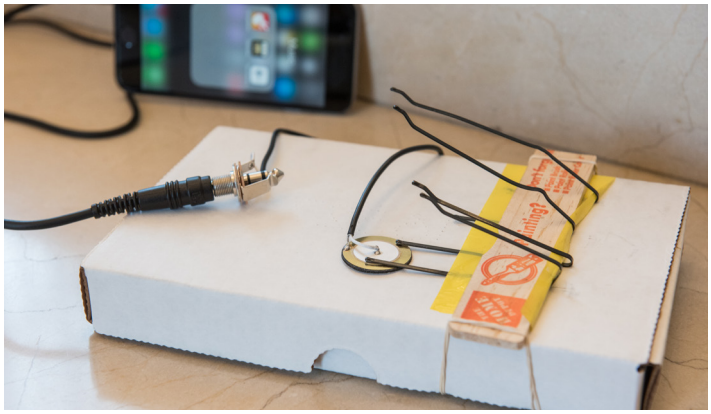
Tool Kit V
Amplification – Electronic

Objective

Investigate the conversion of sound waves into electrical energy via a transducer (i.e., "microphone"). Investigate how, after being converted into electrical energy, those sound waves can be increased or decreased in amplitude. Investigate the reconversion of that electrical energy back into sound waves via another type of transducer (i.e., "speaker").

Materials

- Pre-wired piezoelectric pickup with instrument cable adapter
- Instrument cable and adaptors as required
- Amplifier and speaker [Alternatively, cell phones with headphone inputs may be used.]
- The instrument that you built in "Tool Kit I: Amplification – Acoustic" or an assortment of resonant objects (cups, tin cans, bowls, percussion instruments, or bells)



Piezoelectric pickups are simple transducers that can easily be added to many musical instrument crafts.

Background Information for Educators

A transducer is any object that converts energy from one form into another. In the case of sound, a transducer can convert the mechanical energy of a sound wave (vibrations) into electrical energy (**voltage**). A transducer can covert electrical energy back into sound waves. A **pickup** or a **microphone** can be a transducer that converts sound energy into electrical energy. A **speaker** converts electrical energy back into sound energy. A **biological ear** is a very complex transducer that coverts mechanical sound energy into electrical energy, which a brain then interprets as sound. Transducers are essential tools for the electrical **amplification** of musical instruments as well as for **recording** sounds with electronics. Transducers are also necessary for converting electrically amplified or recorded musical sounds back into something that we can hear via a **speaker**.

Activity

How does a transducer work?

Investigate

Present students with a piezoelectric pickup (i.e., "transducer") connected via cable to an amplifier and speaker.

Create

Experiment with the placement of your piezo transducer to find the best place on your musical instrument for it to pick up its vibrations.

A. ***How do we experience the sound of the instrument if the piezo is held a small distance above the instrument? What if the piezo is placed on the instrument?*** The piezo responds to sound energy by vibrating, and then converts those vibrations into an electrical charge. The more the piezo can vibrate, the better it will work.

B. ***Does the frequency being played affect how well the piezo is able to work?*** Helmholtz resonance demonstrates that a musical instrument will vibrate more efficiently at certain frequencies than at others. If your instrument is vibrating more efficiently, its vibrations will occur at greater amplitude than if it is vibrating less efficiently. Additionally, piezos do not respond well to extremely low or extremely high frequencies.

C. ***Does the piezo work more effectively depending on where you place it on your musical instrument?*** A musical instrument will vibrate in different ways at varied places across its surface because of the way all the various individual frequencies of overtones interact with one another. The sound waves you hear are a compound wave composed of numerous frequencies that all occur simultaneously. Certain places on a musical instrument will vibrate more or less, depending on how these overtones are interacting.

D. ***What does the volume knob on the amplifier do? Can you use the volume knob to compensate for an instrument that does not vibrate very well?*** The piezo will convert the mechanical energy of sound waves into electrical energy (voltage). The amplifier can then increase the amperage of that electrical energy (voltage) before sending it along to a speaker. Imagine waves of electrical energy of low amplitude (soft sounds) being "amplified" into waves of electrical energy of high amplitude (loud sounds).

E. ***What does the speaker attached to the amplifier do?*** The speaker is another kind of transducer that converts electrical energy back into mechanical sound energy (sound waves). If the speaker is given electrical energy of high amplitude, it will vibrate more vigorously than if it is given energy of low amplitude. In other words, to create sound waves of high amplitude (loud sounds), the center of the speaker will actually jump up and down "higher" than it would if it were creating sound waves of low amplitude (soft sounds)

Assessment

Formative

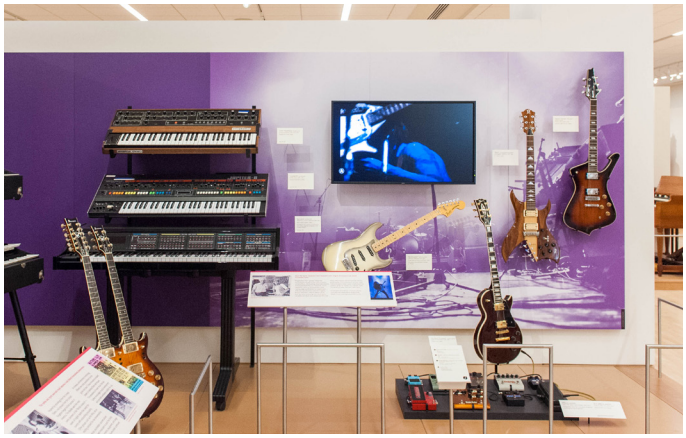
Students will demonstrate their conceptual understanding of transducers by finding the best place to affix the transducer to their musical instrument and turning the volume up or down on the amplifier accordingly.

Summative

Students will explain how transducers work, providing two examples of different types of transducers and their respective uses.

Activity on your visit to MIM: Point out the different kinds of transducers, effects processors, and speakers.

The above activity represents a transducer that converts sound-wave energy (vibrations) into electrical energy. This is the technology inside many microphones and instrument pickups, but it is only one of many different types of transducers. Another very common type of transducer is the electromagnetic transducer, more commonly known as an "electric guitar pickup."



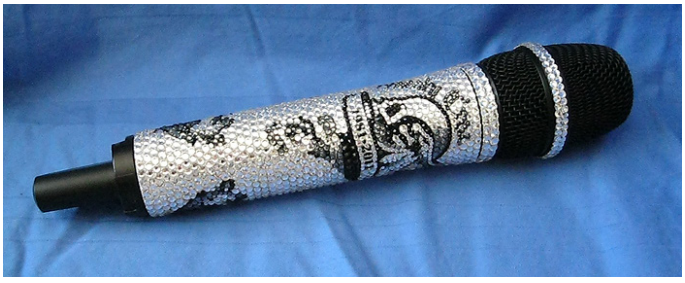
The magnetic pickups on an electric guitar are another form of transducer.

Collection Connection: Electric Guitar

How does the electric guitar work?

The **transducer** (i.e., "pickup") on an electric guitar is a **magnet** wrapped in a wire coil. All electric guitars have at least one such magnetic pickup; some have multiple. In the same way that the placement of a piezo on your musical instrument affected its sound, the placement of a pickup on an electric guitar affects the eventual sound that *that* guitar produces. For this reason, you will often see an electric guitar with more than one pickup. Unlike the piezo pickup you used on your instrument, the pickup on an electric guitar does not respond to sound vibrations. It responds to **magnetism**.

The magnetic pickup on the electric guitar is placed below the steel strings of the guitar. As the steel strings vibrate, the fluctuations in magnetic force caused by their movement above the magnetic pickup is converted into electrical energy. You can experience how this works by waving a piece of metal above a stationary magnet. The magnet will pull toward that piece of metal in the same way the magnetic pickup pulls toward the vibrating steel strings and that pulling motion is what gets converted into electrical energy. From the pickup, the electrical energy can be amplified and sent to a speaker. The electrical energy can also be processed in many ways by adding different sound effects such as distortion. But as the process of creating sounds relies on magnetism, if you were to yell as loudly as you could into the pickup of an electric guitar, nothing would happen (unless you were to yell loud enough to get the metal strings to vibrate too).



Microphones are an additional type of transducer.

Many microphones (but not all) make use of this same principle of magnetism. In the case of a microphone, the sound waves are first picked up by a resonant medium (diaphragm, ribbon, spring, etc.) and then converted to electrical energy. "Dynamic microphones" make use of a delicate metal coil suspended below a magnet. Sound waves make the metal coil move just like the strings on an electric guitar. As the spring moves and the magnet pulls on it, an electric charge is created, which can then be amplified. Other microphones, such as "condenser" or "piezoelectric" microphones, function very similarly to piezoelectric pickup on your musical instrument. These microphones pick up sound vibrations and convert them to an electrical charge via other means.

Additional Resources

The Physics of Piezoelectric Pickups

The Physics of the Electric Guitar Pickup, Amplifiers, and Effects

The Interconnected Nature of the Laws of Physics (Including Sound, Electricity, and Magnetism)

Arizona State University's Consortium for Innovation and Transformation in Music Education (CITME) Curates Numerous STEM/STEAM Music Education Resources