



Investigating Music Lesson Plans

Introduction

This is a set of investigation-style activities that introduce the concepts of sound production, pitch, wavelength and amplitude in relation to music, and explores how these are reproduced and in musical instruments. It is an introduction to the basic principles used in musical instrument design, and can be used as a foundation for our Making Musical Waves competition which will run during the summer term.

These activities support the Sound Waves component of the KS3 curriculum, and Wave Motion component of KS4, and may be adapted to suit your students' stage and learning needs. They are particularly suitable to use in STEM club investigations. An accompanying worksheet is available to download.

Learning Outcomes:

- Be able to define longitudinal and transverse waves and understand frequency, amplitude and wavelength.
- Know that sound is a form of energy and music may be considered as ordered sound.
- Explain that sound moves in vibrations through a medium. Sound needs a medium through which to travel. *Extension: sound travels at different speeds through different media, sound waves move longitudinally through air.*
- Understand that the amplitude of a sound tells us how loud or soft it is. We can increase amplitude in musical instruments by increasing the vibrating surface area. *Extensions: understand how amplitude is defined in longitudinal waves.*
- Know that strings produce transverse waves, and changing the length, tension and thickness of the string alter the pitch and tone produced.
- Know that frequency tells us the pitch of the sound.
- Understand that striking or blowing a pipe creates a vibrating air column, generating sound. Short pipes give higher pitch and longer pipes lower pitch. Find out that capping the pipe drops the sound one octave. *Extensions: Understand the relationship between the wavelength and the pipe length in open and closed pipes. Understand that there is a relationship between the wavelength and the frequency and the speed of sound. Find out that the capped pipe resonates at half the frequency of the open, producing a note one octave lower.*

Safety

Teachers must carry out their own risk assessment for the activities below and take appropriate control measures. We advise that eye protection be worn when demonstrating waves on the slinky and extra care must be taken when using glass bottles. The use of latex balloons and elastic bands containing latex must be omitted in the case of latex allergy.

Note: Due to differences in available equipment, lesson times and class sizes, these activities can be used together or separately over a course of study as required.



Equipment

- PPE as appropriate
- Metal slinky toy
- Sticker
- Plastic cup or flowerpot
- Duct tape
- 2 balloons and a hand pump
- A hexagonal nut
- A marble
- Plastic Straws (biodegradable options are available!)
- Spoons
- String
- Metal domestic cooling rack or oven shelf or a metal coathanger
- Elastic bands of different thicknesses and sizes
- Cardboard boxes (empty tissue boxes work well and have a pre-cut hole)
- Pens and Pencils
- Boomwhackers™ and Octavator end cap, or a home-made equivalent (these can be made with different lengths of plastic tubes such as golf club tubes)
- Glass bottles
- Water
- Rulers or tape measures
- Investigating Music worksheet

Activity 1. Using a slinky to demonstrate transverse and longitudinal waves

Transverse Waves

Have a volunteer hold one end of the slinky stationary. Move the other end up and down (or side to side) continuously. It is possible to create a vertical or horizontal transverse standing wave (with practice it is possible to produce waves with different numbers of anti-nodes). Point out that the “particles” (coils) are displaced perpendicular to the direction of the wave.

- Can the students predict what will happen if you increase the frequency of your movements?
 - Will the waves get longer or shorter?

Longitudinal waves

Keeping one end stationary send a longitudinal wave through the slinky by pushing forward in the plane. Allow it to reflect. Point out that the “particles” (coils) are displaced parallel to the direction the wave is travelling. Point out the *compression* (bunching up) and *rarefaction* (spreading out) of the coils. Make the connection to particles moving in this way in sound waves travelling through air.



A common misconception about sound waves is that the air itself travels from the source to the hearer along with the sound. A bright sticker placed on the slinky about one third of the way along will help illustrate that it is the *movement* that travels and not the particles (coils).

Activity 2. Balloons: Thinking about sound as a vibration

Ask the students to place their fingers gently on their throats and hum.

- *What can they feel?*

Prepare in advance two inflated balloons, one containing a marble and one containing a hexagonal nut or other small irregular object. Hold the balloon near the knot, pointing downwards and move it in a fast rotation so that the object inside moves in fast circles. The balloon with the marble will make very little noise, while the one with the nut makes a loud whirr.

- *Can the students guess which balloon contains which object by listening?*
- *Which object makes the most noise and why?*
- *What is the relationship between the speed of the rotation and the pitch of the noise?*

This demonstration can be used as an activity: have items of varying regularity (such as a marble, a round washer and a nut), and allow the students to investigate the sound-making properties themselves.

Activity 3. Objects on strings: Sound travelling through different media

Demonstration: cooling rack or coat hanger on a string

Tie a length of string to each of two adjacent corners of the cooling rack (or the two bottom corners of the coat hanger). Tie small loops at the ends of the strings. Have a student place the loops on their index fingers and let the tray hang freely (it must not touch their body and they must not hold the string with their other fingers). Gently strike the tray with a fork or spoon.

- Ask the student to describe the sound.
 - *Is it loud or soft, high pitched or low-pitched?*

Then have the student place their index fingers to their face just in front of their ears, and bend forward slightly so that the tray still hangs free. Gently strike the rack again.

- Ask the student to describe what they hear this time.
 - *Is it louder or softer, higher lower-pitched than before?*

The sound is louder and deeper when heard through the fingers. Ask the students how the vibrations are reaching the ears in each case (what are they travelling through?).

- *Think about how close together the particles are in solids and gases:*
- *Are the vibrations in the string are more efficiently transmitted through the string (and fingers) or through the air?*



Activity: Spoons on strings

An alternative, very similar experiment can be carried out by the class by tying a spoon to the middle of a length of string, and finger loops to each end of the string.

Activity 4. Amplification: Sci-fi slinky demonstration

Hold a slinky so that the lower end is on the floor or other hard surface and the top end is at shoulder height. Bounce the end of the slinky off the floor, or have a student gently strike it with a fork or spoon. Listen to the sound and watch the vibrations move along the coil.

Now tape a plastic flowerpot to the top coil of the slinky with duct tape and repeat, holding the flowerpot at shoulder height and letting the coils reach the floor. The sound is amplified a great deal, and a noise like a sci-fi laser is produced.

- *How is the sound different with the pot?*
- *How does the pot amplify the sound?*
 - *Think about how the vibrations pass from the slinky to the air.*
 - *Compare the surface area with and without the pot.*

The vibrations in the slinky cause the pot and the air inside it to vibrate. These vibrations build up, and the sound gets louder.

- *Can the students think of any examples of this kind of amplification in musical instruments (for example, think about the shapes of wind instruments)?*

Activity 5. Box Guitars: investigating pitch and amplitude in stringed instruments

Provide elastic bands of different thicknesses and lengths, and empty tissue boxes. First ask the students to compare the sound of elastic bands when strummed on their own, and when stretched over the box opening. They should notice that the use of the box makes the sound louder.

- *Can they think of musical instruments that make use of this effect?*

Allow the students to explore the relationship between pitch and the thickness and tension of the bands, by placing bands of different lengths and thicknesses around the box.

- *Can you see the bands vibrating?*
- *Which vibrate more quickly:*
 - *Thick or thin bands?*
 - *Loose or taut bands?*

Students should notice that thinner and tauter bands vibrate more quickly and produce a higher pitch than thicker or looser bands.

- *How does a guitarist/cellist use this relationship when tuning their instrument?*



Students may be able to make the connection with tuning a stringed instrument by winding/unwinding the string around a peg to alter the tension.

Stretch a band over any empty box (a pre-cut hole is not necessary here). Slide two pens or pencils underneath and at right angles to the band. Strum the band in between the pens.

- *What happens to the pitch of the note as you vary the distance between the pens?*

Students should notice that shortening the “string” produces a higher pitch.

- *How does a guitarist or violinist change the string length while they play?*

Extension: Refer back to the slinky: the vibration is travelling along the string or elastic band in a *transverse* wave, but the sound wave set in motion through the air is *longitudinal*. Sound waves moving through air are longitudinal regardless of the source.

Activity 6: Bottles

Fill bottles to different heights.

- *Can the students to predict which will give the highest note when **gently** tapped with a spoon?*
- *What about when blown across the top?*

Test the hypothesis.

- *When blown, the fullest bottles give the highest pitch, but when struck, the opposite is true. Why?*
- *What is vibrating to generate the sound in each case?*

When struck, the glass vibrates. When water is added to the bottle, it damps the vibrations, slowing them down and lowering the frequency of the note. When you blow across the bottles, you create a vibrating column of air above the water. The longest column of air produces the lowest frequency vibrations.

So the fullest bottles give the lowest notes when struck, but the highest when blown.

Extension: Ask students to measure the bottle and use a marker pen to make marks halfway and three quarters from the bottom. Blow across the top of the bottle. Compare the notes produced by the empty bottle and the half and $\frac{3}{4}$ full bottles.

- *Can you find a relationship between the length of the air column and the pitch of the note?*

Halving the length of the air column should produce a note one octave higher.



Activity 7. Wind instruments: length and pitch, straw oboes

Cut the top of a straw to a trapezium shape (not to a point), and flatten the two “reeds” that result against each other between finger and thumb:



Cover your teeth with your lips and hold the straw between your lips, taking care not to squash the reeds which must be able to vibrate. Blow down the straw. This takes practise but a loud note can be produced.

- Experiment with different lengths of straw to find the relationship between length and pitch.

Activity 8. Boomwhackers

Show the students the Boomwhackers and ask them to predict which will make lowest and highest notes.

Using a set of 8, hand each Boomwhacker to a student and ask them arrange themselves in a line in order of pitch from lowest to highest **without playing them**. Now ask each student in turn to play their Boomwhacker by gently striking it against a surface.

- *Are they in the correct order? If not, move into the correct order.*
- *What is the relationship between the length of the tube and the pitch of the note?*

Try humming different notes into the tubes. When you hit the resonant frequency the note will be amplified and you will feel the tube vibrate.

- *Can the students to predict what will happen to the note when you cap the tube at one end?*
- *Will the note be higher or lower?*

The note produced by the capped (closed at one end) tube is one octave lower than produced by the open tube.

Extension: For KS4 students, Boomwhackers can be used to explore the mathematical relationship between wavelength and frequency and the speed of sound in air.

- *The note produced by the open tube has a wavelength twice the length of the tube.
- *The note produced by the capped tube has a wavelength 4 x the length of the tube.
- By measuring the Boomwhacker, students can calculate the approximate wavelength of the note (wavelength = 2x length of tube when open, and 4x length of tube when capped at one end).

Note: this relationship is not exact. An end correction approximately 0.3 x diameter (closed tube) or 0.6 x diameter (open tube) can be added to the tube length to get a closer approximation of the wavelength and speed of sound if desired.



- Using this relationship, by measuring the length of the tubes and finding the wavelengths, students can estimate the speed of sound in air :

$$\text{Speed of sound (m/s)} = \text{Wavelength (m)} \times \text{frequency (s}^{-1}\text{)}$$

The frequencies of the notes produced by the Boomwhackers are tabulated below:

Boomwhacker note	Frequency in Hz
Low C (red)	256.0
D (orange)	288.0
E (yellow)	320.0
F (light green)	341.3
G (dark green)	384.0
A (purple)	426.7
B (pink)	480.0
High C (red)	512.0

Michael J. Ruiz, *Boomwhackers and End-Pipe Corrections*, The Physics Teacher **52**, 73 (2014)

Michael C Lopresto, *Experimenting with end-correction and the speed of sound*, Physics Education, **46**(4), 437 (2011)

* A standing wave is produced in the tube. The open tube has displacement antinodes at both ends and the closed tube has a displacement node at the closed end and antinode at the open end:

