THE EDUCATION FUND

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2022-2023

Ideas with IMPACT

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Hoo-ray for Ratios! (In Music, Math, Physics, & the Universe)

Hooray for Ratios!

(in Math, Music, Physics, Art and the Universe)

"Pythagoras for the rest of us!" or "Pythagosauras Rex"

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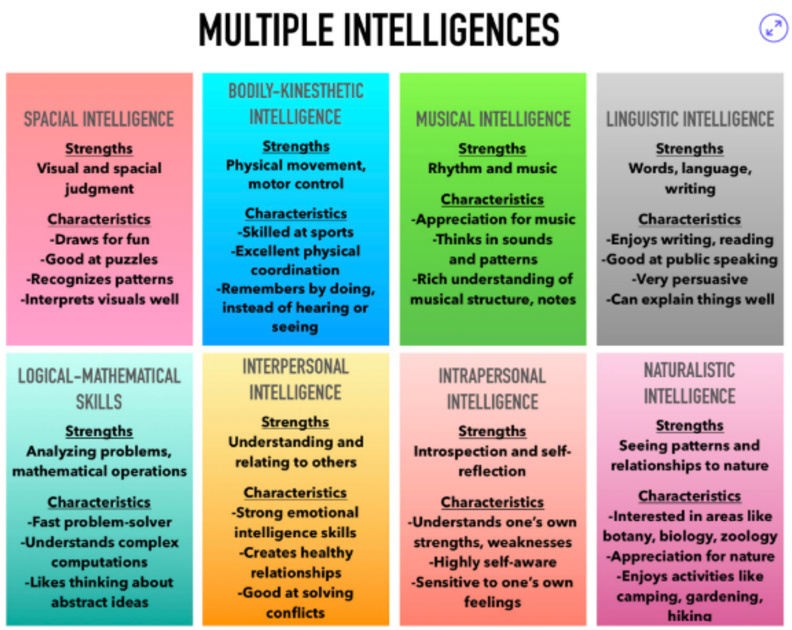
Background

One of the most insightful observations I feel I have made of my students over the past 30+ years of teaching, is that those who are able to make relevant and meaningful connections among their various classes will be the ones who succeed the most, both academically and in life. Much too often is the unfortunate case where students compartmentalize the various disciplines and, in failing to see relationships among the various subjects, they remain at a disadvantage. The discipline of music is especially unique in that within its pedagogy, nearly ALL bridges to the other subjects can, with proper guidance, be traversed. Back in 1983, Harvard psychologist Howard Gardner postulated that humans have multiple intelligences that can be categorized in 8 groupings, music being one. My contention is that music is not a separate intelligence, but a combination of all of the others.



This project connects geometry, mathematics, physics, arts & crafts, AND music bringing them all together in real world creation of homemade musical instruments, with the help of our old friend Pythagoras. This project takes the traditional view of Pythagoras and his famous Pythagorean theorem and turns it on its head. While most people associate Pythagoras with the equation $a^2 + b^2 = c^2$, this project will explore arguably what he was MOST passionate about, which wasn't so much his equation, but the fact that he discovered within his famous triangle secrets to the universe which contain many "magic" ratios that can be utilized to create beautiful music. Not just a mathematics parlor trick, he discovered that objects which create sounds inherently utilize simple ratios capable of making beautiful consonant notes, thus paving the way for the creation of our major scale in music that we continue to use to this day!

Goals and Objectives

The goal of this project is to help students and teachers recognize that the structure of music can be used to link many different disciplines, with special attention to harmonic ratios. Once it is discovered that, existing in nature, there is a harmonic overtone series that can be expressed as simple numerical ratios, and that those ratios create consonant pleasing tones and harmonies, one can use this knowledge to not only understand how various musical instruments work, but also create their own instruments by following these simple guidelines.

It has been shown that students who build and create their own instruments are much more engaged and more likely to continue formal music instruction on "real" instruments. They also change their attitudes about math and science when they not only see but understand how the various disciplines are interconnected as well as how the physical universe has simple ratios built into its own design.

By understanding how the universe itself has simple ratios embedded in its design, it allows for students to inter-relate music, math, and science in new and profound ways. When this basic insight is gained and then applied to creating homemade instruments, it will increase interest and participation in the instrumental programs at the school with excitement and engagement in learning "real" instruments.

The five main goals of this project for BOTH TEACHERS AND STUDENTS are as follows:

1) Teachers and students will learn about physics, acoustics, and how simple ratios are seen in the naturally occurring harmonic series, paving the way for the development of the modern major scale.
2) Teachers and students will be able to share their newfound appreciation of Pythagorus as not just the “theorem guy” but how his observations and ideas utilizing simple ratios in music creation are just as significant and profound!
3) Teachers and students will gain an understanding of how simple ratios can be used to build a consonant sounding major musical scale.
4) Teachers and students will be able to apply their newfound knowledge in order to take very inexpensive materials and create homemade wind, string, and pitched percussion instruments.
5) Teachers AND students will have loads of fun learning about ratios, building instruments, and creating music!!

Florida Standards

Note: Because this project can be presented in the various academic disciplines of math, science, music or art, the following CPALMS Florida State Standards can be applied with slight variations across the grade levels and curriculum spectrum.

MU.68.F.1.1 Create a composition and/or performance, using visual, kinesthetic, digital, and/or acoustic means to manipulate musical elements.

MU.912.H.3.1 Apply knowledge of science, math, and music to demonstrate, through an acoustic or digital performance medium, how sound production affects musical performance.

MAFS.912.G-GPE.2.6 Find the point on a directed line segment between two given points that partitions the segment in a given ratio.

MA.7.AR.3.2 Apply previous understanding of ratios to solve real-world problems involving proportions.

MAFS.6.RP.1.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.

SC.7.P.10.3 Recognize that light waves, sound waves, and other waves move at different speeds in different materials.

SC.4.P.10.1 Observe and describe some basic forms of energy, including light, heat, sound, electrical, and the energy of motion.

VA.68.S.1.1 Manipulate content, media, techniques, and processes to achieve communication with artistic intent.

Materials/Costs

Note: materials include demonstration instruments and enough supplies for each student to create their own 8 note 1 octave pan flute, as well as one demonstration glass bottle glockenspiel as a single class instrument. As funds allow, additional materials could be purchased for individual home made glass bottle glockenspiels. The PVC/plastic bottle single string guitar project is presented only as an optional extra.

1. Demonstration materials - any available premade instruments, a) at least one using strings (chordophone) such as guitar, violin, or ukulele; b) at least one using air (aerophone), such as plastic recorder, flute, or trumpet, and, if available, c) one using struck bars with a mallet (idiophone) such as glockenspiel, or xylophone. Note: If funds are not available, use YouTube!

Costs: FREE if borrowed from music room - OR if Not Available …

i. Sample aerophone - student recorder approx. $5.00
https://www.amazon.com/Ravel-PR19CGN-Recorder-Green/dp/B004S287VK/ref=sr_1_1?crid=12NKJUSBG88YL&keywords=recorder+instrument+for+kids&qid=1661720049&sprefix=recorder%2Caps%2C109&sr=8-1

ii. Sample chordophone - student ukulele approx $30.00
https://www.amazon.com/Martin-Smith-UK-222-Soprano-Ukulele/dp/B077F1G21S/ref=sr_1_17?crid=3UU5M161HJ0AQ&keywords=ukulele&qid=1661720331&refinements=p_n_feature_keywords_two_browse-bin%3A6145589011&rnid=6145585011&s=musical-instruments&sprefix=ukulele%2Caps%2C123&sr=1-17

iii. Sample idiophone - glockenspiel approx $30.00
https://www.amazon.com/Eastrock-Xylophone-Professional-Glockenspiel-Child-Safe/dp/B08K4MH3JK/ref=sr_1_25_sspa?crid=2PZFZ5O1HNXLE&keywords=xylophone+instrument&qid=1661720560&s=musical-instruments&sprefix=xylophone%2Cmi%2C100&sr=1-25-spons&psc=1




iv. Sample Tuning Fork for demonstration approx. $6.00
https://www.amazon.com/cdar-Stainless-Musical-Instrument-Songful/dp/B09RQY4VPY/ref=sr_1_4?crid=RPICQVEF6VHL&keywords=tuning%2Bfork&qid=1661824213&rnid=2470954011&sprefix=tuning%2Bfork%2Caps%2C122&sr=8-4&th=1

2. Homemade Instrument Materials

v. Chromatic Instrument tuner app (FREE - various iOS & Android)
https://www.musicianwave.com/best-guitar-tuner-apps-free-android-ios/
https://apps.apple.com/us/app/instuner-free-chromatic-tuner/id603425027
https://apps.apple.com/us/app/tuner-lite-by-piascore/id635828559
https://play.google.com/store/apps/details?id=hai.lior.instrumenttunerfree&hl=en_US&gl=US

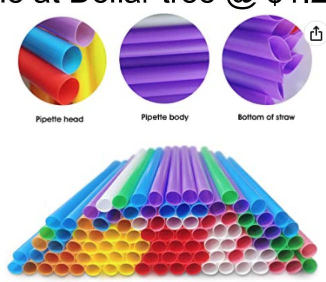
vi. Boba Tea Straws Pack of 300 (0.43" Wide X 9.45" Long) $22.00
https://www.amazon.com/RENYIH-Milkshake-Disposable-Wide-mouthed-Individually/dp/B08TC8NKYV/ref=sr_1_7?crid=2MBDHYGVQ58QR&keywords=boba+tea+straws&qid=1661723036&sprefix=boba+tea+%2Caps%2C135&sr=8-7

vii. Poster Tack (to plug up straw ends and as fine tuners)
(available at dollar tree @ $1.25 each)
https://www.dollartree.com/jot-poster-tack-264oz-packs/178402

viii. Scissors, Clear Packing Tape, Rulers

ix. Set of 8 matching glass containers such as vases, bottles, jars, and/or drinking glasses (available at dollar tree @$1.25 each) 8 for $10.00
https://www.dollartree.com/floral-supplies/vases-containers

x. 1 Set of stainless steel cutlery (used as mallets) $2.50
(available at Dollar tree @ $1.25 each)

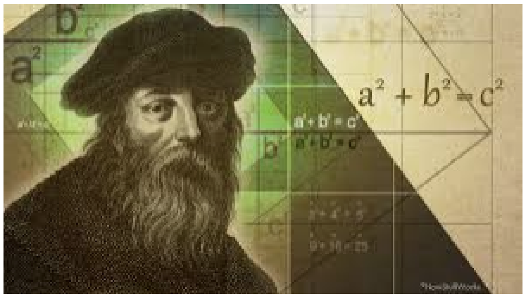


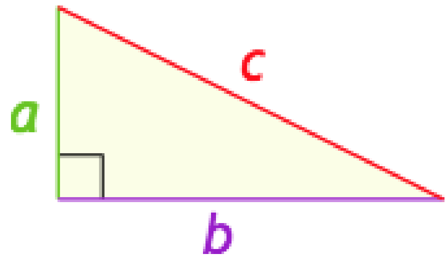
xi. OPTIONAL: HOME MADE PVC/Plastic Bottle GUITAR For homemade fretted single string guitar - plastic bottle (used as resonator) with bottle cap (used as bridge), 24” x ¾” pvc pipe (for neck) 6’ of thin nylon string, 6 plastic ties (for frets), scissors, tape measure https://www.youtube.com/watch?v=S8UT1iEj_p4

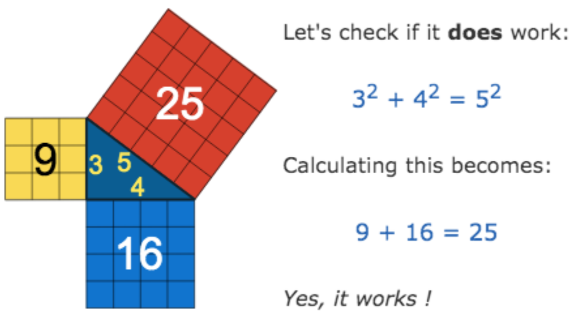
Lesson Plan

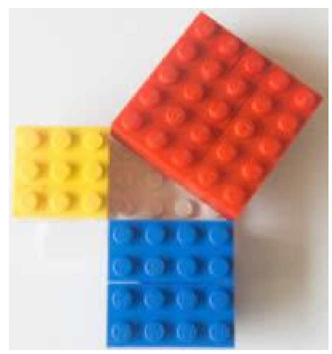
Part 1: Exploring Pythagorus' Magic Triangle and Ratios

Let us begin by considering the famous Pythagorean Theorem $a^2 + b^2 = c^2$. In a right-angled triangle, the square of a (a^2) plus the square of b (b^2) is equal to the square of c (c^2):

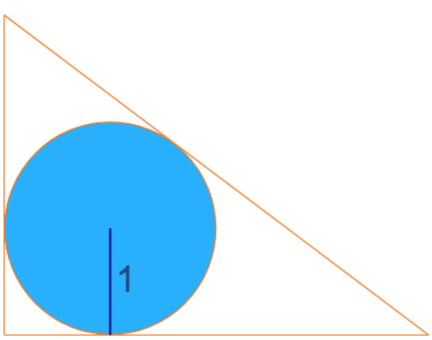


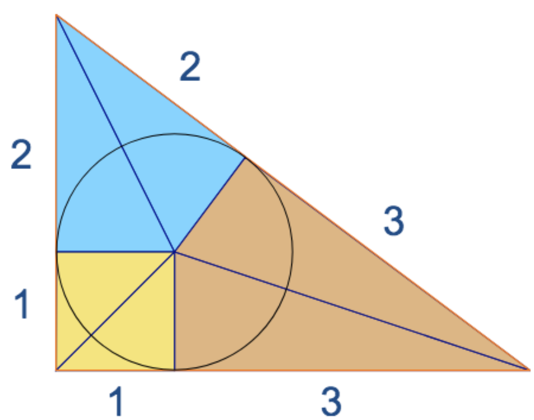






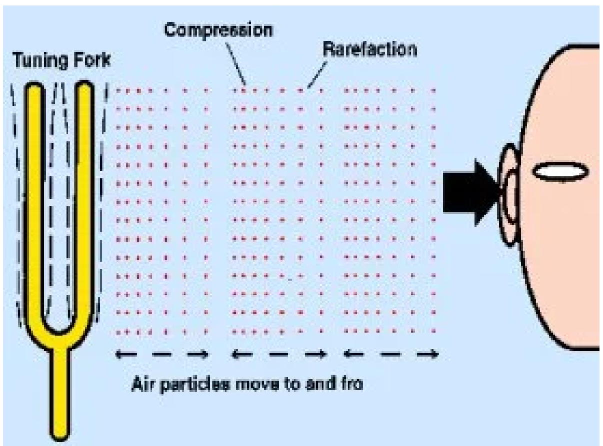
Instead of just looking at the squares, let us consider the simple ratios of 3:4:5. The 3,4,5 triangle has contained within it a hidden simple beauty. At its heart is an inscribed "unit" circle that has a radius of exactly 1. And using that circle we then can cut our triangle into 6 smaller triangles, where each one is ALSO a right triangle revealing other simple ratios of 2:1, 3:1, and 3:2! These "magic ratios" which Pythagorus discovered are ALSO found throughout the natural world, and will help us understand both physics AND music.





Part 2: Musical Sound, the Harmonic Series in Nature and Ratios

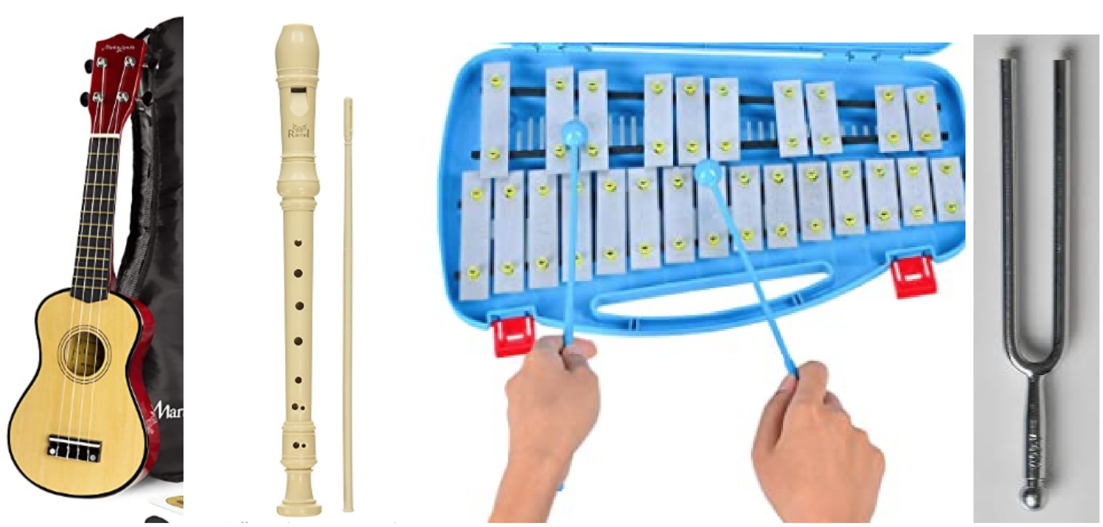
As you are probably aware, any sound is the vibration of air. In order to produce sounds that are musical, those vibrations have to have steady repeating cycles. These vibrations are measured in frequency as Hertz (cycles per second) and the faster the vibrations, the higher the musical pitch is that we perceive. Conversely, slower vibrations are what we call low notes. Also important to remember is that the larger the sound source is (such as a tuba) the lower notes it produces, while small instruments, like a flute or piccolo, produce faster vibrations with higher frequencies that we perceive as higher notes (or pitches). (Teacher demonstrates how tuning fork works/sounds)



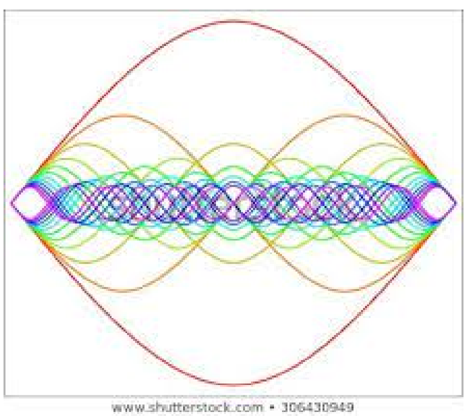
A piccolo produces high-frequency sound waves and high-pitched sounds.

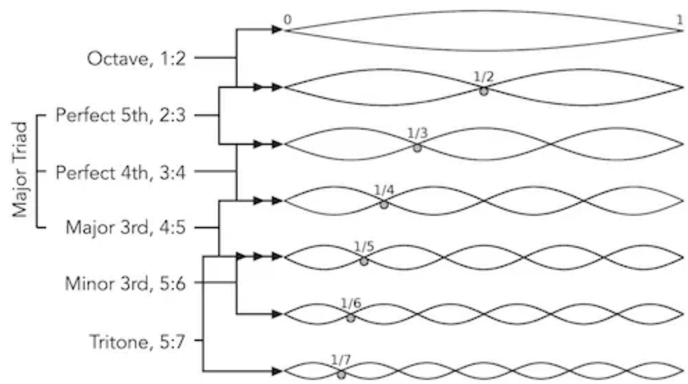
A tuba produces low-frequency sound waves and low-pitched sounds.

Now let us consider acoustic musical instruments and how they actually produce these notes. Nearly all pitched instruments can be classified in three types of sound makers, 1) chordophones (vibrating strings) such as violin or guitar, aerophones (vibrating columns of air) such as trumpet or clarinet, or idiophones (solid objects that vibrate at a fundamental resonant frequency) such as xylophones, glockenspiels, or a tuning fork. Different notes are produced by changing the length of the string, column of air or size of the struck material.

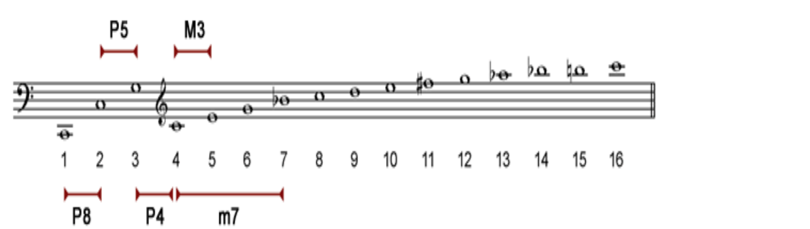


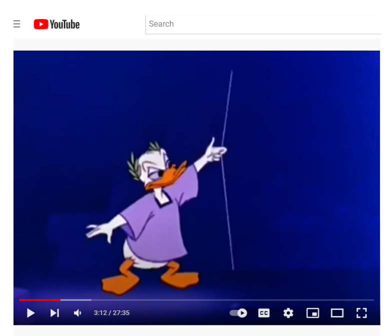
What most people, even trained musicians, DON'T fully understand is that, in the case of a stringed instrument, an individual plucked string not only vibrates back and forth from end to end at just a single fundamental frequency, but ALSO vibrates at a less amount but twice as fast dividing the string into two segments, and ALSO again at 3 times the frequency, dividing into three sections, and so on, creating a naturally occurring series of overtones called the harmonic series. Essentially what occurs is that a single vibrating string sounds not just a single note but a multitude of different notes, all combining together to make a composite "string timbre". In fact, different instrument timbres are defined by relative loudness of the various overtones. Contained within the natural physics of the vibrating string are all the building blocks of musical intervals that we use to build our scales, AND EACH of these intervals can be expressed as simple number ratios. The octave is a 1:2 ratio, perfect fifth is 2:3, perfect fourth is 3:4, major third is 4:5 and so on. Let me demonstrate on the string instrument I brought here today. If I pluck a string to hear the fundamental note, and then, by gently touching the string at each of the "nodes" at the halfway point, ⅓, ¼ etc. each time the string will ring out with the corresponding "harmonic" note. This is exactly how the frets work too. The 12th fret is exactly halfway (a 2:1 ratio) between the nut and bridge creating a perfect octave. Fret #7 sounds a perfect fifth at ⅔. The fifth fret is ¾ making a perfect fourth. And so on…





The harmonic series defines many of our intervals. Listed below are the octave, fifth, fourth, major third and minor seventh:





Check out Donald Duck in Mathmagic Land Video!!! https://youtu.be/8BqnN72OlqA

ALL INTERVAL RATIOS
(Just Intonation)
Unison = 1:1
Minor 2nd = 16:15
Major 2nd = 9:8

Minor 3rd = 6:5
Major 3rd = 5:4
Perfect 4th = 4:3
Tritone = 7:5
Perfect 5th = 3:2

Minor 6th = 8:5
Major 6th = 5:3
Minor 7th = 7:4
Major 7th = 15:8
Octave = 2:1

CHORD RATIOS Major triad w/8ve = 8:6:5:4 Minor triad w/8ve = 20:15:12:10 Diminished triad= 36:30:25

Part 3: Creating Sound with Straws/Exploring Musical Intervals & Ratios

Participant/Student activity: We are now going to take this info we've discovered to actually create music! Everyone will take a single straw, cover the bottom with your finger, hold it vertically with the open end up against your chin with the very top right at the edge of your bottom lip. Now try to make a sound by blowing across the top at a slight downward angle. It may take some practice to find the "sweet spot" but it is important to realize that you are blowing more across the top of the opening rather than down into the opening. If you are having difficulty, imagine the stream of air coming out of your perched lips is as thin as the straw itself and then you need to bisect that stream across the back edge of the opening of the vertical straw (see right) (FYI - McD straws work best!!)

Once you can make a sound, let's explore some simple ratios. First try to fold the straw so that it is in two segments where one is twice as long as the other (to try to create an octave). Hint: the fold needs to be located two thirds of the way so the 2 segments form a 1:2 ratio. Play both sides to try to make an octave to sound like "Somewhere Over the Rainbow." Slightly adjust where the fold is to "tune" the interval. Now try a fold closer to the center trying to create a 2:3 ratio making a perfect fifth that sounds like "Twinkle Twinkle". Another fold slightly more to the center should create a 3:4 ratio producing a perfect fourth sounding like "Here Comes the Bride". Once you understand and experience the concept we can move forward to actually create our 8 note, one octave homemade pan flute!

Part 4: Building your own Pan Pipes

For our actual one octave pan pipe we will use multicolored thick boba straws. We will start with the red one and trim off the end to make a flat edge. Next we plug one end with some poster tack by pressing the straw and twisting (like a cookie cutter) to create a perfect seal. We are going to use the help of a free online chromatic tuner to see how far from A 440 we are. Trim off a little of the straw at a time until you get to A 430 and then stop!! You can then fine tune it by using the edge of a marker or new pencil to slowly push up the clay to shorten the air column until the sustained tone matches 440 Hz exactly. If you go too sharp, simply use the pencil from the other end to push the clay back down. Remember, you can always make your air column shorter, but if you cut off too much straw, you cannot go back and make it longer! If this DOES happen… no worries, just use this “too short” straw for a different one of the shorter (higher notes). Once A440 is tuned, measure the length of the straw IN CENTIMETERS. Using the ratios below, simply calculate the other straw lengths for each interval, up to the octave which is half of the longest. **Unison = 1:1** **Major 2nd = 9:8** **Major 3rd = 5:4** **Perfect 4th = 4:3** **Perfect 5th = 3:2** **Major 6th = 5:3** **Major 7th = 15:8** **Octave = 2:1** For instance, if the length of the original bass note “unison” straw was 30cm, in order to calculate the length of the major 2nd, simply multiply by the fraction 8/9 (multiply by nine and divide by eight) yeilding a length of 26.67cm. IMPORTANT: before making the cut, allow yourself a few extra mm for the tack plug. Note: for the sake of time, the provided straws have already been marked where they need to be cut, along with scale degree numbers and notes labeled.

At this time, everyone will cut their straws at the markings, insert the tack plugs, and begin “tuning” each of the notes to match the calculated frequencies shown below using the “JUST INTONATION” chart. (Note: this is slightly different than the equal temperament that most chromatic tuners use. Both are shown below. Further explanation or discussion is possible but beyond the scope of this project. Two free online tuners are given here.https://theonlinemetronome.com/instrument-tuner https://tuner.ninja/ There are also numerous free Android and iOS chromatic tuner apps that work just as well on your phone or tablet. (see list in reference section). It is important to note that you will need to find one that shows specific cycles per second or Hertz (Hz) because many just display the note and gauge showing how flat or sharp the source tone is.

Reference Notes for A Major Scale starting on A_4 = 440.00 Hz

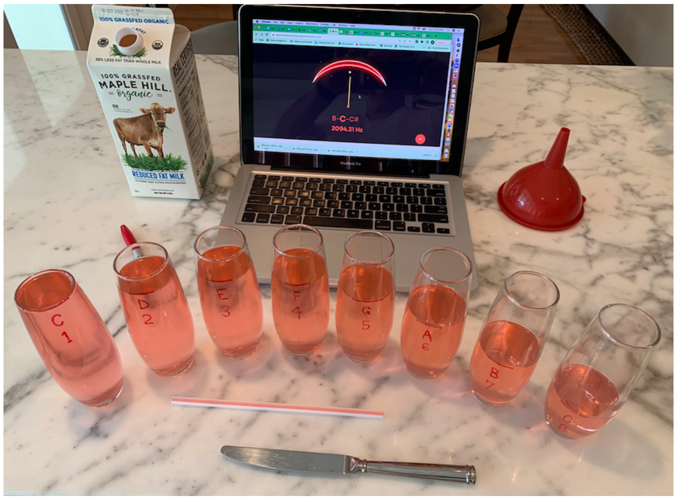
JUST INTONATION (using ratios) (only works w one key, but has “pure” intervals)	**EQUAL TEMPERAMENT (using $\sqrt[12]{2}$)** (“well tempered” adjusted slightly out of tune intervals so it will work in all keys. Calculated using the 12th root of 2)
1 A_4 = 440.00 Hz = 440(1)	1 A_4 = 440.00 Hz = 440(1)
2 B_4 = 495.00 Hz = 440(9/8)	2 B_4 = 493.88 Hz = $440(1 + 2\sqrt[12]{2})$
3 $C\#_5$ = 550.00 Hz = 440(5/4)	3 $C\#_5$ = 554.37 Hz = $440(1 + 4\sqrt[12]{2})$
4 D_5 = 586.67 Hz = 440(4/3)	4 D_5 = 587.33 Hz = $440(1 + 5\sqrt[12]{2})$
5 E_5 = 660.00 Hz = 440(3/2)	5 E_5 = 659.25 Hz = $440(1 + 7\sqrt[12]{2})$
6 $F\#_5$ = 733.33 Hz = 440(5/3)	6 $F\#_5$ = 739.99 Hz = $440(1 + 9\sqrt[12]{2})$
7 $G\#_5$ = 825.00 Hz = 440(15/8)	7 $G\#_5$ = 830.61 Hz = $440(1 + 11\sqrt[12]{2})$
8 A_5 = 880.00 Hz = 440(2)	8 A_5 = 880.00 Hz = 440(2)

Once each straw is tuned to the specified note, they are laid out on a flat surface from left to right, longest to shortest with the open tops all aligned using the edge of a ruler. The surplus straw material left over from the cuts will be trimmed to uniform length in order to be used as spacers. (See sample). Clear packing tape is affixed to the front side to hold the panpipes and spacers together. Before proceeding, the alignment of the straw tops are inspected, and adjusted if necessary so that they all line up perfectly. The panpipes are carefully picked up and turned over so that the instrument can be laid on top of a curved surface, and more tape is applied to hold the concave shape in place, allowing for easier playing. You now have an instrument where you can play any diatonic melody using the full 8 notes of a major scale. If time allows, the class will try to play together the beginning of “Jingle Bells” using the straws 3,3,3   3,3,3   3,5,1,2,3   and also the beginning to “Joy to the World” using the straws 8,7,6,5   4,3,2,1   5,6,   6,7   7,8.

Part 5: Building your own Glass Xylophone

Creating your own glass xylophone is another project you can do with your students. For a xylophone with an 8 note diatonic major scale, you will need 8 identical glass containers, colored water, something you can use as a hard mallet (such as metal cutlery), and your chromatic tuner app. What will take the most time is experimenting with various glass containers (such as drinking glasses, mason jars, glass bottles, vases, etc.) to find something that resonates well when struck by a hard object (such as metal butter knife, or wooden mallet). It is important to realize that ALL objects have their own resonant frequency, and some resonate easier than others. Note: for educational purposes, a glass container that is thin and tall will allow for easier viewing of the different water levels. While you would think that adding more water would make the sound higher, it actually has the opposite effect. This is because, since the entire object vibrates, the added water actually slows down the vibrations. The opposite is true if you use bottles as aerophones. In this case, when blowing across bottle tops, adding water makes the air column shorter and so, the pitch goes up.

In practicality though, it is difficult to calculate specific ratios when creating a glass xylophone, so the best results are a matter of trial and error, and are most effective



when "tuning" the notes, to use both a chromatic tuner app AND a trained musical ear. Also, because cheap glass products are not all identical when being manufactured, in our case the water amount volumes for the root and the octave were not an exact 2 to 1 ratio. Note: this observation, in itself, could be a valuable learning tool, as you explain to your students that, while these "perfect ratio" concepts in theory, make perfect sense, when applied to the "real world", too often there are imperfections in the materials, and as such, sometimes adjustments need to be made to achieve successful results!

It should be noted that it is also fun for you and your students to experiment with different "mallets" used, as the different materials of metal, plastic, wood, (or even other glass) each have a unique sound quality when striking a glass object. If you have access to the music or band room, try to borrow as many different types of percussion mallets, drum sticks, or other objects to try out when playing your glass xylophone.

Yet another variation of the glass xylophone, is a really cool playing technique, which is to dip your finger in the water and gently rub around the rim of the glass, creating an otherworldly pure tone. https://youtu.be/7hOar8dXNbA However, that seems to really only work well with very expensive crystal, and usually takes some time to get the hang of the technique. (Also be sure to check out Ben Franklin's invention of the Glass Armonica - https://youtu.be/57-JQlwRDqc)

As always, these projects can be altered and adapted to fit your situation, budgetary constraints or your students interests and/or abilities. Instead of just 8 diatonic major scale notes, try to add the five black notes, placing the layout to look like a piano keyboard allowing you to play any song in any key. You can also get larger or smaller glass containers and extend your instrument to multiple octaves! For simpler variations, or for elementary, individual notes could easily be created and used as replacement for or in addition to Orff instruments. Even simple ostinatos will get your students more engaged if they were "instrumental" in the creation of the project.

EXTRA: Building your own PVC & Plastic Bottle Single String Guitar

While we do not have the time here to go through the entire process of building this single string guitar project today, I have brought one I made at home to show you and let you try it out for yourself. If anyone is interested, they can follow this very comprehensive youtube video below. FYI - the measurements for the placement of the optional frets utilize the exact same ratios as already discussed and presented here again for your reference.

ALL INTERVAL RATIOS	Minor 3rd = 6:5	Minor 6th = 8:5
(Just Intonation)	**Major 3rd = 5:4**	**Major 6th = 5:3**
Unison = 1:1	**Perfect 4th = 4:3**	Minor 7th = 7:4
Minor 2nd = 16:15	Tritone = 7:5	**Major 7th = 15:8**
Major 2nd = 9:8	**Perfect 5th = 3:2**	**Octave = 2:1**

For homemade fretted single string guitar - plastic bottle (used as resonator) with bottle cap (used as bridge), 24” x ¾” pvc pipe (for neck) 6’ of thin nylon string, 6 plastic ties (for frets), scissors, tape measure https://www.youtube.com/watch?v=S8UT1iEj_p4

Resource List

Donald in Mathmagic Land Video
https://youtu.be/8BqnN72OlqA

Math is Fun Website
https://www.mathsisfun.com/pythagoras.html

Musical Ratios/Harmonic Series Websites
http://www.musicawareness.com/intervals.html
https://www.teoria.com/en/reference/g-h/harmonics.php
https://www.oberton.org/en/overtone-singing/harmonic-series/
https://mathcs.holycross.edu/~groberts/Courses/MA110/Lectures/PythScale-web.pdf

Free Online, iOS, and Android Chromatic Tuners
https://tuner.ninja/
https://theonlinemetronome.com/instrument-tuner
https://www.musicianwave.com/best-guitar-tuner-apps-free-android-ios/

Note Frequency Reference Chart (Equal Temperament)
https://pages.mtu.edu/~suits/notefreqs.html

PanPipe Sites
https://www.sasksciencecentre.com/real-science-real-fun/straw-pan-pipes
https://youtu.be/sglOT1J80Ss

Glass Xylophones Sites
https://youtu.be/xNSUnNQUX0s
https://youtu.be/7hOar8dXNbA
https://youtu.be/57-JQlwRDqc

Homemade PVC & Plastic Bottle Guitar
https://www.youtube.com/watch?v=S8UT1iEj_p4

Demonstration Instrument Materials

i. Sample aerophone - student recorder approx. $5.00
https://www.amazon.com/Ravel-PR19CGN-Recorder-Green/dp/B004S287VK/ref=sr_1_1?crid=12NKJUSBG88YL&keywords=recorder+instrument+for+kids&qid=1661720049&sprefix=recorder%2Caps%2C109&sr=8-1

ii. Sample chordophone - student ukulele approx $30.00
https://www.amazon.com/Martin-Smith-UK-222-Soprano-Ukulele/dp/B077F1G21S/ref=sr_1_17?crid=3UU5M161HJ0AQ&keywords=ukulele&qid=1661720331&refinements=p_n_feature_keywords_two_browse-bin%3A6145589011&rnid=6145585011&s=musical-instruments&sprefix=ukulele%2Caps%2C123&sr=1-17

iii. Sample idiophone - glockenspiel approx $30.00

https://www.amazon.com/Eastrock-Xylophone-Professional-Glockenspiel-Child-Safe/dp/B08K4MH3JK/ref=sr_1_25_sspa?crid=2PZFZ5O1HNXLE&keywords=xylophone+instrument&qid=1661720560&s=musical-instruments&sprefix=xylophone%2Cmi%2C100&sr=1-25-spons&psc=1

iv. Sample Tuning Fork for demonstration approx. $6.00

https://www.amazon.com/cdar-Stainless-Musical-Instrument-Songful/dp/B09RQY4VPY/ref=sr_1_4?crid=RPICQVEF6VHL&keywords=tuning%2Bfork&qid=1661824213&rnid=2470954011&sprefix=tuning%2Bfork%2Caps%2C122&sr=8-4&th=1

Homemade Instrument Materials

v. Chromatic Instrument tuner app (FREE - various online, iOS & Android)

https://www.musicianwave.com/best-guitar-tuner-apps-free-android-ios/
https://apps.apple.com/us/app/instuner-free-chromatic-tuner/id603425027
https://apps.apple.com/us/app/tuner-lite-by-piascore/id635828559
https://play.google.com/store/apps/details?id=hai.lior.instrumenttunerfree&hl=en_US&gl=US

vi. Boba Tea Straws Pack of 300 (0.43" Wide X 9.45" Long) $22.00

https://www.amazon.com/RENYIH-Milkshake-Disposable-Wide-mouthed-Individually/dp/B08TC8NKYV/ref=sr_1_7?crid=2MBDHYGVQ58QR&keywords=boba+tea+straws&qid=1661723036&sprefix=boba+tea+%2Caps%2C135&sr=8-7

vii. Poster Tack (to plug up straw ends and as fine tuners)
(available at dollar tree @ $1.25 each)

https://www.dollartree.com/jot-poster-tack-264oz-packs/178402

viii. Scissors, Clear Packing Tape, Rulers
Set of 8 matching glass containers (vases, bottles, jars, and/or drinking glasses
(available at dollar tree @$1.25 each) 8 for $10.00

https://www.dollartree.com/floral-supplies/vases-containers

ix. 2 Sets of stainless steel cutlery (used as mallets) $2.50
(available at dollar tree @ $1.25 each)