

Using Math to Create a Musical Sandbox

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Abstract

OK Go Sandbox is a free online resource for educators that uses OK Go's music videos as starting points for guided inquiry challenges that inspire students to explore various STEAM concepts. Drawing from the lessons available through OK Go Sandbox, this workshop investigates the scientific and mathematical processes of creating sound as it relates to composing music.



Figure 1: *OK Go poses with the “instruments” they used to create a song in the OK Go Sandbox challenge video “Surrounding Sounds.”*

Introduction

The Grammy Award-winning band OK Go has long been regarded as “the video band.” They earned this title by dedicating their music videos to exploring the extraordinary intersection between math, engineering, and art. Their international audience has watched in awe as the group danced in zero gravity, drove a stunt car through a musical obstacle course, shot an entire video in four seconds and slowed it down to match the song, created a two story tall Rube Goldberg machine, and more. Because these videos are so innovative, educators began using the music videos to inspire their students to engage with concepts that are typically taught through lectures or reading. After seeing such a strong response to their videos, OK Go wanted to create a resource to help teachers better utilize their videos. Thus, OKGoSandbox.org was born. OK Go Sandbox emphasizes learning through play and exploration, mirroring OK Go’s creative process while making their music videos. We are a free online resource for educators that uses OK Go’s music videos as starting points for guided inquiry challenges that inspire students to explore various STEAM concepts. Drawing inspiration from the OK Go Sandbox activity “Surrounding Sounds,” this workshop will use math and physics to demonstrate the musical properties of everyday objects.

The Math of Music

Pitched Western music consists of 12 pitch classes: C, C#/Db, D, D#/Eb, E, F, F#/Gb, G, G#/Ab, A, A#/Bb, B. These notes in ascending or descending order make a chromatic scale. Each of these pitches is one half step away from the one directly next to it. A half step is the term we use to describe an increase or decrease in frequency by a factor of ~ 1.059 . Sharps (#'s) and flats(b's) are often used to indicate a half step in pitch. For example, to go up a half step from C, you add a sharp after it, giving you C#. If a pitch already has a sharp or a flat after it, you move on to the next letter name in the sequence. Therefore, one half step up from C# is D. Some pitches are naturally a half step apart, meaning that you don't need to put a sharp or a flat on the existing note to move a half step to the next one. Instead, you move directly to the next letter name. For example, B is a natural half step away from C, and E is a natural half step away from F. If we were to assign numbers to each pitch of the chromatic scale in the same order listed above, it could be notated as {0, 1, 2, 3, 4, 5, 6, 7, 8, 9, t(10), e(11)}. The pitches used in this OK Go Sandbox workshop are {G A B C D E F G}, which translates to the numbers {7 9 e 0 2 4 5 7}. Looking at the pitches as numbers makes it easier to identify the half steps in between notes. If +1 equals a change of one half step, then the ascending distance between the pitches used in this workshop would be {+2,+2,+1,+2,+2,+1,+2}. Combinations of half and whole notes create what are called intervals. The pitches made in this workshop will use different intervals to create the melodies to four songs.

A great application of the physics of sound can be found in the cut pipes used in this activity. The pipes are cut to very specific lengths so when one open end of the pipe is struck, the pipe creates a predetermined note. While trial and error is a feasible way to find these specific lengths, lots of time can be saved by applying a branch of physics known as acoustics. Acoustics is the study of waves and their interactions with their medium and their surroundings. In the case of our pipes, the medium of the wave is air, and their surroundings are the inside of the pipe. The lowest note in our activity, G3, has a frequency of 196.00 Hz. This means that a G3 sound wave will oscillate 196 times each second. The wavelength of that same wave can be determined by: $\lambda = (V / f)$, where V is the speed of the sound of the wave. Since our medium is air, our wave is a sound wave and our pipes will be measured in inches, C will be the speed of sound in air, measured in inches per second. This value is 13503.9 in/s. Using this equation, we calculate that our wavelength for a G3 sound wave is 76.749 in. Transverse waves in a tube open at both ends have a convenient property to take advantage of, the length of the tube is always equal to $\frac{1}{2}$ of the wavelength of the sound they produce. Because of this, the length of our tube, L, can be expressed by the following: $L = (\lambda / 2)$. Therefore, our G3 pipe must be 38.374 inches in length.

The Workshop

This workshop explores the musical properties of the everyday objects we find all around us. From horse-shoes to PVC pipes, and cell-phones to soda bottles, any object has musical potential. This workshop allows participants to learn about music as an accessible art that can be enjoyed anywhere with any supplies. This workshop integrates math, science, and visual art with concepts of pitch, melody, rhythm, accompaniment, and tempo to create a community based learning experience. The OK Go music video "Needing/Getting" features a OK Go driving a stunt car through a musical obstacle course. In this workshop, we will use this music video to explain the significance of exploratory learning in education and the nature of sound, pitch and frequency, as well as how they can be modified. This workshop, run by the OK Go Sandbox team, will include a brief presentation on the math and physics of music, and viewing of several OK Go and OK Go Sandbox videos. After the presentation concludes, participants will be invited to each select one of hundreds of random objects placed throughout the room to use as their own musical instrument, finding objects that match specific notes as they explore. They can choose from a pre-tuned object or attempt to tune it themselves using a pitch detection device. Once each workshop participant has found their instrument, they will work together to play a medley of songs guitar hero style from a display projected at the front of the room. No knowledge of sheet music is required to participate in this activity, and it has been successful with individuals of all ages and musical experiences.