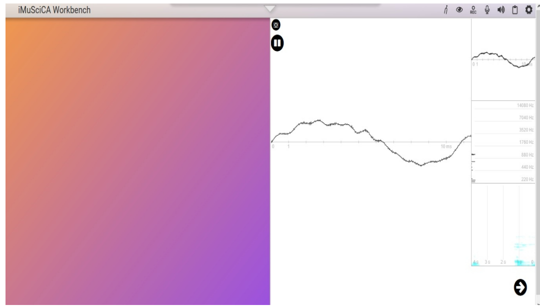
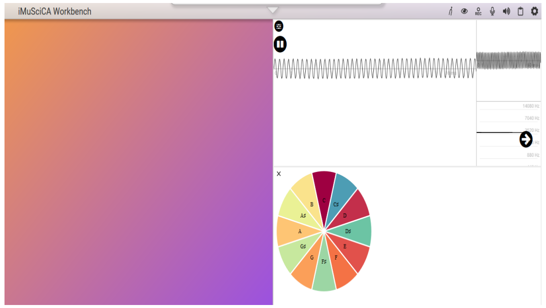
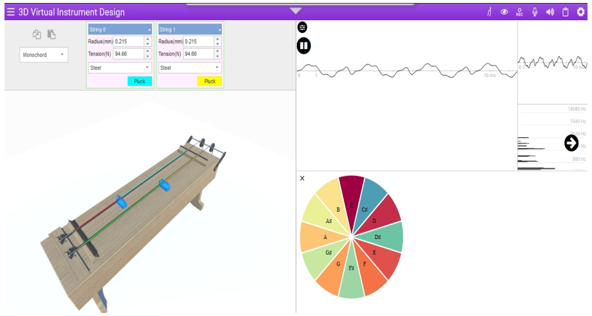
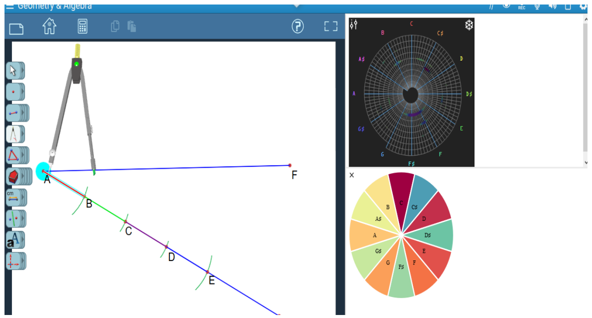
Title:	Let’s play Sectio Canonis v2		
Keywords:	Monochord, frequency, tension, length, musical patterns, geometrical proportions, Division of the Canon (Sectio Canonis), Chords.		
Short Description:	In the scenario “Let's Play sectio canonis v2” students develop a segment division in 2, 3, 4, 5, and 6 equal parts. They investigate the properties of each part along with the triangles produced. They continue measuring further divisions and they write down their conclusions. At the end, students explore the larger sides of the triangles and their properties forming a minor chord. The ideal teaching requirements for this scenario is to be implemented by a Music teacher and a Physics or Mathematics teacher.		
Lesson Plans included:	• Producing a minor chord on a diatonic scale out of proportions from Sectio Canonis • Understanding the necessity of the musical scale out of mathematical limitations • Learn about Euclides' Sectio Canonis	Date:	30/6//2018
Educational Objectives:	Learn the relationship between Sectio Canonis, frequency, tension and length of a monochord. Explore the similarities between the Pythagorean proportions and tension of an instrument’s sounding body. Understand the consonants of a minor chord.	Estimated Duration:	10 hrs
Author(s):	P. Stergiopoulos	Age Group:	15-17 (14-16)
Contributor(s):		Language:	English
Status:	Final	Difficulty Level:	High
Dissemination level:	Public	Special Needs Addressed:	No

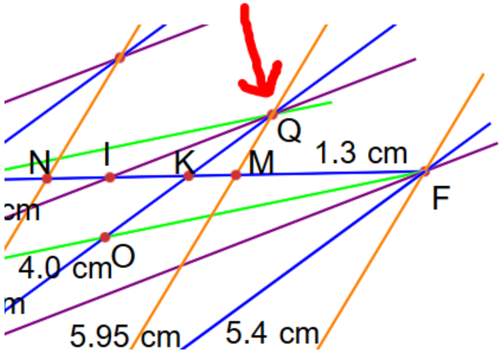
Description: Students explore the properties of triangles projected in string lengths following the intercept theorem of Thales. By transforming the lengths of triangle-sides into string lengths, they observe their sounding properties. Particularly they observe the properties of the division by 6. The longer sides sound a minor chord. Finally they perform the chord in sequence. **This ten-hours scenario requires that students have either their own computer using the iMuSciCA workbench or collaborate in groups of two per computer.**
E: Engineering/Technology, S: Science/Mathematics, M: Music

Phases	Field	Time	Description	Activity	Remarks
Imagine	M	1	What kind of music do we like? Can you sing your favorite music?	Teacher encourages students to sing a song. Each student sings part of a song and observes the live analysis of the performance	 *Figure 1: Using 2D visualization with mic*
Engage		1	What makes a tune nice or interesting to hear?	Music teacher plays (or sings) a song deliberately out of tune. The true (exact) notes of the tune are played on the pitch wheel	Teacher encourages students to respond differently. Every answer can be discussed. Special emphasis should given on the “accuracy” of pitch. A small part (or motive) of a song is chosen (not more than 5 notes). Only a few notes of a pattern are enough to demonstrate the essence of intervals.

				 *Figure 2: Using Pitch wheel to follow the notes and the mic and to explore the properties of the same pitch* Teacher triggers a discussion with a question: How do we define “good” in a song or in a melody we like to listen?	
Create	E	1	Can you reproduce the notes using a virtual monochord?	Try to find the notes using one string of the monochord. Observe the reaction of bottom right analyzer. Then do the same by playing the appropriate note at the pitch wheel.	Teacher helps students reproduce the notes of a song's motive using the 3D Instrument Design

				 *Figure 3: Using a monochord to explore the properties of the same notes* Do they respond the same? If yes, then go on with the rest of the notes. If no, try on.	
Imagine	S	1	What is the history of pitch accuracy?	 *Figure 4: Reference to the history of Pythagoras* Teacher referes to the history of Sectio Canonis, Euclides and the Pythagoreans and introduces its relation with the proportions.	Teacher helps students understand that all the music we hear is based on pitch accuracy depending on the system that the division takes place. Music teacher starts a brief discussion about the history of tuning systems from Pythagorean systems to nowdays approach.

Create	E	2	How can we experiment with Geometry in Music?	We use the compass to define the points of division following the intercept theorem.  *Figure 5: Using the Geometry & Algebra environment to introduce the division of the Canon* Two points will divide the canon in two equal segments producing the octave, three points will produce the fifth and four points will produce the fourth. Students follow the steps in order to produce division up to 6 points.	At this stage Introduction to the basic elements of tonality are being introduced (please consult relevant material from the "[House of Chords]" and "[Defining the Octave]" On the Geometry & Algebra environment, teacher allows the extension of segments above AF and encourage students to observe and experiment with the lengths of the triangles produced.

					 *Figure 6: Observing the sounding lengths of similar triangles using the points of interception* On the 3D Instrument design environment students listen to the ratio 3/5

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<td>Analyze</td>
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<td>1</td>
<td>Exploring the ratios</td>
<td>

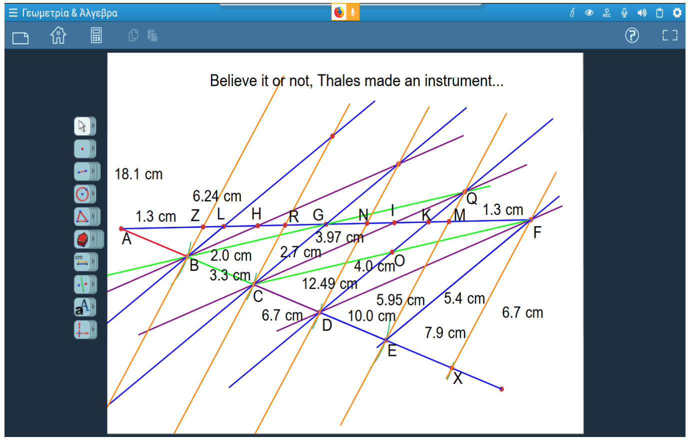

Figure 7: Dividing segment AF into six segments

Students experiment in proportions ½, 2/3, ¾, 5/4, 6/5 and they measure lengths for each division. Findings are noted down on a table.

<table>
<tr><th colspan="2">Table of observations</th></tr>
<tr><th>Ratio</th><th>Fundamental note</th></tr>
<tr><td>...</td><td>...</td></tr>
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After transferring the length of the initial segment (AF) to the 3D Instrument Design environment and listen to the results, music teacher guides the students to match the results with the harmonic degrees of the diatonic scale. Namely: **1st – Tonic, 3rd – Mediant, 4th – Subdominant, 5th – Dominant**
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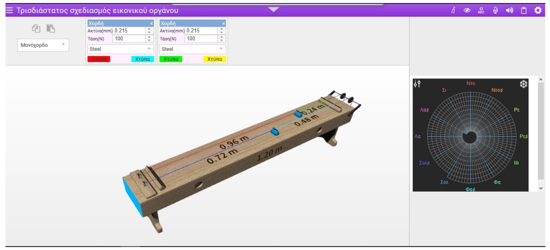

Figure 8: Observing the sounding lengths of 4/5 and 3/5

Teacher encourages students to keep testing further divisions. A discussion on the findings and the results written on table helps students understand the challenges of exploring the divisions in order to find a proper octave division.

Music teacher reveals the ratios that produce the diatonic scale in the proper order: 1 , 8/9, 4/5, 3/4, 2/3 , 3/5, 8/15, ½

They write down each measurement using 2D and 3D visualizations. They compare the sounding results with a physical instrument.
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<td>Questions:

-What happens to ratio 5/6 ? To which interval this ratio is close to?

-Can we try other ratios? Instead of isolating just one part could isolate two? If we apply this to the ratios we have been experimented so far, what do we expect? Which ratio produces “new” interval after that (compared to AF) ?

Students experiment with ratio 3/5 and they compare it to 4/5.</td>
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<td>Redlect</td>
<td>M</td>
<td>1</td>
<td>The longer sides of the triangles</td>
<td>Students start experimenting with the sounding lengths of the longer sides of the trianlgles produced by dividing in six parts. Namely: XF, EM, DN

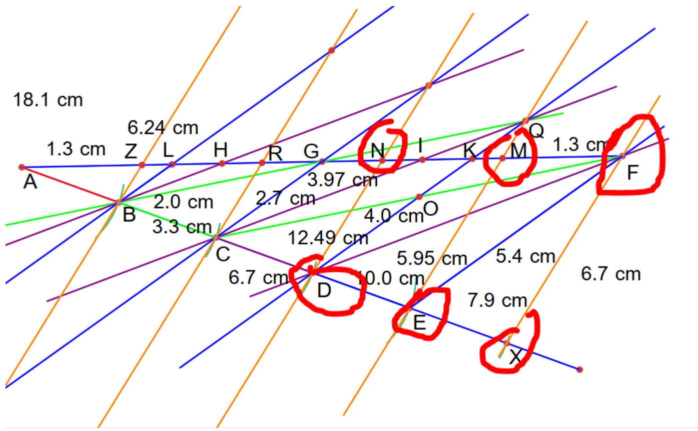

Figure 9: Experimenting with the longer sides of the trianles from 6th division

Students transfer their sounding lengths on three different computers. Is it close to a chord? Which one ?</td>
<td>Students reflect on the results of their measurements trying to find consonances between the sounding lengths of the longer sides. A variety of this experiment could be of the triangles and the segments profuce by the division.</td>
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					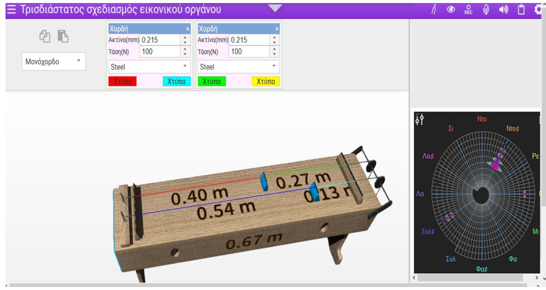 *Figure 10: Example of proportional sounding lengths with equal tension of the longer sides from division by 6, producing a plain fourth (C#-F#)*
Communicate	M	2	Producing a close to a minor chord out of the experiment	Groups of three computers produce two (or more) minor chords. Students within one group with equal initial lengths (AF) reproduce a minor chord when all three computers sound simultaneously. Diffrent combinations of groups form part of a strange (or consonant) harmonic sequence.	Music teacher helps students coordinate. A physical conducting-gesture, such as the movement of the hand, can coordinate one (or more) computer groups. Students share a brief music-happening with their classmates live in the classroom.